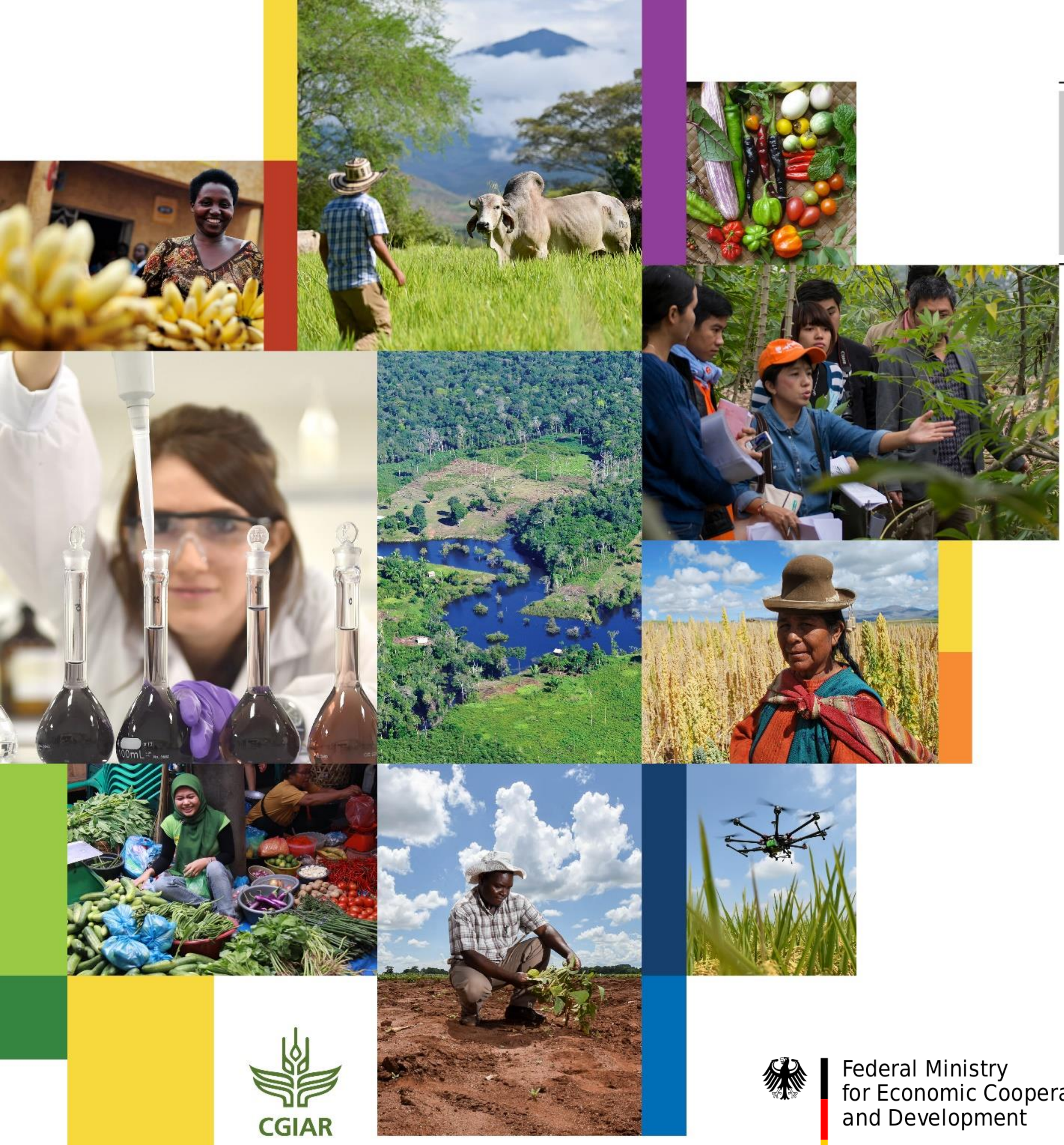

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Scaling up Soil Carbon Enhancement for Food Security and Climate Across Complex Landscapes in Kenya and Ethiopia: Dissemination Workshop

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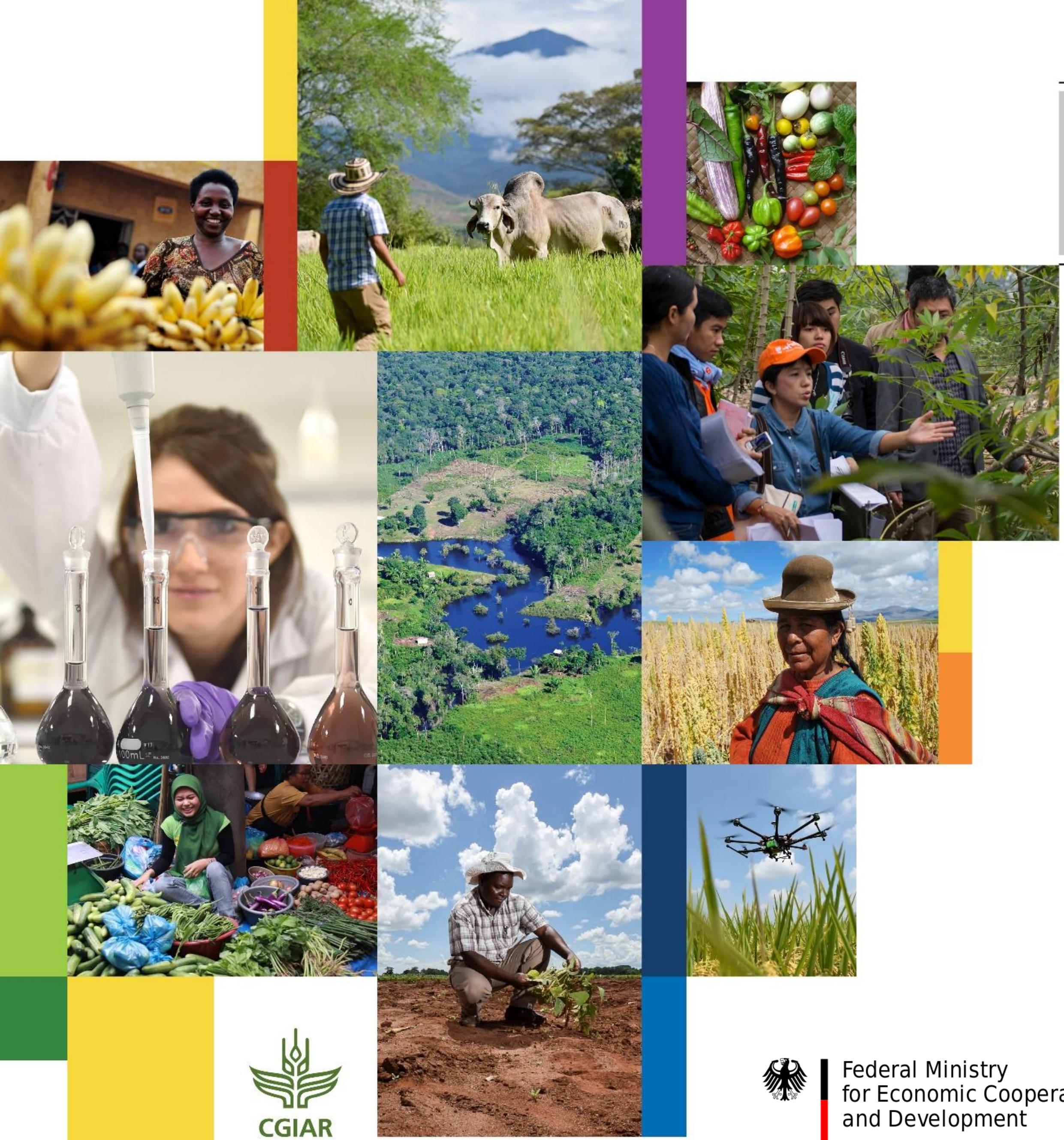
Workshop Program – Day 1 – December 10

- **2:30-2:45 pm:** Welcome Introduction and workshop overview
- **2:45-3:00 pm:** Remarks from GIZ Ethiopia and Kenya
- **3:00-3:30 pm:** Technical keynote address: Overview of soil carbon importance and status of soils
- **3:30-4:25 pm:** Panel: Biophysical evidence for enhancing soil carbon
- **4:25-4:55 pm:** Panel: Socio-economic opportunities and constraints for adopting soil carbon enhancement interventions
- **4:55-5:00 pm:** Wrap up from Day 1

Workshop Program – Day 2 – December 11

- **2:30-3:00 pm:** Welcome addresses from Ethiopian and Kenyan partners
- **3:00-3:45 pm:** Panel on soil carbon modelling in east Africa
- **3:45-4:30 pm:** Facilitated discussion on stakeholder perceptions of soil carbon
- **4:30-5:00 pm:** Concluding panel: what is needed for success in scaling up soil carbon enhancement in east Africa and beyond
- **5:00pm:** Wrap up and thank you



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Assessing soil organic carbon sequestration potential in Kenya and Ethiopia cropland areas

Sylvia Nyawira

Crop and soil carbon modeller

s.nyawira@cgiar.org

10/12/2020

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Soils provide multiple benefits and ecosystem services

Climate change mitigation

Soils under **sustainable management** practices play an important role in mitigating **climate change** through **carbon sequestration** and reducing **CO_2 greenhouse gas emissions**

Improved nutrient cycling

Increasing **organic matter inputs** to the **soils** improves **nitrogen cycling** through **reducing nitrate leaching risks**

Enriched soil biodiversity

Soils that are **rich in SOC** support a wide variety of living **organisms** which are **essential** for the **cycling** of **ecosystem nutrients**

Improved water retention

Higher **SOC** Improves **soil structure soil aeration,** and **water retention** thus **reducing the risk of soil erosion**

Improved food security

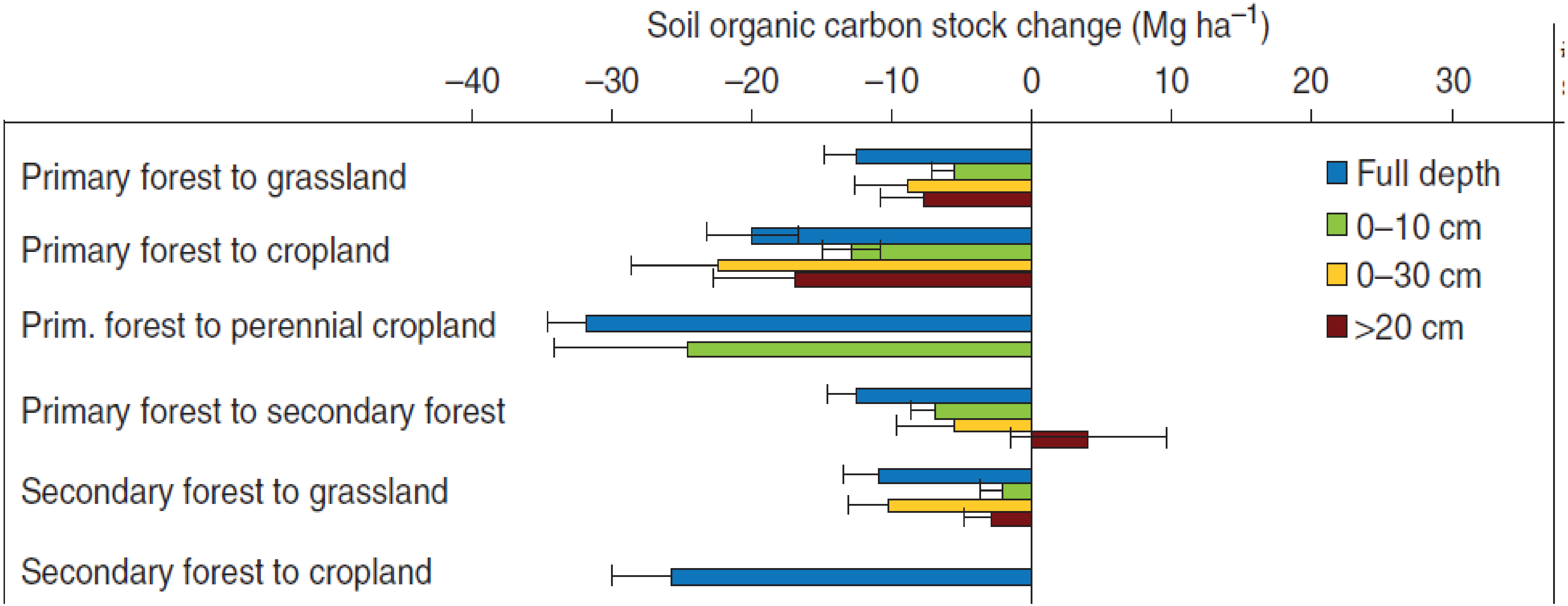
Soils rich in **SOC** **have high crop productivity**

Reduced agricultural production costs

Enhancing **SOC sequestration** can **reduce the long-term needs** for mineral fertilizer, i.e nitrogen

Sustainable development goals

Soil carbon loss in response to Land use change



Source: Don et al 2011, Global Change Biology

South African Journal of Plant and Soil 2020, 37(1): 35–49

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ISSN 0257-1862 EISSN 2167-034X
https://doi.org/10.1080/02571862.2019.1640296

Soil organic carbon in agricultural systems of six countries in East Africa – a literature review of status and carbon sequestration potential

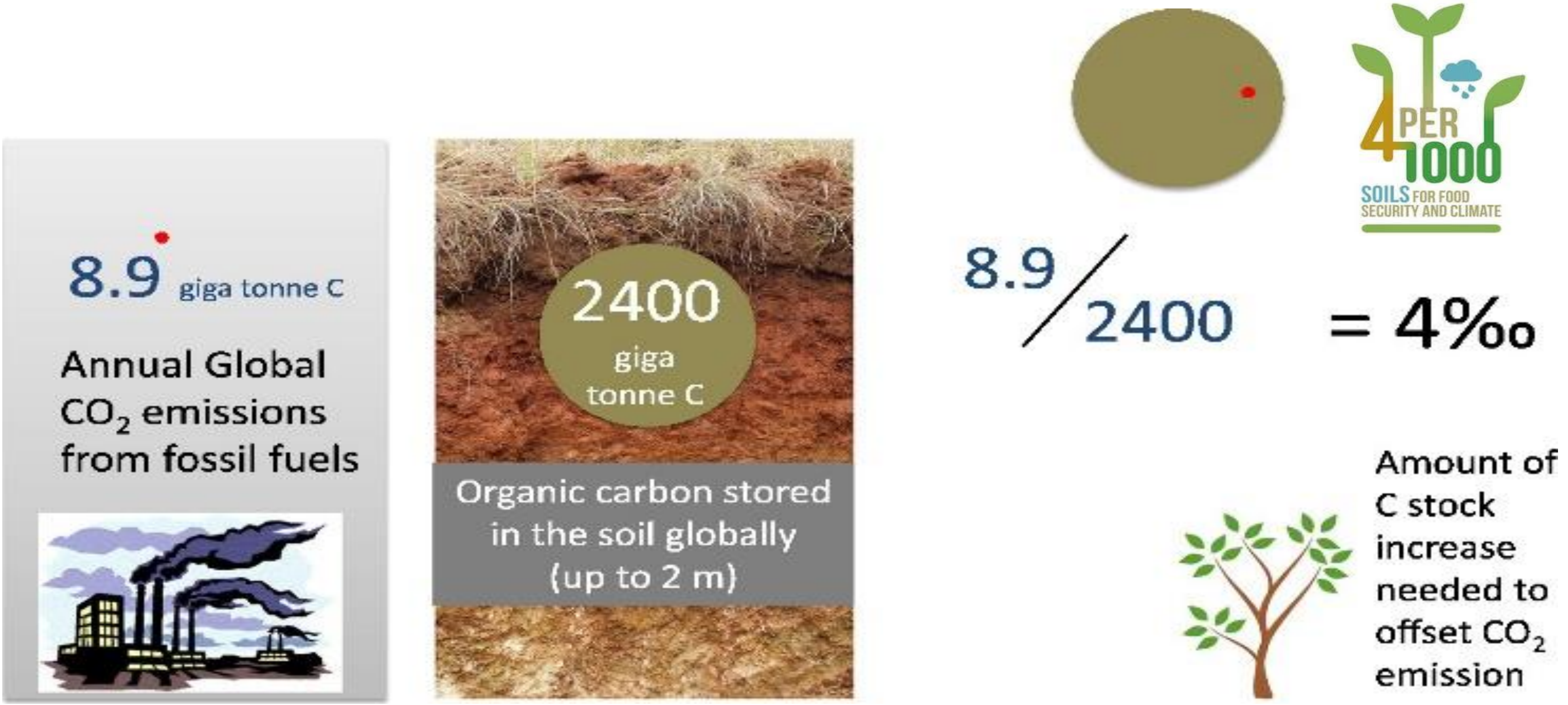
Namirembe S[1]*, Piikki K[2,3], Sommer R[4], Söderström M[2,3], Tessema B[5], Nyawira SS[3]

[1] Stepup Standard Ltd., Kampala, Uganda
[2] Swedish University of Agricultural Sciences (SLU), Skara, Sweden
[3] International Center for Tropical Agriculture (CIAT) Nairobi, Kenya
[4] WWF Deutschland, Agriculture & Land Use Change, Berlin, Germany

Losses of 6.7, 13.0 and 2.8 t C ha^{-1} year^{-1} over short (<10), medium (10-25) and long time (>25) scales.

through BMPs. Reported losses of SOC in the top 30 cm of the soil profile in short (<10 years), medium (10–25 years), and long (>25 years) term were 6.7 ± 6.0, 13.0 ± 9.2, and 2.8 ± 1.0 t C ha^{-1} year^{-1}, respectively, for forest-to-cropland; and 16.0, 2.1 ± 2.2 and 0.3 ± 0.8 t C ha^{-1} year^{-1} respectively, for woodland-to-cropland conversion. Duration to steady-state SOC was 21–38 years for forest-to-cropland conversion. Short-term SOC sequestration (t C ha^{-1} year^{-1}) in the 0–30 cm layer as a result of BMPs was 19.7 ± 3.9 from crop residues, 14.8 ± 8.7 from farmyard manure, 3.5 ± 4.5 from inorganic fertilizers, 2.7 from agroforestry, and 2.5 from improved fallow. However, the studies reviewed were mostly short-term and concentrated to a few locations. Future research should address these gaps.

Soil organic carbon sequestration aspirations

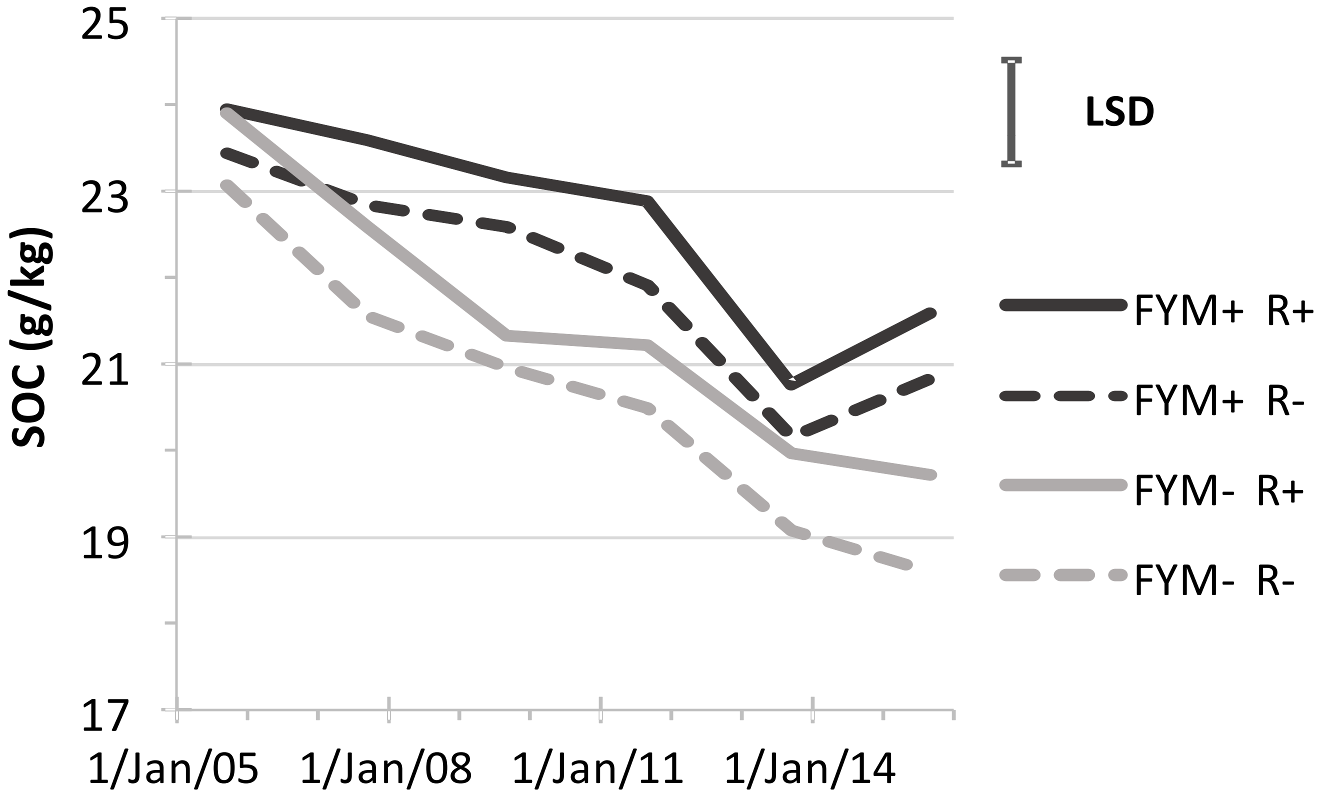


Source: Ademe 2015

How much is achievable, where and for how long in cropland areas?

Observed and simulated losses under improved management – Western Kenya trial

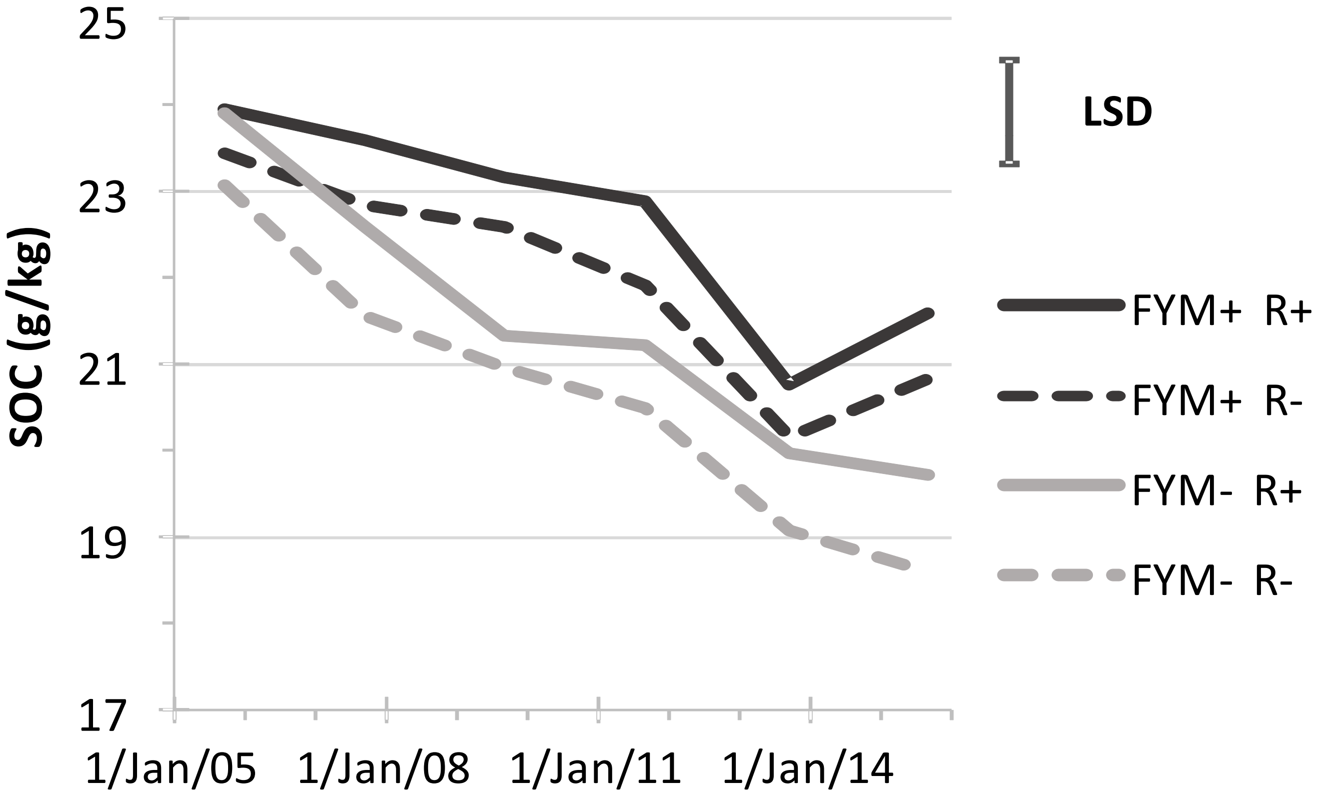
ISFM



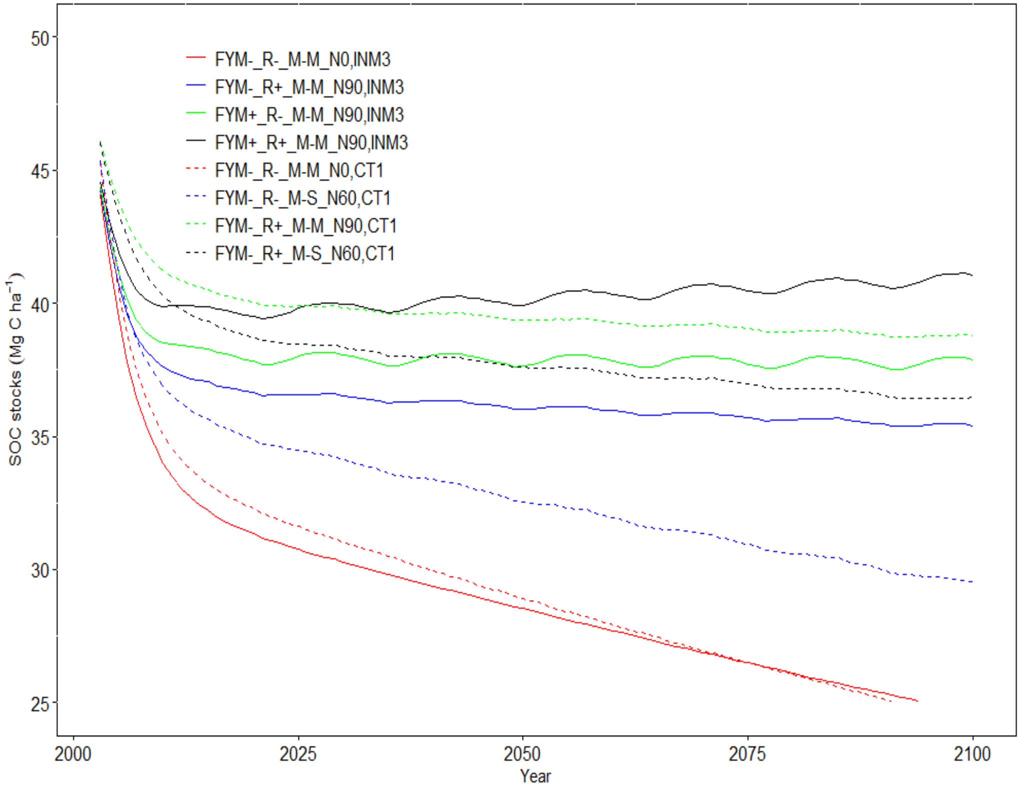
Source: Sommer et al. 2018

Observed and simulated losses under improved management – Western Kenya trial

ISFM

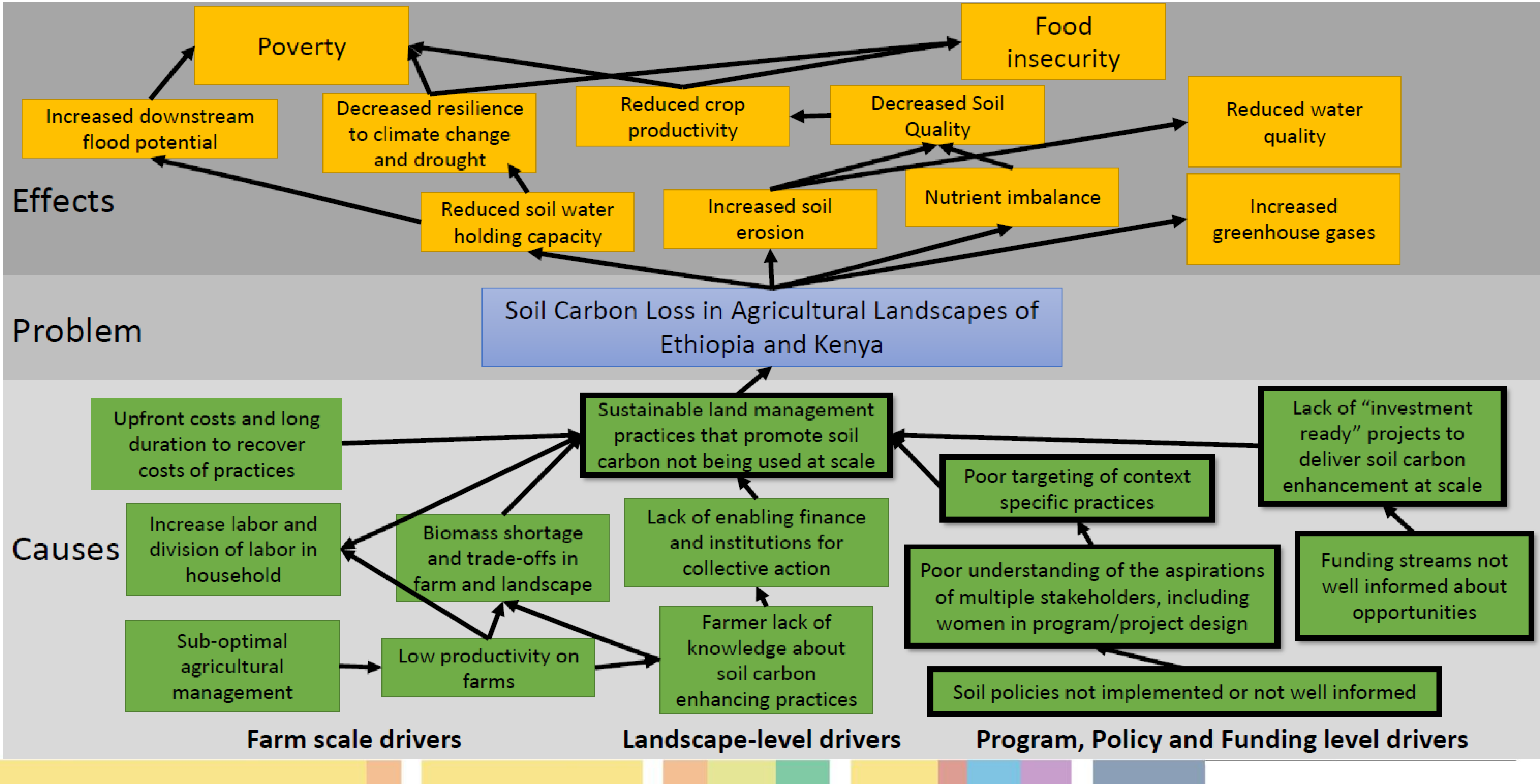


Source: Sommer et al. 2018

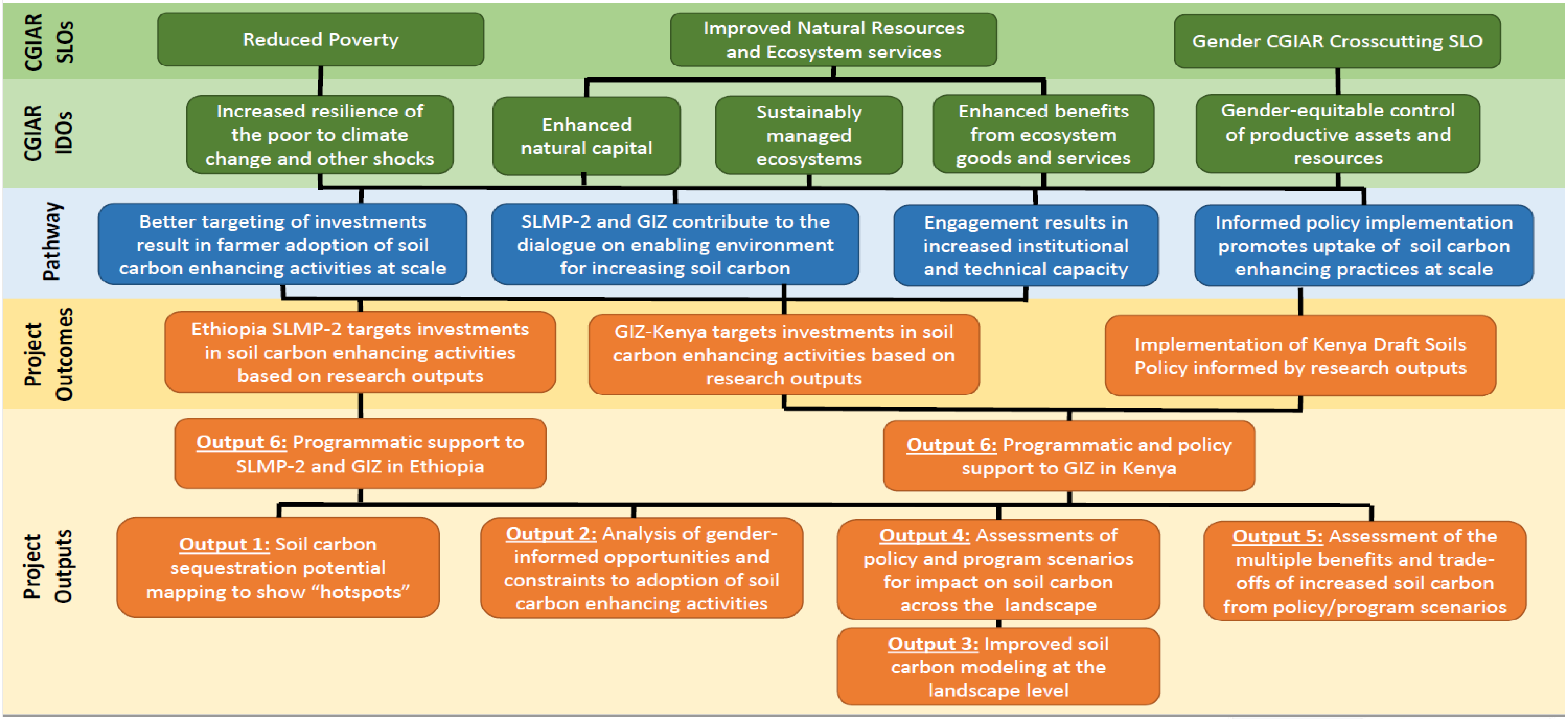


Source: Nyawira et al under review

Project problem



Project Impact Pathway



Integrated approach of assessing soil organic carbon

Biophysical aspects of SOC

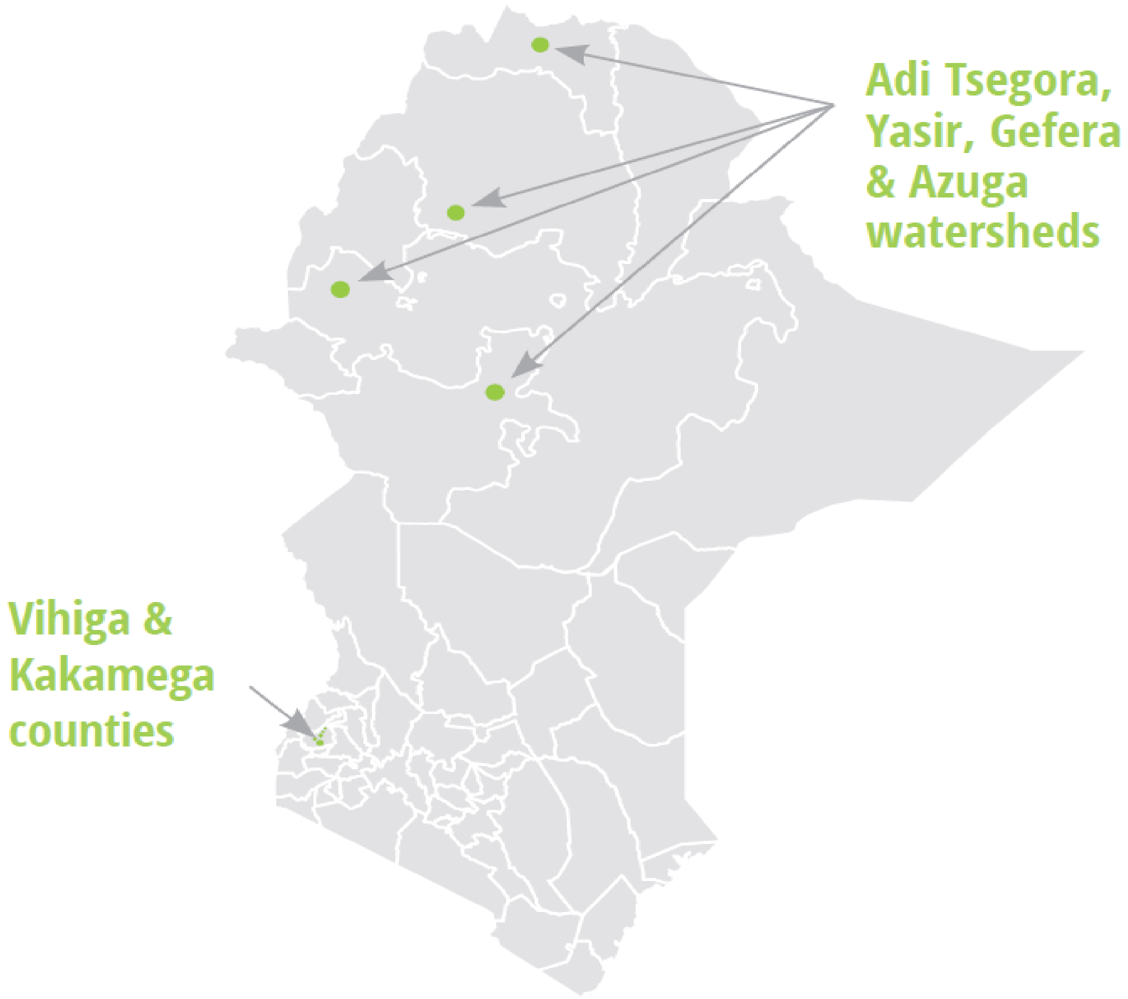
- Point scale measurements and hotspot mapping of SOC in selected landscapes
- On farm modelling of SOC dynamics
- Large-scale modelling of SOC sequestration potential under different crop management options

Socioeconomic aspects of SOC

- Evaluating farmers decisions on land management options
- Assessing the barrriers and constraints to adoption
- Cost-benefit analysis on scenarios of large scale adoption of different crop management options

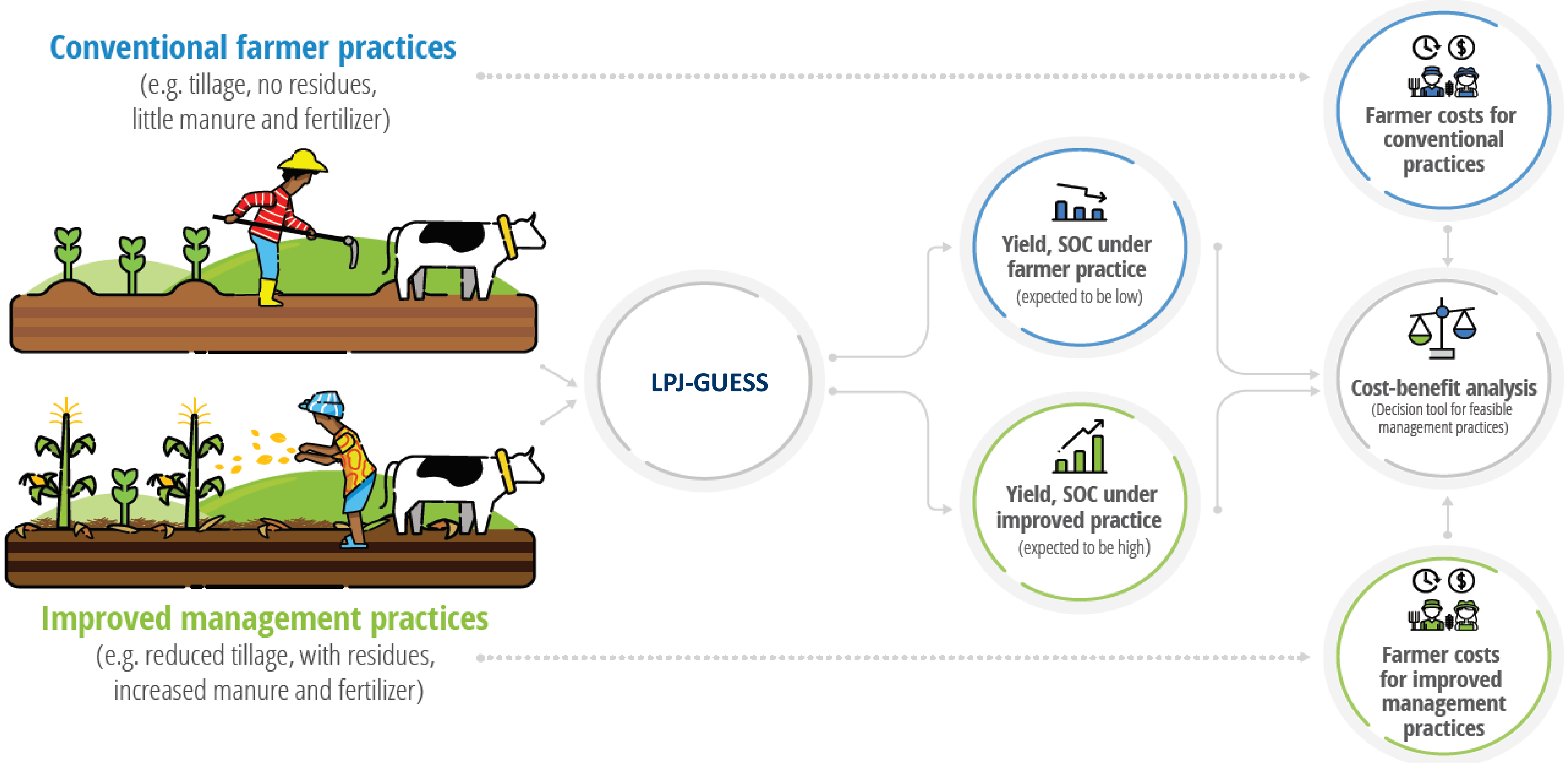
Integrated approach of assessing soil organic carbon

- Point scale measu landscapes
- On farm modellin
- Large-scale model nt crop management opti



- Evaluating farmer
- Assessing the barr
- Cost-benefit analy nt crop management opti

National-scale modeling framework



Socioeconomic framework and tools

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Thank you!

Sylvia Nyawira

Crop and Soil Carbon Modeler

s.nyawira@cgiar.org

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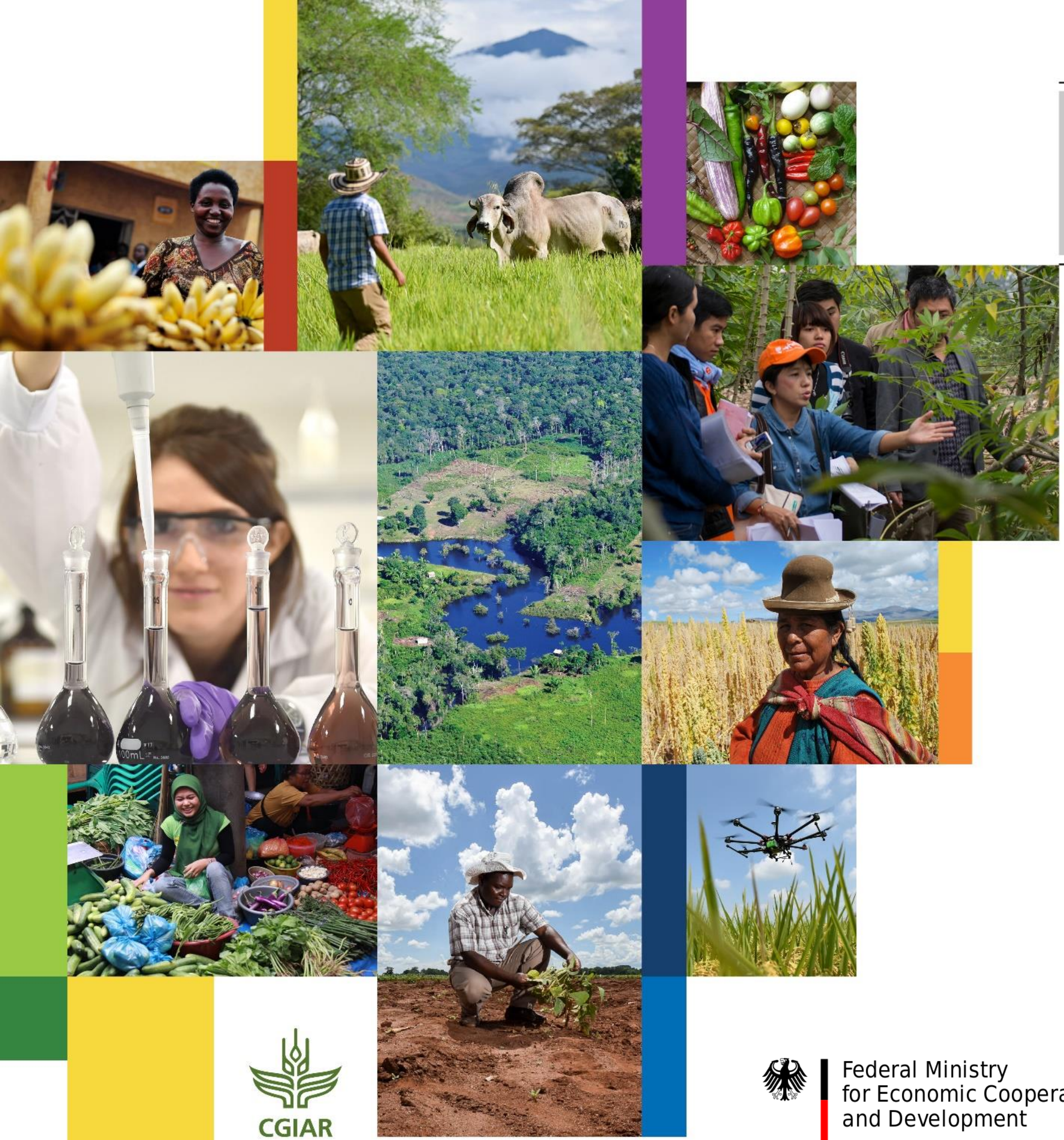

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Spatio-temporal dynamics of agricultural drought and soil organic carbon in the highlands of Ethiopia

Zerihun Chere

Addis Ababa University

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- Introduction
- Methods & Materials
- Results & Discussions

- Agricultural drought occurs when soil moisture is not enough or support plant growth

- In Ethiopia, where the economy is strongly relying on rain-fed agriculture, drought has constantly led to widespread crop failure & food shortages. E.g. 2015 drought left more than 10.2 million people

- Moreover, SOC stock has become most vulnerable in highlands of Ethiopia
- In this favor, RS data & GIS techniques provide new opportunities for producing large information on the evolution of droughts at large spatio-temporal scales and predicting stock of SOC.
- This study aims to map and examine the spatio-temporal patterns of agricultural drought (based on VHI & SPI) & nn establish r/n ship b/n RS derived variable & SOC stock.

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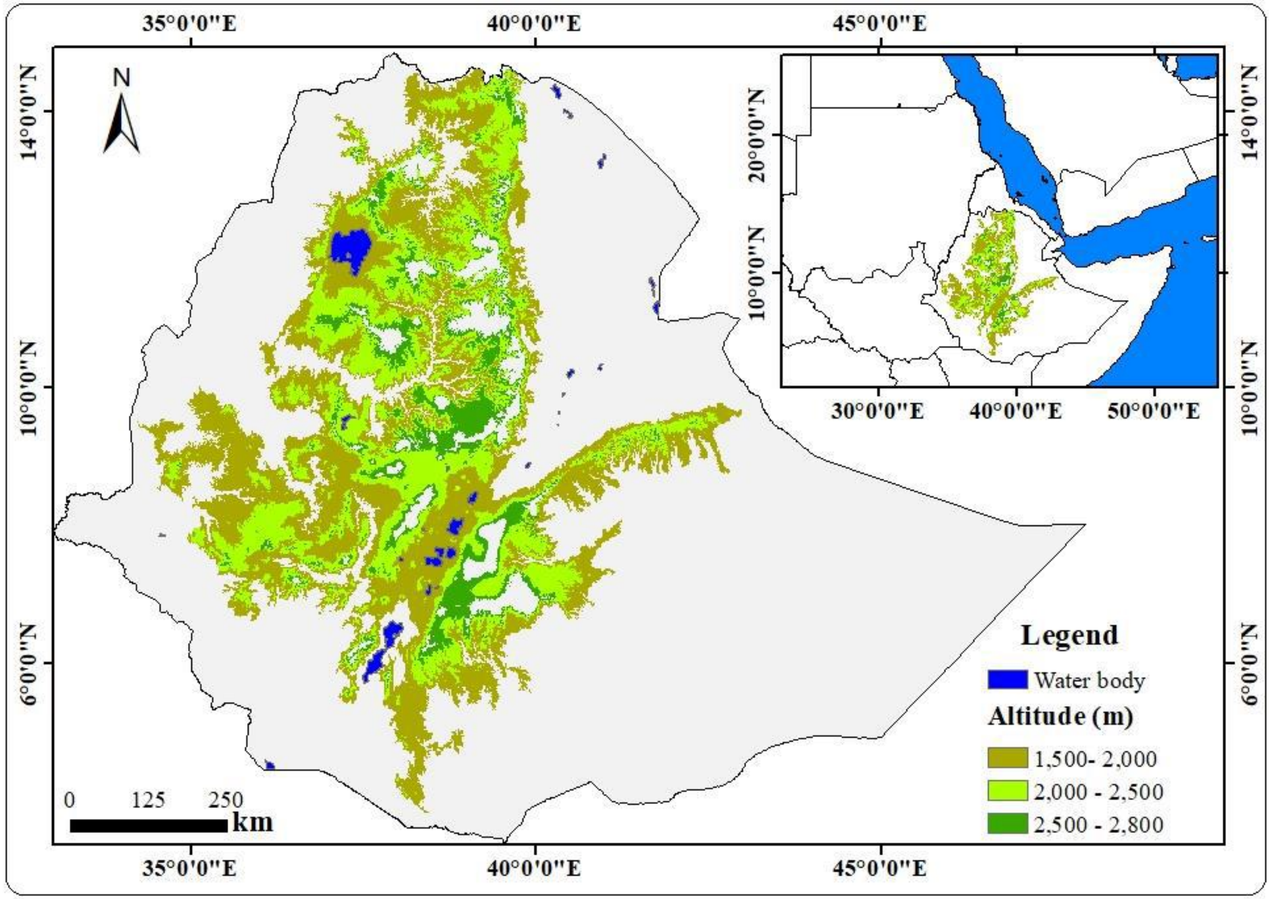
Geographical extent;
3°48’5″-14°37'28″N &
34°12'6″E-42°58′48″E
Geographical area
320, 442 sq.km



In this paper, MOD11A2 Terra LST & eMODIS NDVI are used to estimate VHI & CHIRPS to estimate SPI to monitoring agricultural drought & crop yield for validation

eMODIS NDVI

VHI

MOD11A2 LST

Vegetation condition index (VCI)

Temperature condition index (TCI)

$$VCI_i = \frac{NDVI_i - NDVI_{\min}}{NDVI_{max} - NDVI_{min}}$$

$$TCI_i = \frac{BT_{max} - BT_{\mathrm{i}}}{BT_{max} - BT_{min}}$$

Vegetation Health Index (VHI)

VHI = a*VCI + (1-a)* TCI

low VHI

(Kogan et al. 1995)

high VHI

VHI < 40 drought

VHI > No drought

(Kogan, 2019)

ILRI

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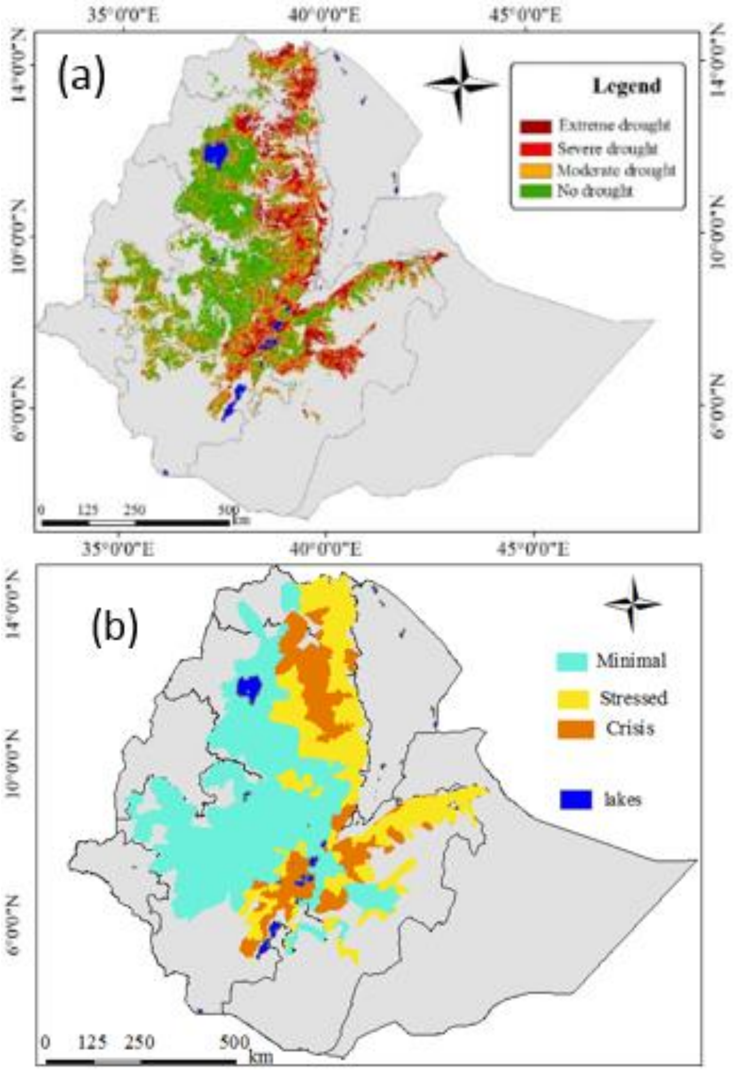
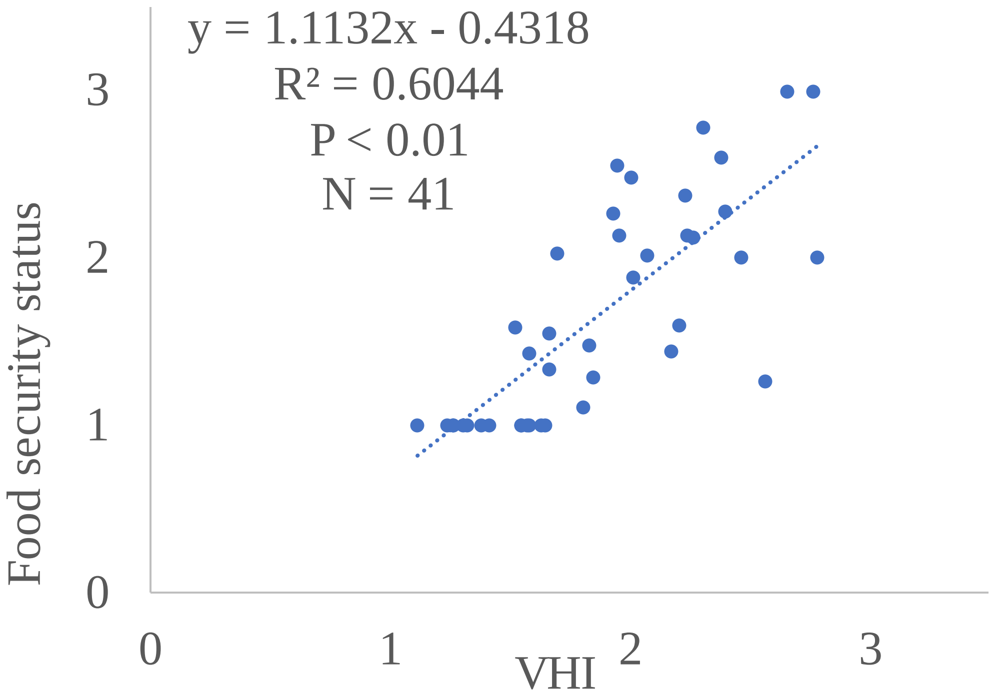
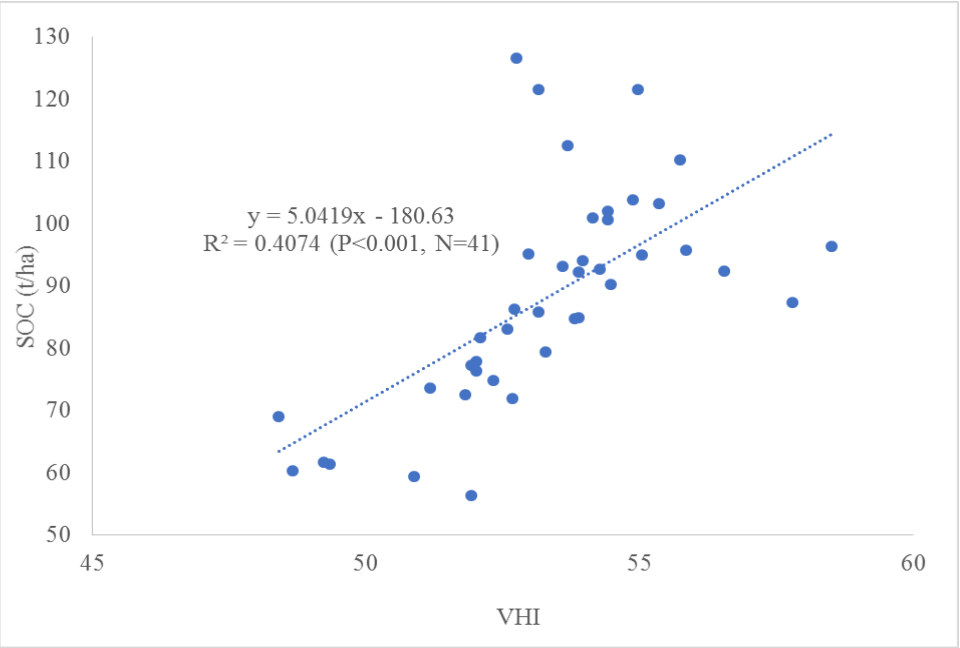
- The study revealed 2009 and 2015 as the drought years
- Central & northern highlands (Tigray, East Amhara, East Shewa in oromia), West & East Hararge and Silti and Alaba were identified as most vulnerable agricultural production areas.
- It is also found that VHI has positive relationship with SOC stock and drought frequency from VHI has negatively correlated with SOC stock

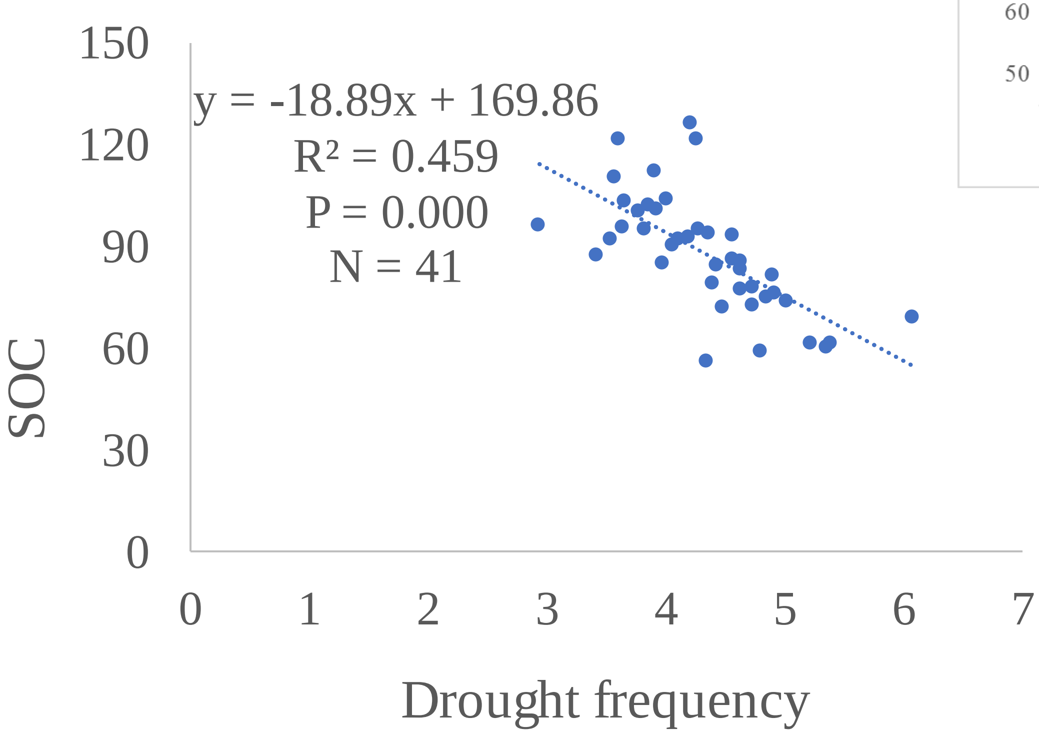
Average VHI for 2015 and food-security situation





Relationships between VHI and SOC stock





- This study found that the combined VHI-SPI can potentially be used to improve agricultural drought monitoring and early warning system
- VHI can potentially used as a good predictor variable for spatial mapping of SOC stock.

Thank you for Listening

Agriculture, Ecosystems and Environment 300 (2020) 106997

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journal homepage: www.elsevier.com/locate/agee

Soil organic carbon dynamics along chrono-sequence land-use systems in the highlands of Ethiopia

Assefa Abegaz[a,*], Lulseged Tamene[b], Wuletawu Abera[b], Tesfaye Yaekob[c], Habtamu Hailu[d], Sylvia S. Nyawira[e], Mayesse Da Silva[f], Rolf Sommer[g]

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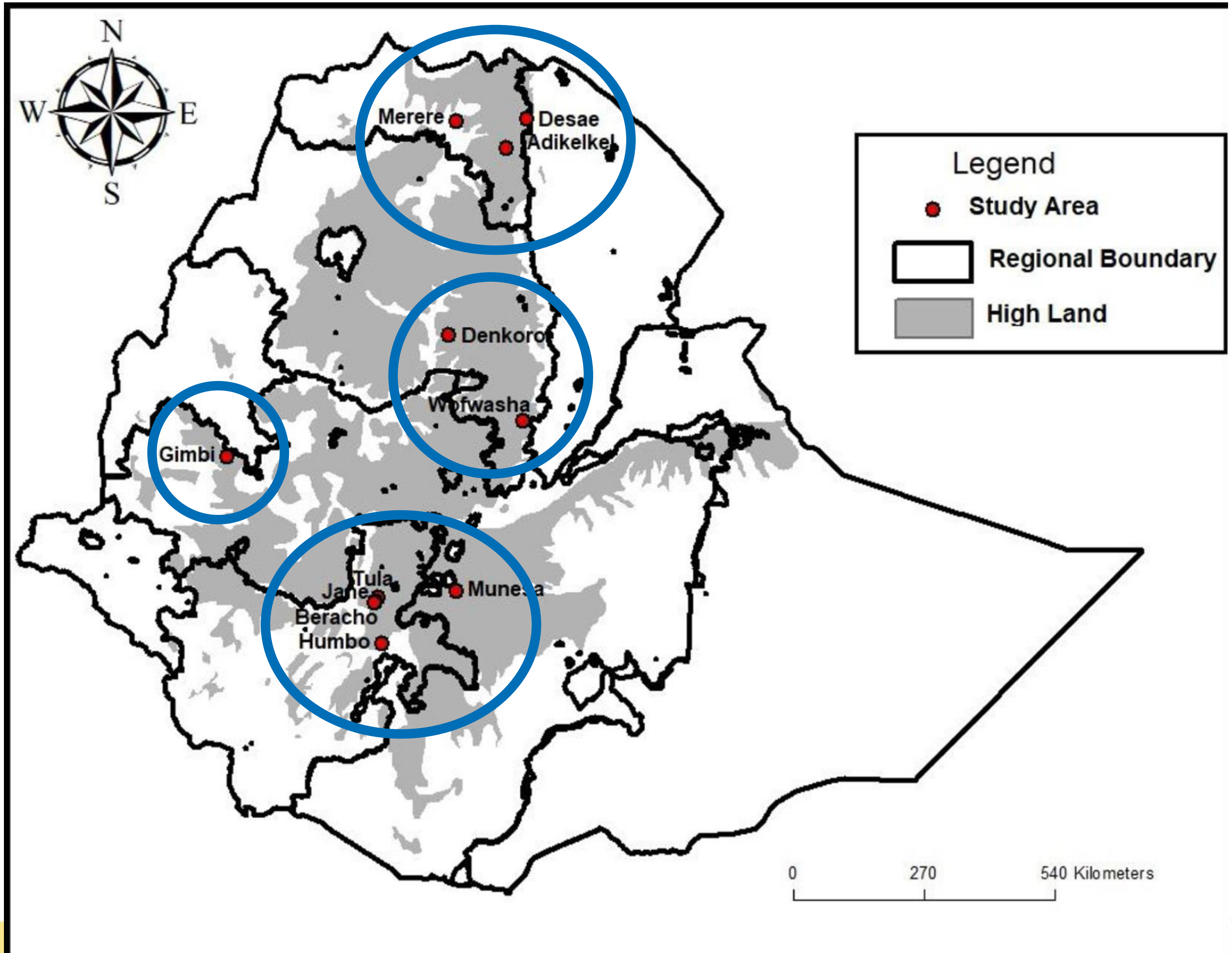
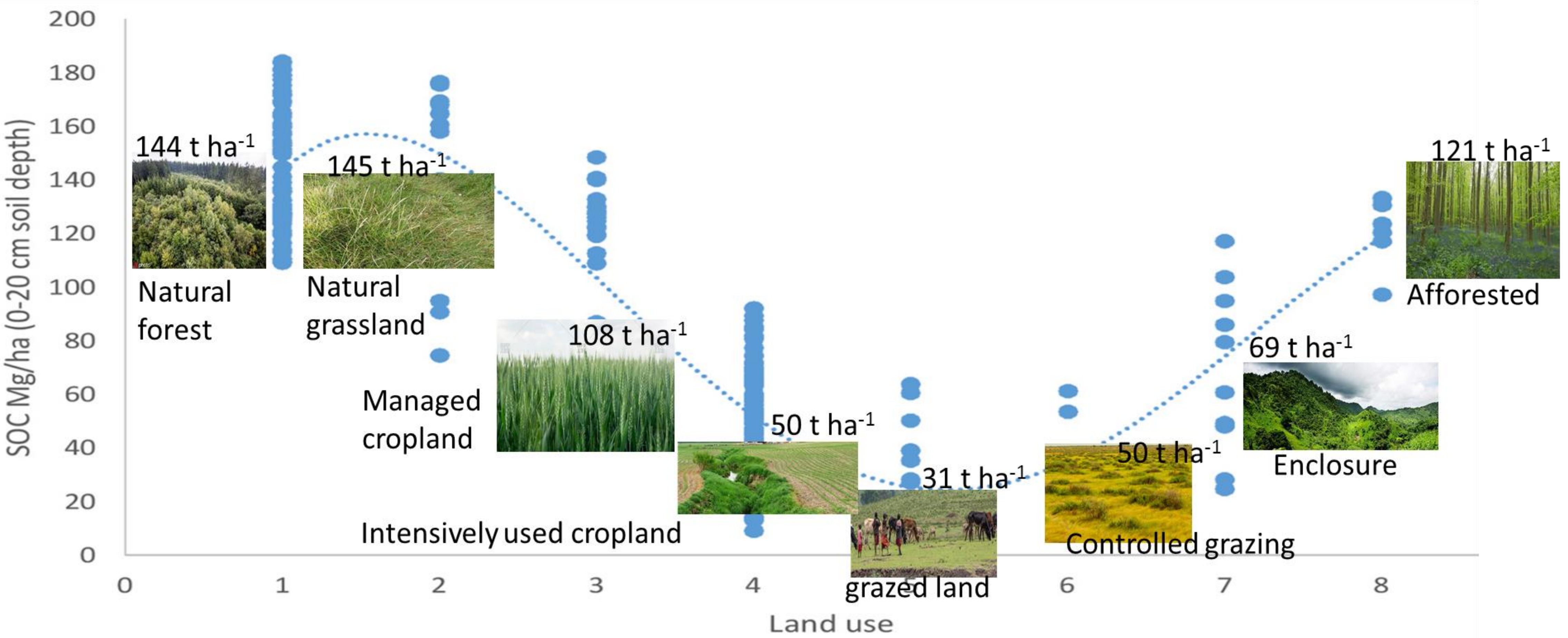
Research objectives

- The specific objectives were to:
  - analyze SOC stock loss due to land degradation
  - analyze gain due to land restoration; and
  - estimate the partial balance of SOC stock

Map of Ethiopia; showing the highlands of Ethiopia (light-dark-shaded area), and sampling areas (red-shaded small-circular area)

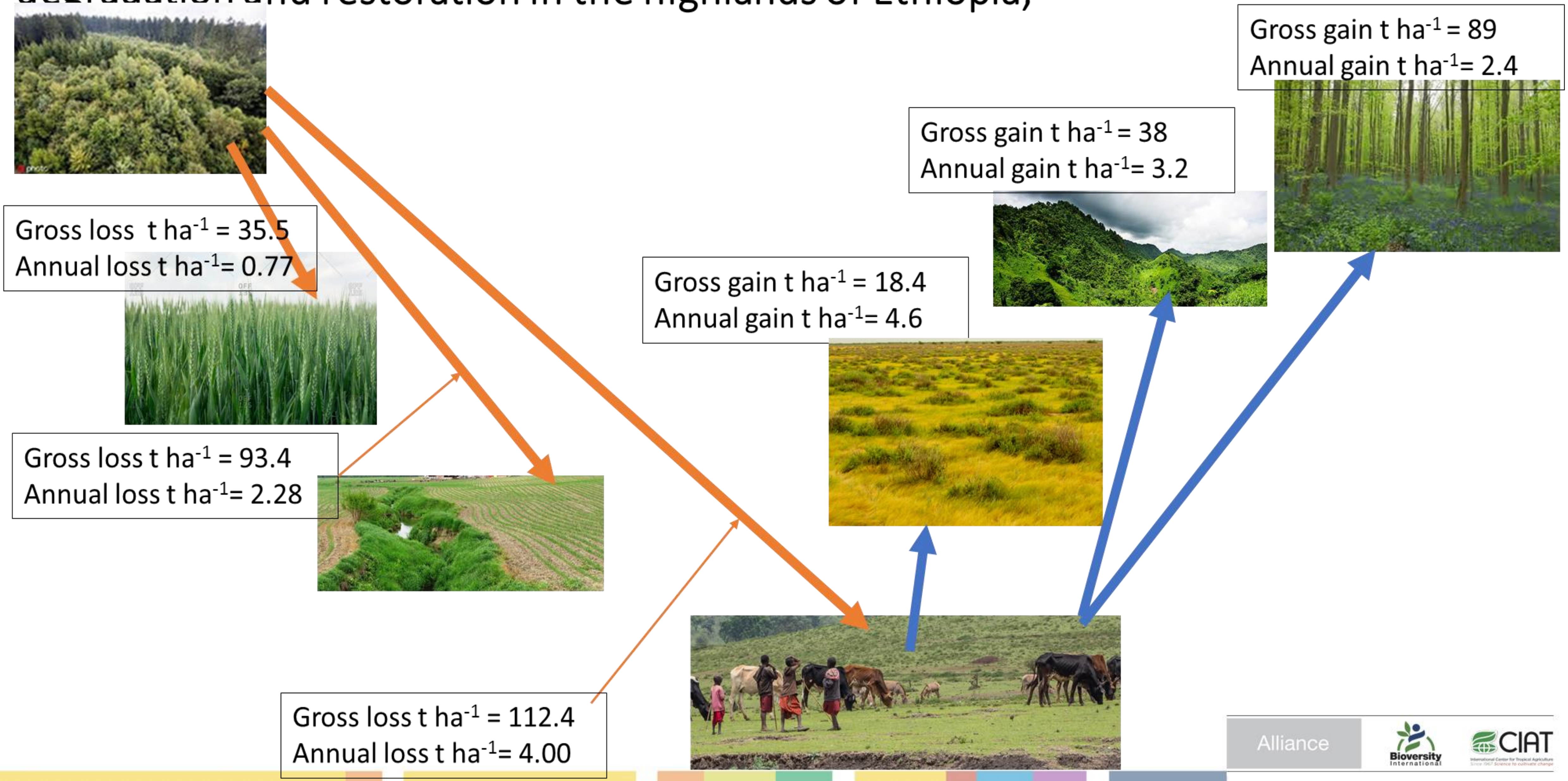


Mean SOC stock (t ha^{-1}) along chrono-sequence land-use types

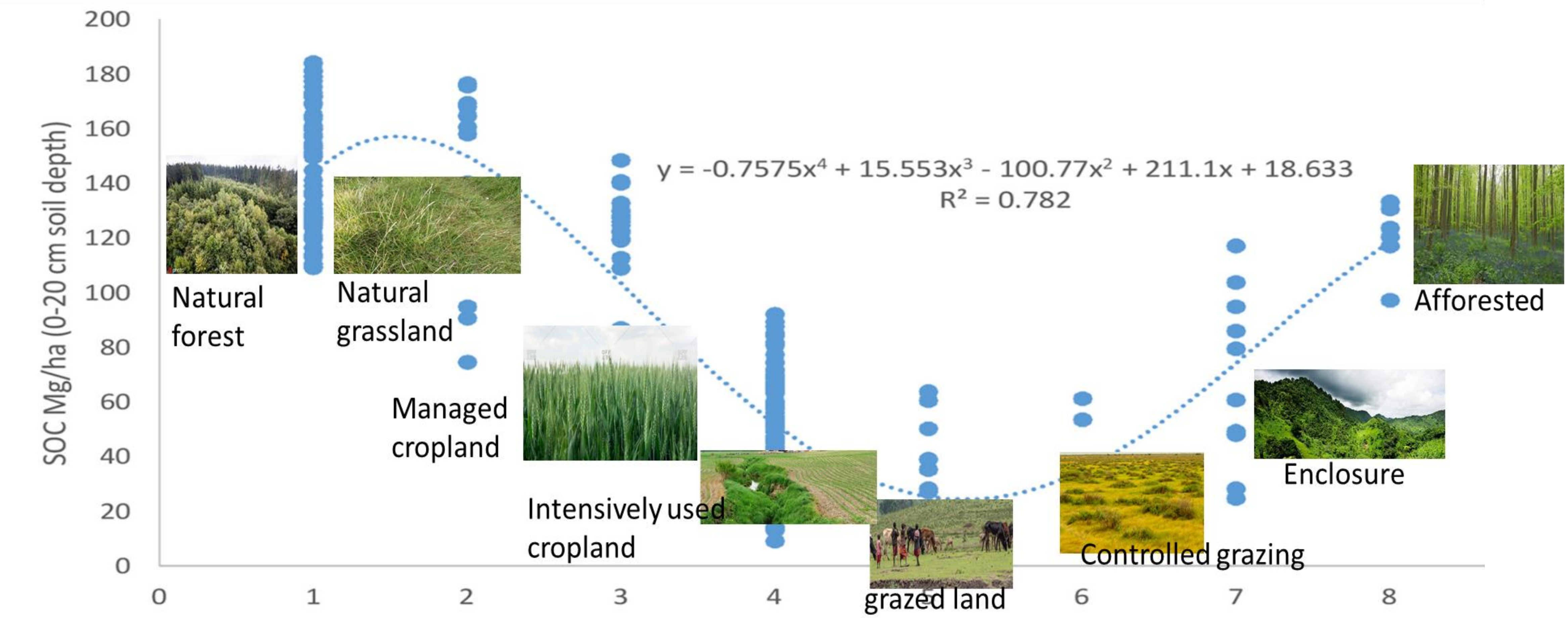


1=Forestland, 2=Guasa grass, 3=Managed cropland, 4=Intensively used cropland, 5=Intensively used grazing land, 6=Controlled grazing, 7=Enclosure, 8=Afforested land

Gross loss and gain, & annual rate of changes of SOC stock t ha^{-1} as caused by land degradation and restoration in the highlands of Ethiopia,

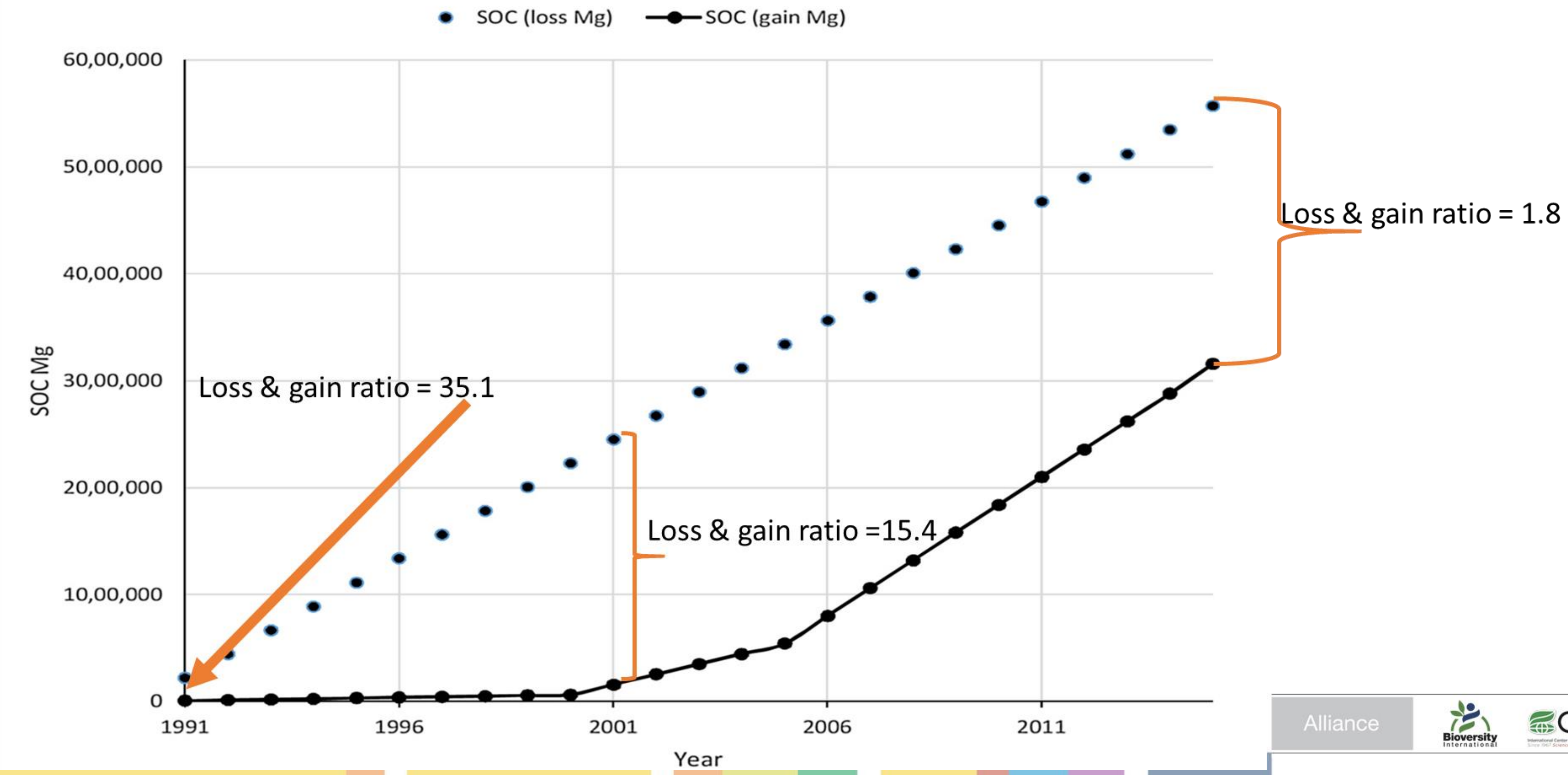


SOC stock dynamics in relation to land-use/cover changes



1=Forestland, 2=Guasa grass, 3=Managed cropland, 4=Intensively used cropland, 5=Intensively used grazing land, 6=Controlled grazing, 7=Enclosure, 8=Afforested land

Losses and gains in SOC stock because of deforestation and plantation in the highlands of Ethiopia during 1991–2015



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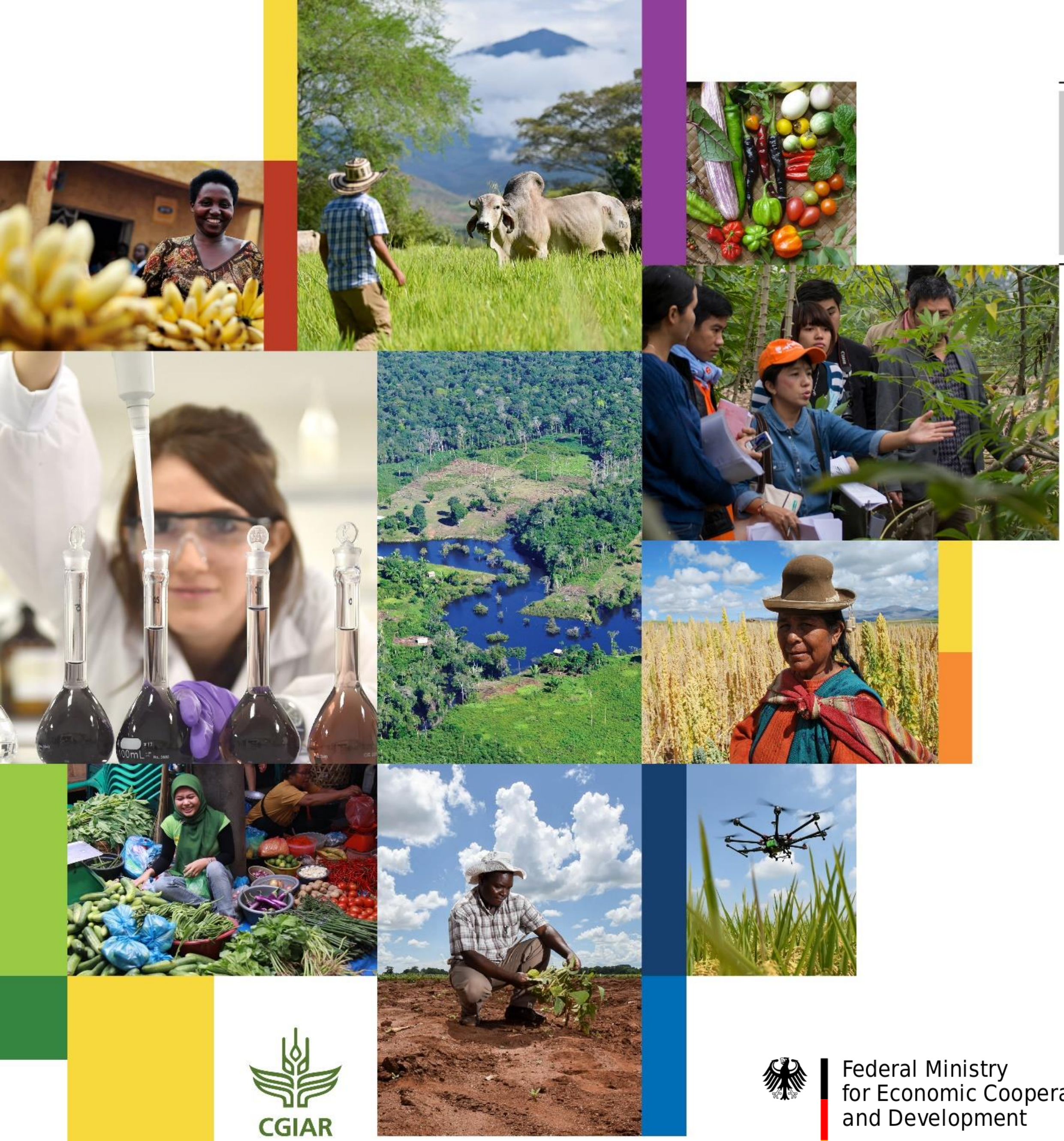
Conclusion

- Conversion of degraded farm lands to either controlled grazing lands, enclosures, or afforestation significantly increases SOC stock and is a sustainable practice to be adopted across the highlands of Ethiopia.
- Since natural ecosystems (forest and grasslands) are reservoirs of huge amount of SOC, there should be more determined efforts towards an effective protection of these ecosystems so as to avoid deforestation and ensure conservation of SOC stock.



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On-farm work on soil organic carbon and modelling of soil organic carbon sequestration in selected farmer plots

Mercy Jebet

Soil scientist

UNIVERSITY OF NAIROBI

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INTRODUCTION

Soils are key in carbon sequestration and the largest terrestrial organic carbon pool (Yigini and Panagos, 2016)

Severe depletion of the SOC pool in smallholder farms; degrades soil quality, reduces biomass productivity, and adversely impacts other ecosystem services (Lal, 2018; Jackson *et al.*, 2017)

OBJECTIVES

Evaluated the predominant agronomic management practices among smallholder farmers and their influence on SOC content

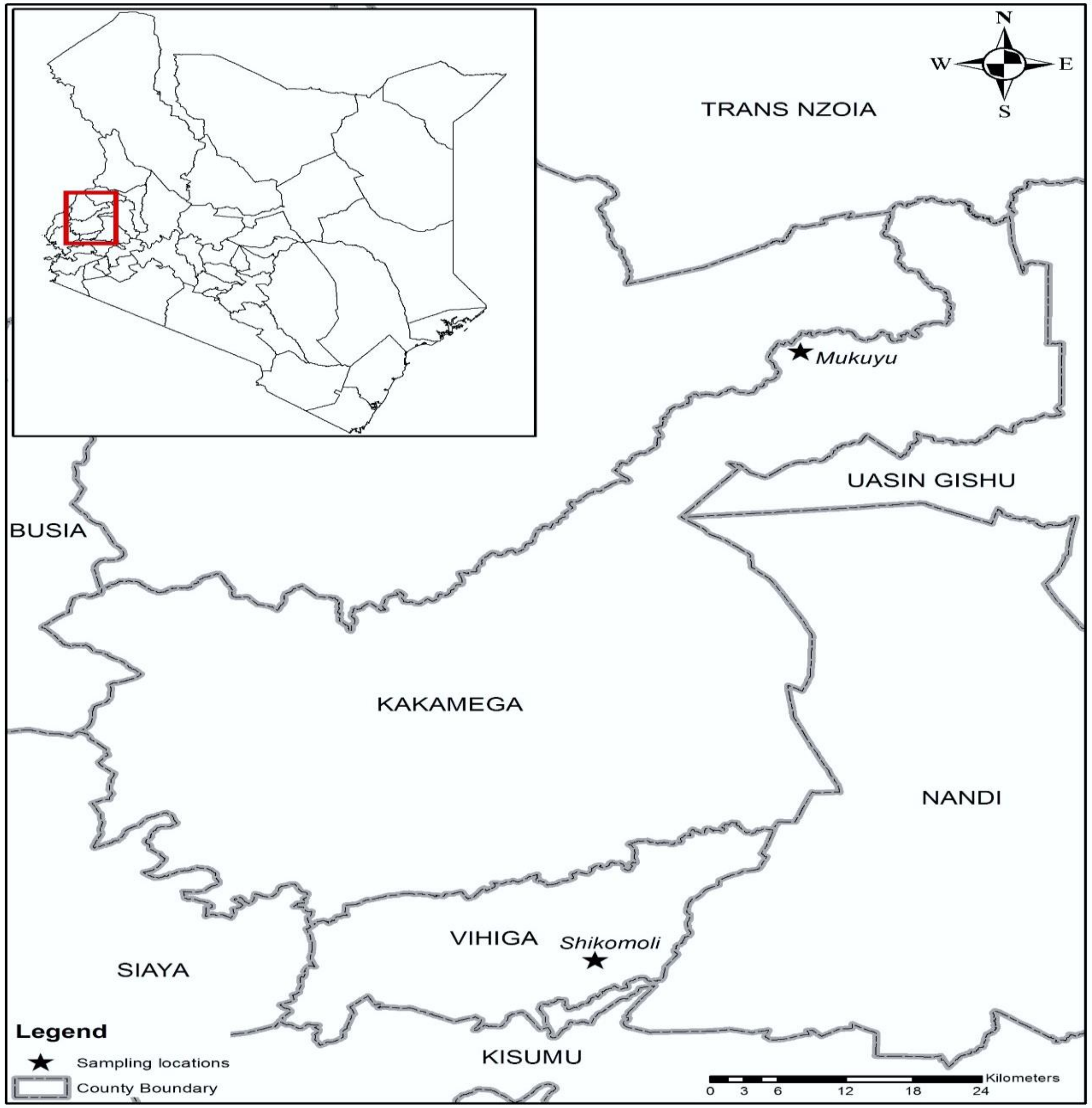
Determined the effect of soil physicochemical properties on SOC down the depth

Simulated SOC dynamics under different management practices using CropSyst model.

METHODOLOGY

Site: Mukuyu and Shikomoli villages, Western Kenya

- Survey was conducted to identify predominant management practices
- Soil physical and chemical analysis of; bulk density, texture, pH, total carbon, total nitrogen, cation exchange capacity, available phosphorus, exchangeable aluminium and micronutrients
- We modelled SOC sequestration potential under current management practices and improved practices (minimum tillage and full residue retention) using CropSyst model from selected farmers



METHODOLOGY CONT'D

- The management practices of the selected farmers are shown in the table below;

Farm	Mineral fertilizer application (kg N/ha)	Type of mineral fertilizer	Manure application (t/ha)	Proportion of crop residue retained (%)
Farm 1	9	DAP,CAN	0.4	5
Farm 2	13	CAN	1	20
Farm 3	36	DAP, CAN, Urea	-	5
Farm 4	38	DAP, CAN	-	10
Farm 5	72	CAN, NPK	-	70
Farm 6	26	CAN, Mavuno	-	20

DAP-Diammonium phosphate; CAN-Calcium ammonium nitrate; NPK- Nitrogen phosphorus and potassium

KEY FINDINGS

Manure application in combination with chemical fertilizer were the main management practices

However the amount applied was below the recommended levels

SOC stocks reduced down the depth for all sites

Total organic nitrogen, carbon to nitrogen ratio, cation exchange capacity and manganese had a positive association with SOC stocks at depths

KEY FINDINGS CONT'D

- TON, TOC, P and CEC were deficient in at all depths

		Soil Parameters										
Depth (cm)	Site	TON (%)	TOC (%)	pH	BD (g/cm3)	P (ppm)	CEC (cmol/kg)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Al (cmol/kg)
0-20	Shikomoli	0.08	0.89	5.67	1.52	27.94	6.18	10.01	41.54	36.46	0.48	0.45
	Mukuyu	0.11	1.44	5.85	1.42	26.40	9.28	5.44	36.45	60.47	0.66	0.30
20-40	Shikomoli	0.07	0.76	5.56	1.58	21.18	5.73	6.92	29.22	30.45	0.19	0.43
	Mukuyu	0.09	1.15	5.75	1.40	20.55	9.94	3.59	20.47	53.85	0.55	0.39
40-60	Shikomoli	0.07	0.71	5.54	1.60	21.89	5.77	5.86	25.35	31.26	0.29	0.57
	Mukuyu	0.08	1.01	5.81	1.50	15.33	8.81	3.54	16.99	44.72	0.47	0.37

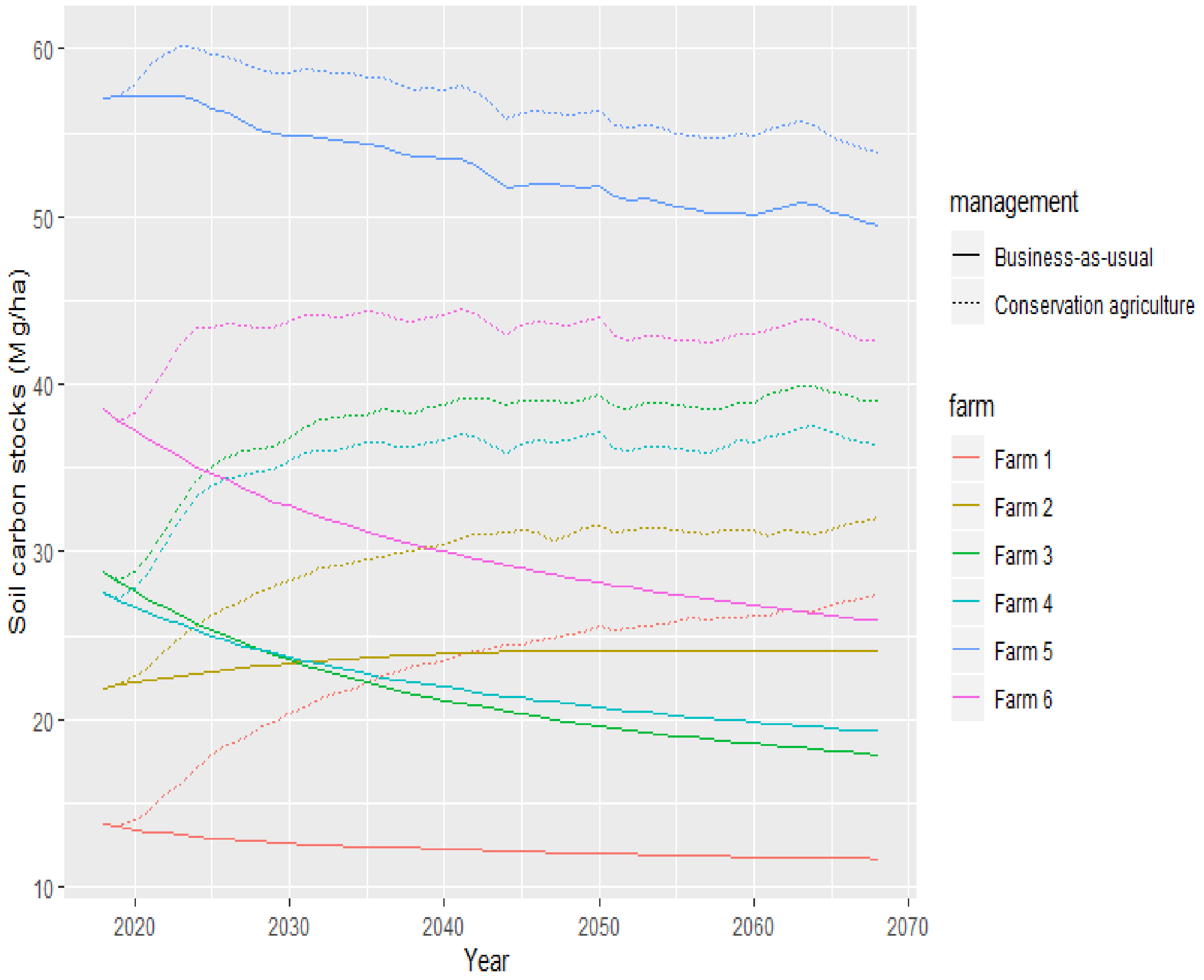
TON= total organic nitrogen, TOC= total organic carbon, BD=bulk density, P= available phosphorus, CEC= cation exchange capacity, Zn= zinc, Mn= manganese, Fe= iron, Cu= copper, Al= exchangeable aluminum

KEY FINDINGS CONT'D

The average annual loss of SOC stocks in the upper 20 cm for current management ranged from 0.03 to 0.19 t C/ha/yr.

Switching to conservation agriculture, SOC stocks increased to up to 0.28 t C/ha/yr

Both management systems experienced crop water stress more compared to nitrogen stress



CONCLUSION

Minimum tillage combined with residue retention are potential management practices to sequester SOC.

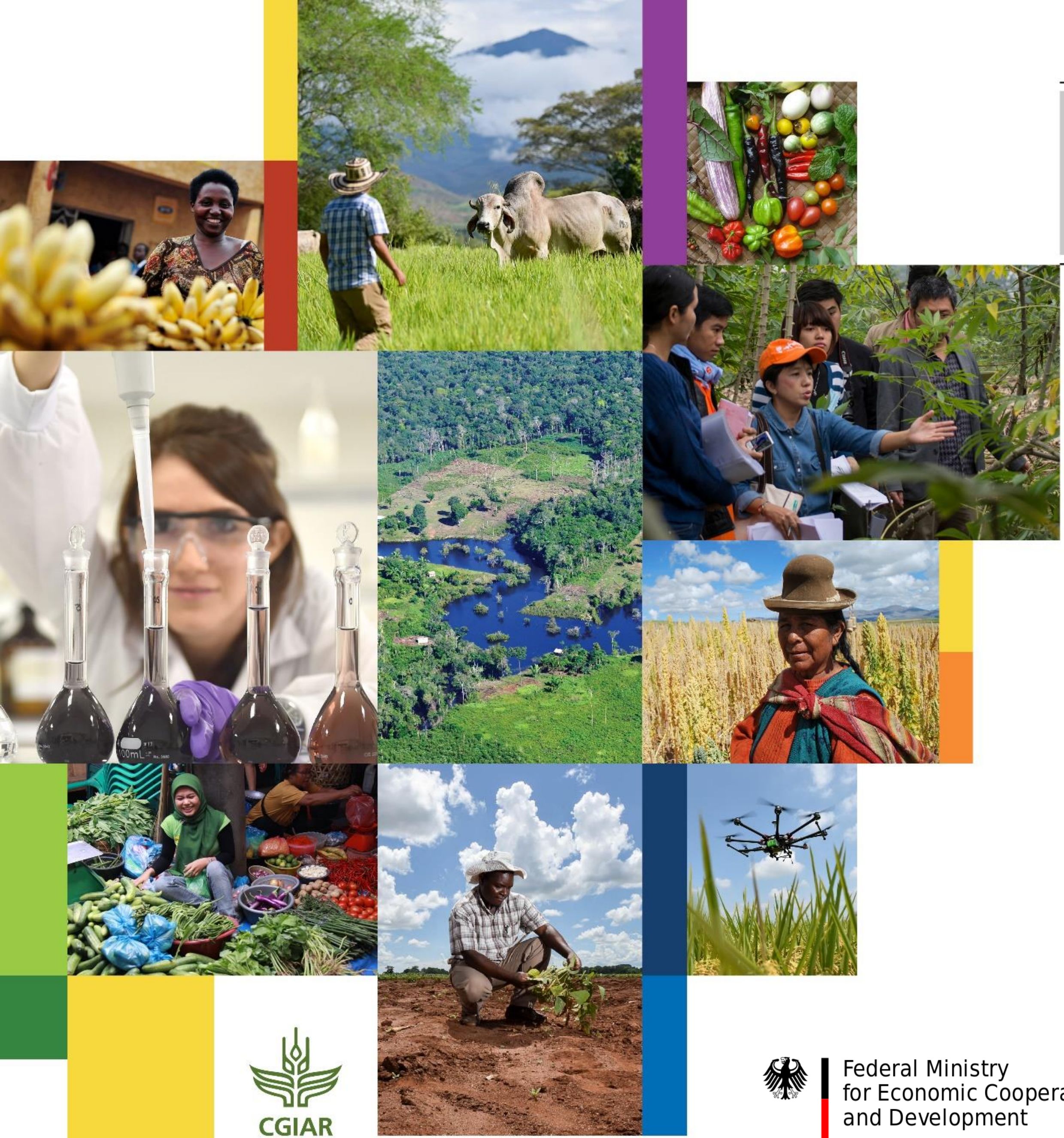
SOC sequestration was higher at upper depth compared to sub-surface layers

Mukuyu had a higher sequestration rate compared to Shikomoli due to differences in soil texture and climatic conditions

Thus to implement improved management practices, site-specific conditions need to be considered.

There is a need to adopt practices that increase soil total nitrogen, carbon to nitrogen ratio, cation exchange capacity and manganese since they are crucial in SOC sequestration down the depth

THANK YOU



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Hot spot mapping of SOC sequestration potential –Kenya case study

Kristin Pikki and Mats Söderström

SLU
Swedish University of Agricultural Sciences

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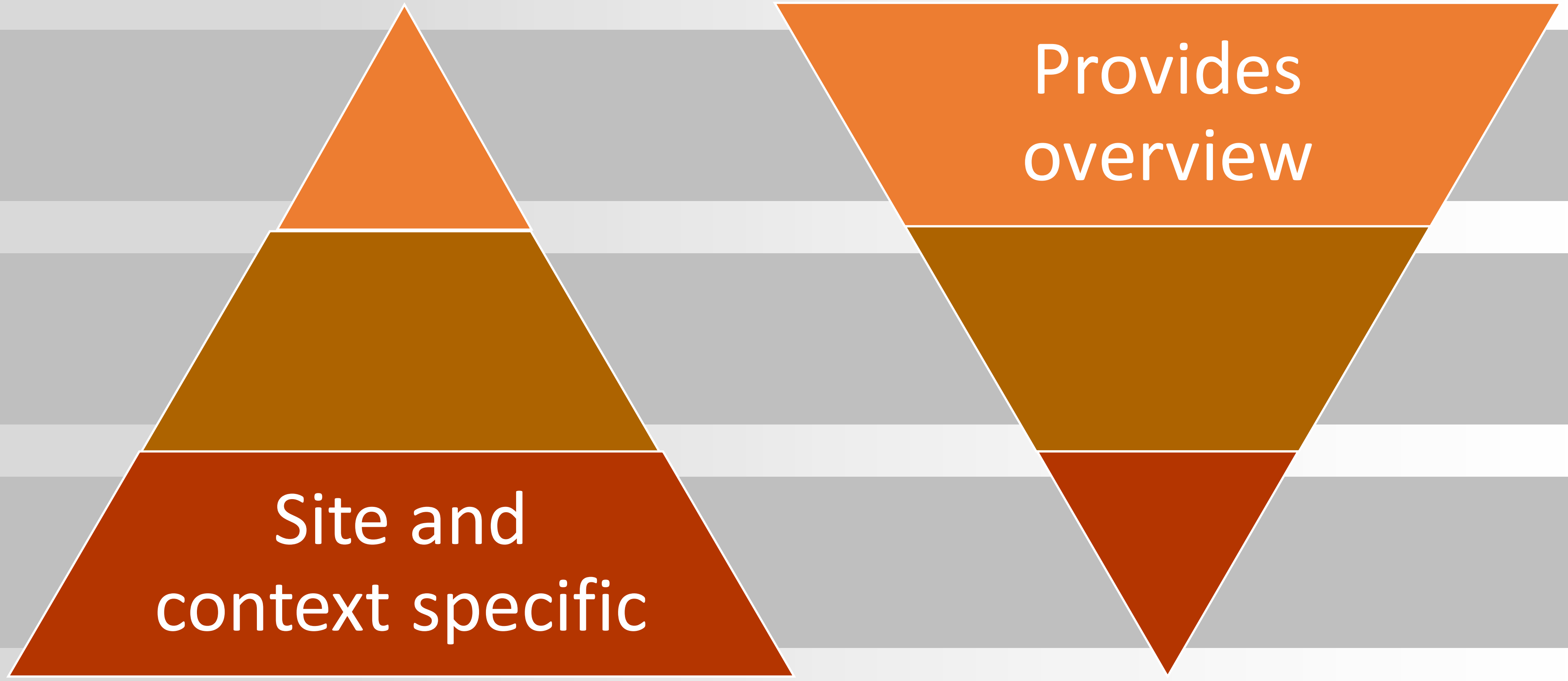
Hot spot mapping of SOC sequestration potential

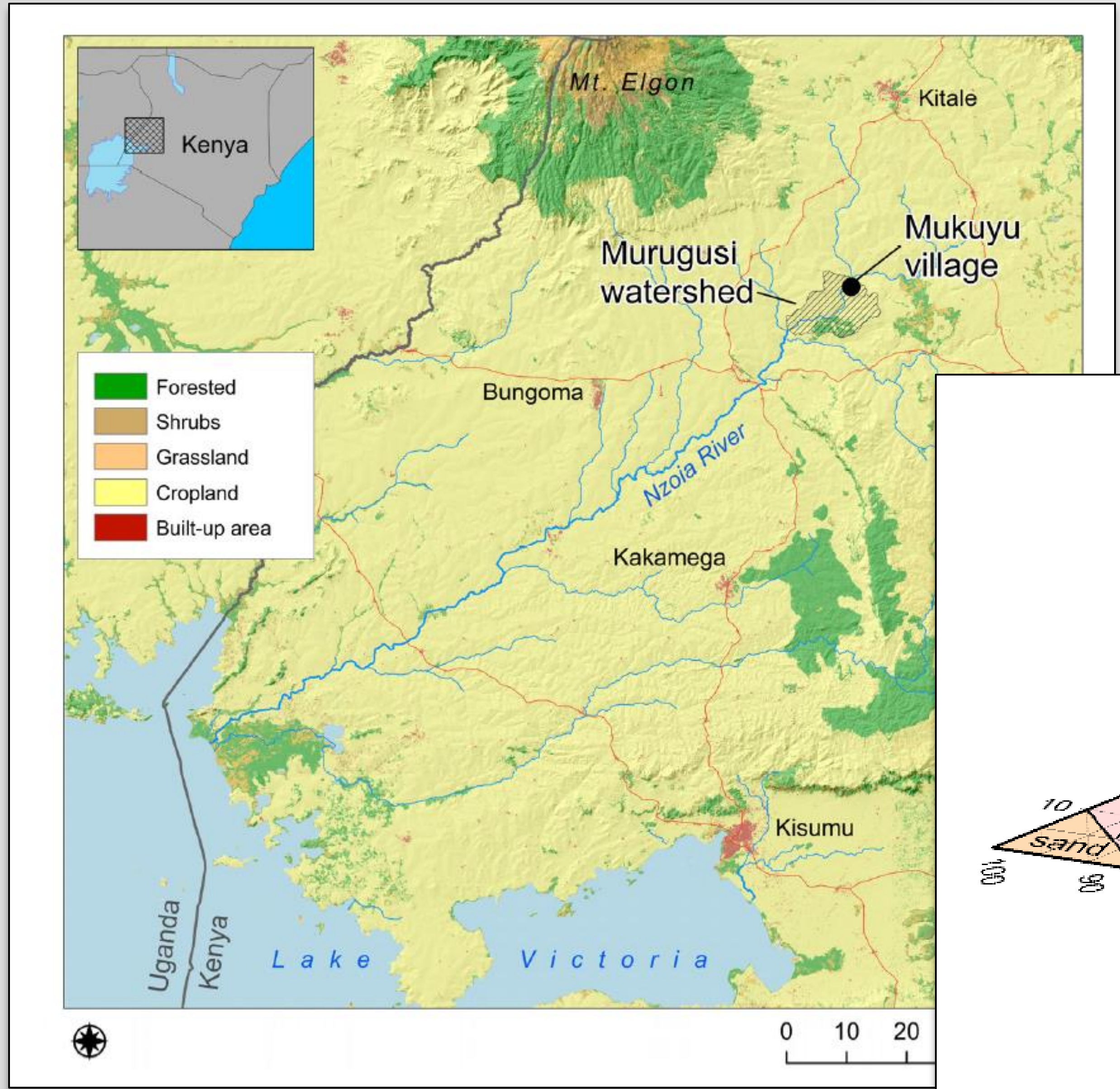
Can guide high-level planning and decision-making

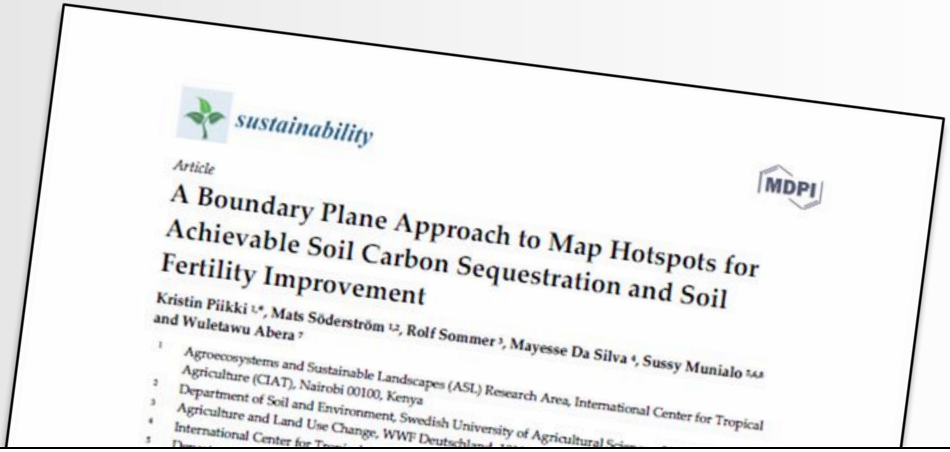
Can guide local decisions on investments and management



Local empirical modelling and mapping

Global mechanistic modelling and mapping




sustainability

MDPI

Article

A Boundary Plane Approach to Map Hotspots for Achievable Soil Carbon Sequestration and Soil Fertility Improvement

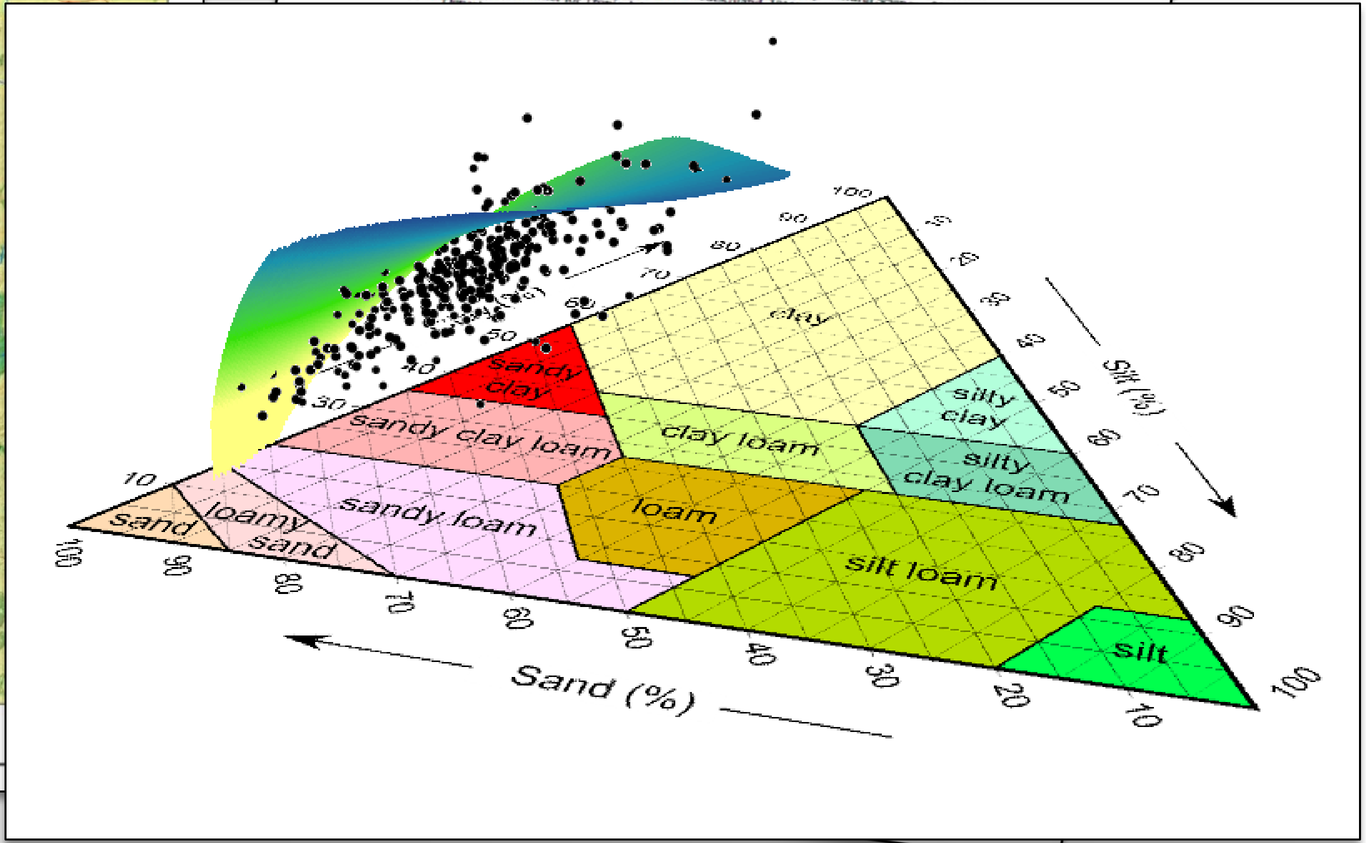
Kristin Piikki, Mats Söderström, Rolf Sommer, Mayesse Da Silva, Sussy Munialo and Wuletawu Abera

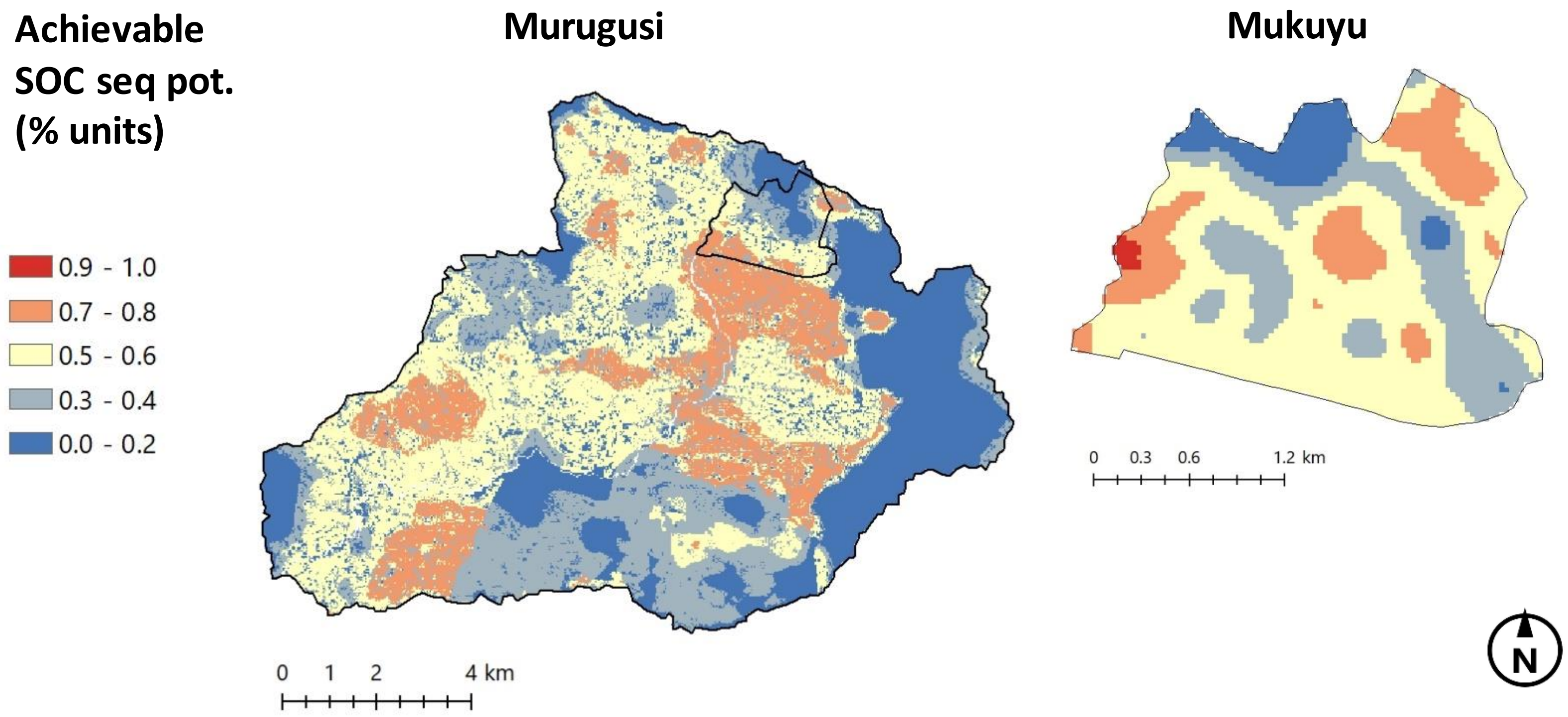
Agroecosystems and Sustainable Landscapes (ASL) Research Area, International Center for Tropical Agriculture (CIAT), Nairobi 00100, Kenya

Department of Soil and Environment, Swedish University of Agricultural Sci...

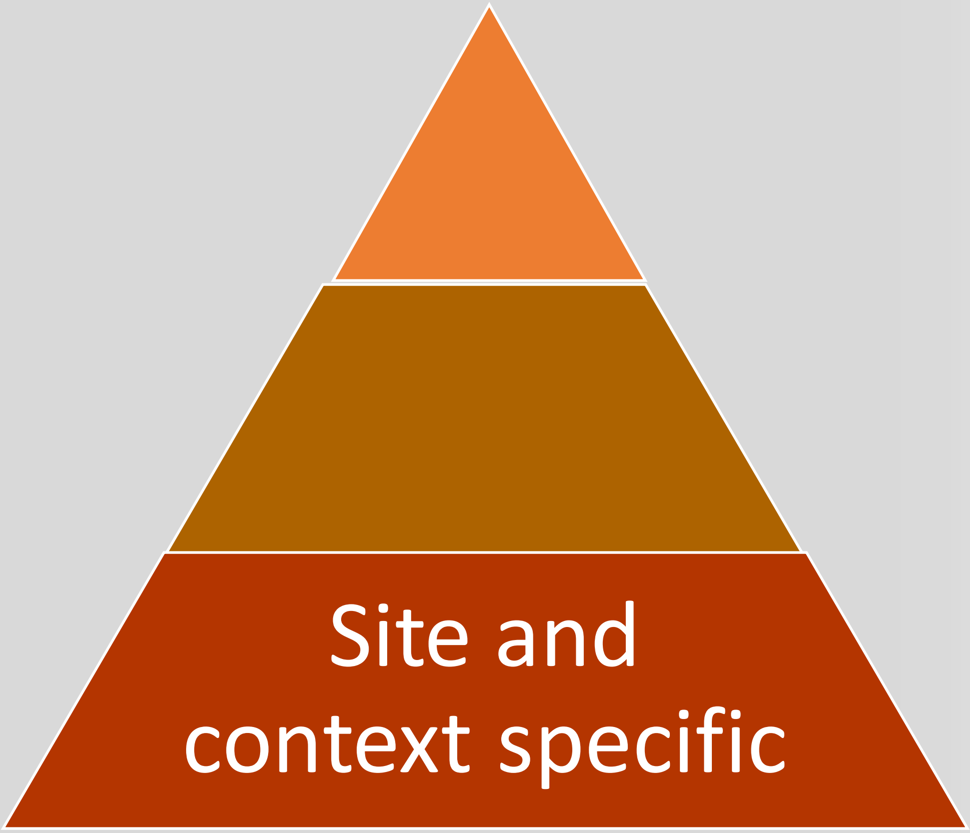
Agriculture and Land Use Change, WWF Deutschland...

International Center for Tropical...





Achievable SOC sequestration

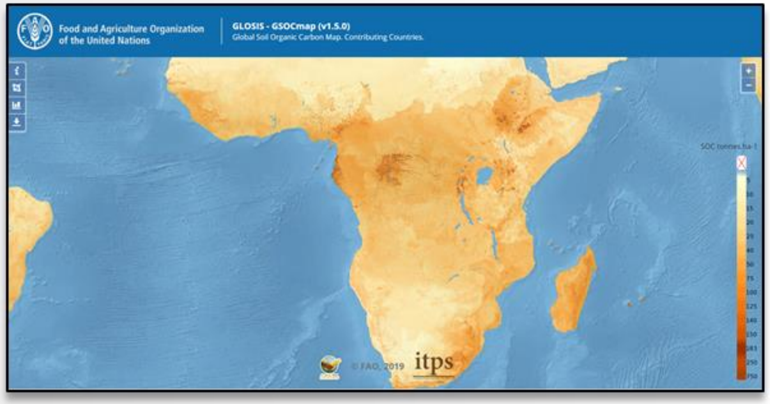


Local empirical
modelling and mapping

Can guide local decisions on investments and management

Local data ensures no false pretences

How to acquire local soil data?



Is it available already?

NO

How to acquire it?
Proximal sensing/Wet chemistry

YES

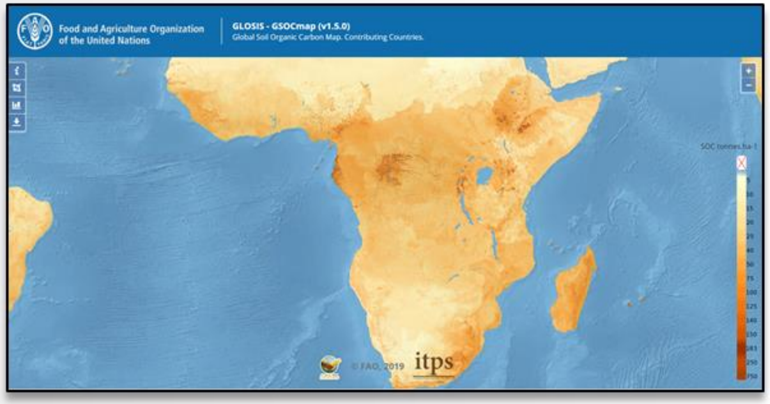
Does the accuracy meet my need (at the intended scale of use)?

NO

Can it be improved/downscaled?

YES

How to acquire local soil data?



Is it available already?

NO

How to acquire it?
Proximal sensing/Wet chemistry

YES

Does the accuracy meet my need (at the intended scale of use)?

NO

Can it be improved/downscaled?

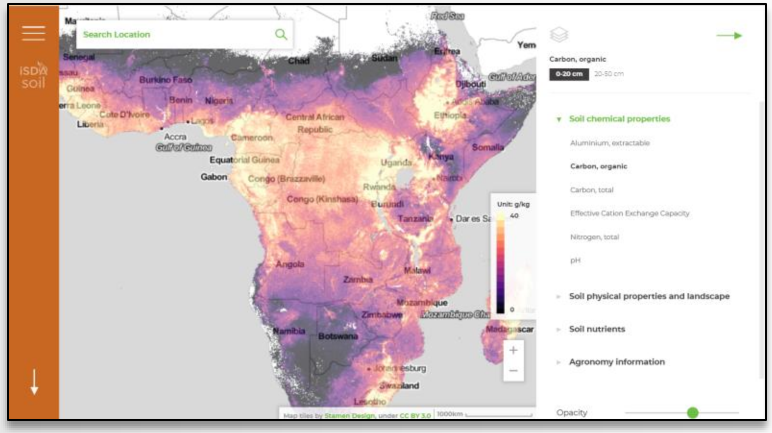
YES

The GSDM tool for data sampling and mapping

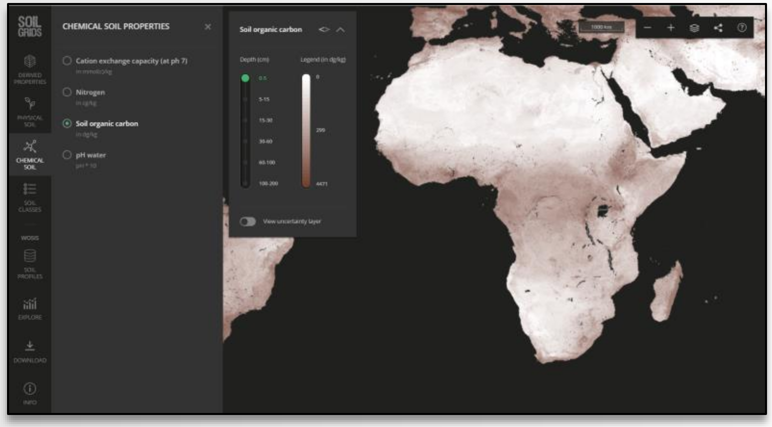
There are many public soil maps…

Amazing!

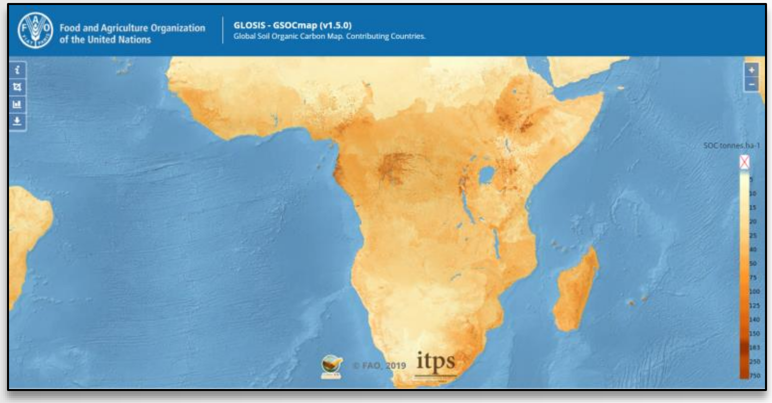
…but they may be hard to ***access*** *and* ***assess*** *and* ***improve*** *by local samples*



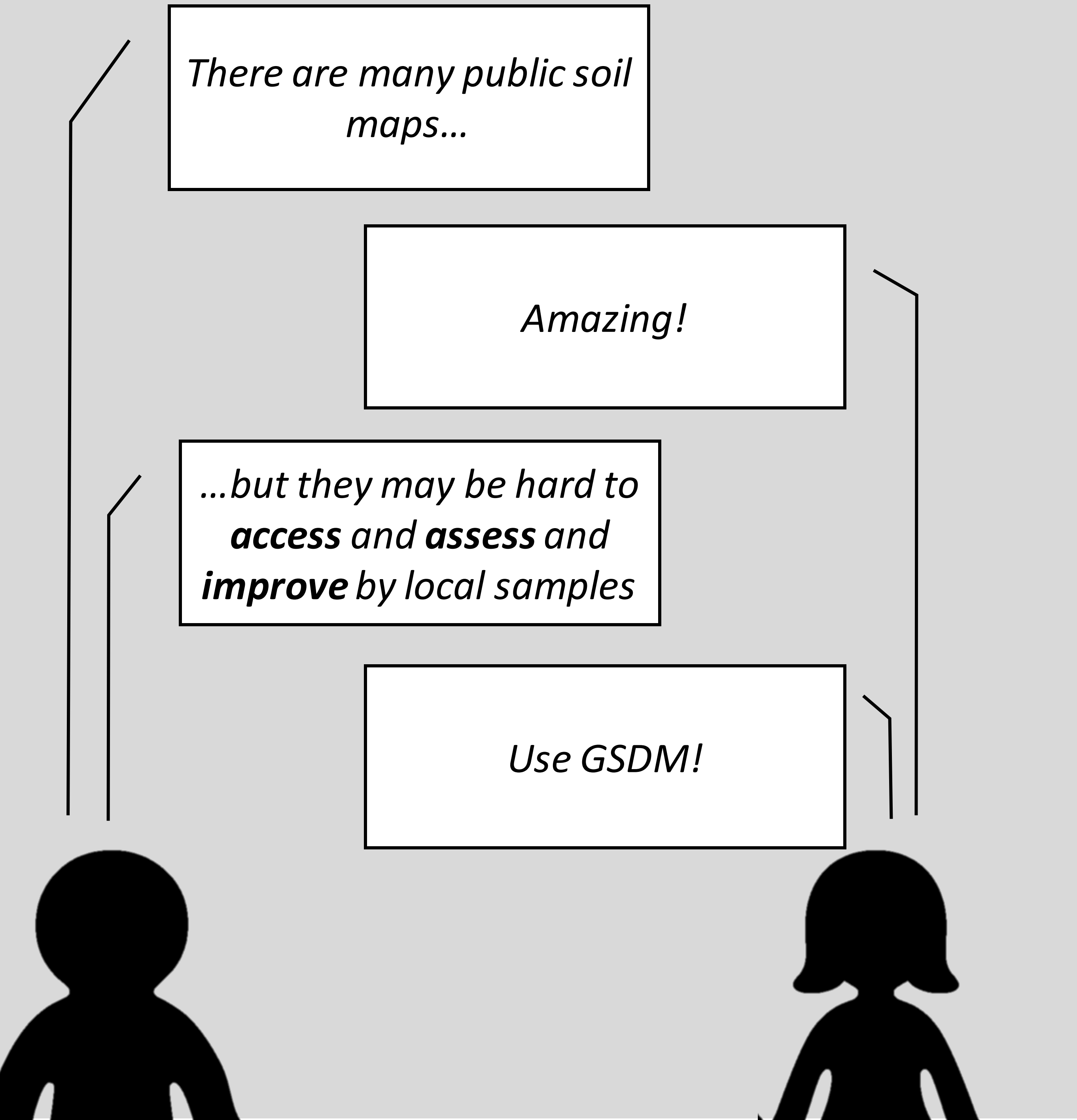
iSDAsoil

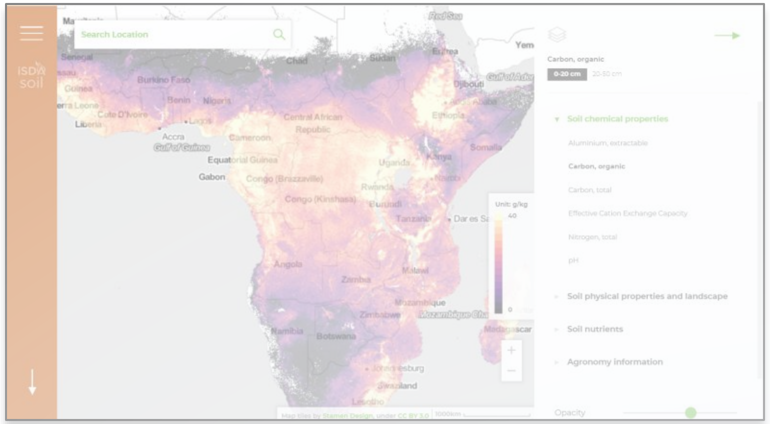


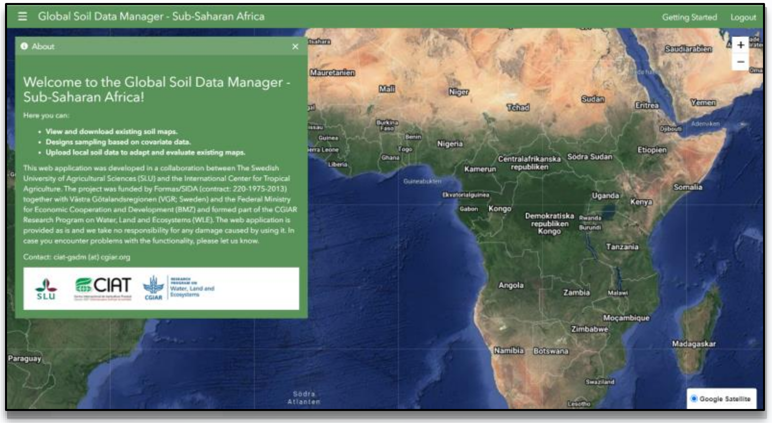
Soilgrids 2.0

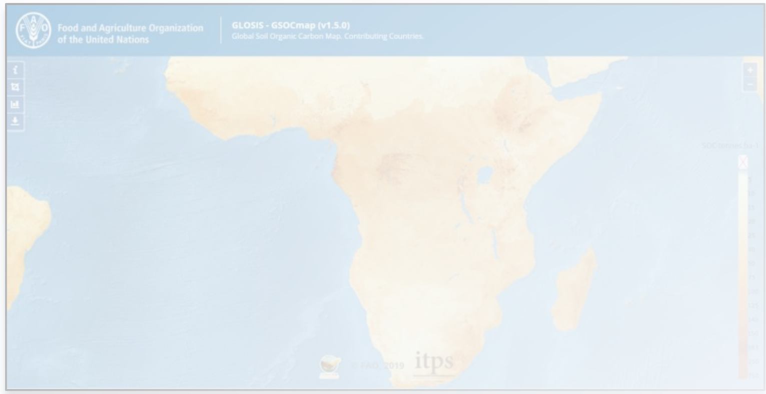


GLOSIS -GSOCmap


There are many public soil maps…
Amazing!
…but they may be hard to **access** and **assess** and **improve** by local samples
Use GSDM!

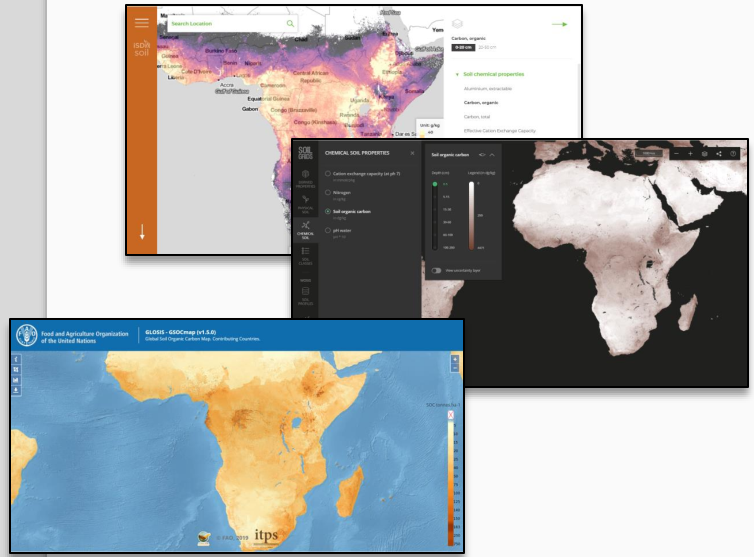



Global Soil Data Manager - Sub-Saharan Africa
Welcome to the Global Soil Data Manager - Sub-Saharan Africa!



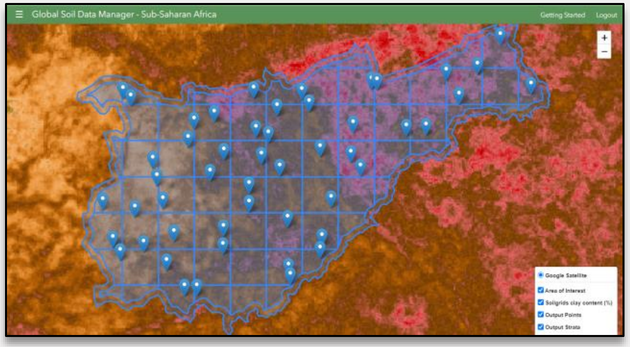
GSDM

Global digital soil maps



- [x] Availability
- [x] Spatial resolution
- [ ] Data accuracy

Local adaptation



- [x] Availability
- [x] Spatial resolution
- [x] Data accuracy

Local use

For example:
targeting interventions to enhance SOC sequestration

SOC sequestration potential assessment

Into the future

First version developed in projects

Continued development and running depend on collaboration with partner organization

Selected outputs

Alliance

Web application:
Global Soil data manager. Available at: https://gsdm.online/

Peer reviewed articles:
Namirembe, S., Piikki, K., Sommer, R., Söderström, M., Tessema, B., & Nyawira, S. S. (2020). Soil organic carbon in agricultural systems of six countries in East Africa–a literature review of status and carbon sequestration potential. South African Journal of Plant and Soil, 37(1), 35-49. Link

Piikki, K., Söderström, M., Sommer, R., Da Silva, M., Munialo, S., & Abera, W. (2019). A boundary plane approach to map hotspots for achievable soil carbon sequestration and soil fertility improvement. *Sustainability*, *11*(15), 4038. Link.

Tessema, B., Sommer, R., Piikki, K., Söderström, M., Namirembe, S., Notenbaert, A., ... & Paul, B. (2020). Potential for soil organic carbon sequestration in grasslands in East African countries: A review. Grassland Science. Link

Policy brief
Namirembe S., Piikki K., Sommer R., Söderström M., Bezaye T., Nuyawira, S. (2018) Improving crop productivity and mitigating climate change by building up carbon stocks in soils of East Africa. Brief published by AgriFoSe2030. Link

Presentations at conferences
Mutua J., Piikki, K., Söderström M. (2019). The Sub-Saharan Africa Soil Data Manager (SSA-SDM). Abstract for oral presentation. AfricaGIS 2019 conference, Kigali, Rwanda. Link.

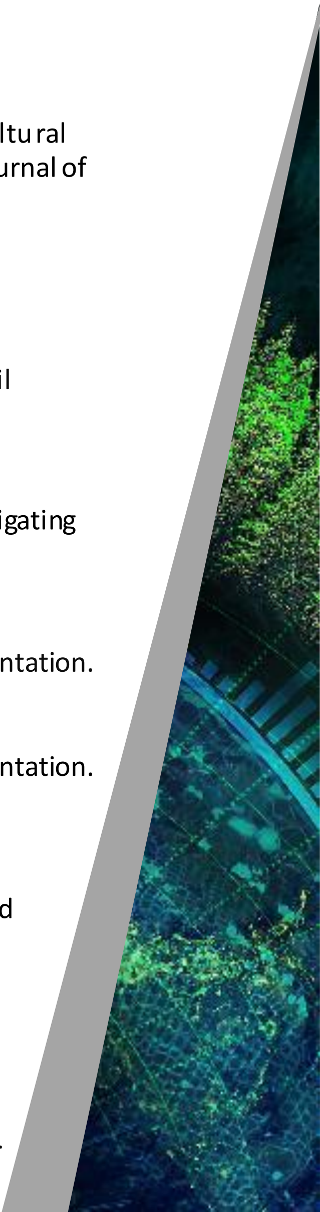
Piikki, K., Söderström M., Mutua J. (2019). The Sub-Saharan Africa Soil Data Manager (SSA-SDM). Abstract for oral presentation. Agri4D 2019 conference, Uppsala, Sweden. Link

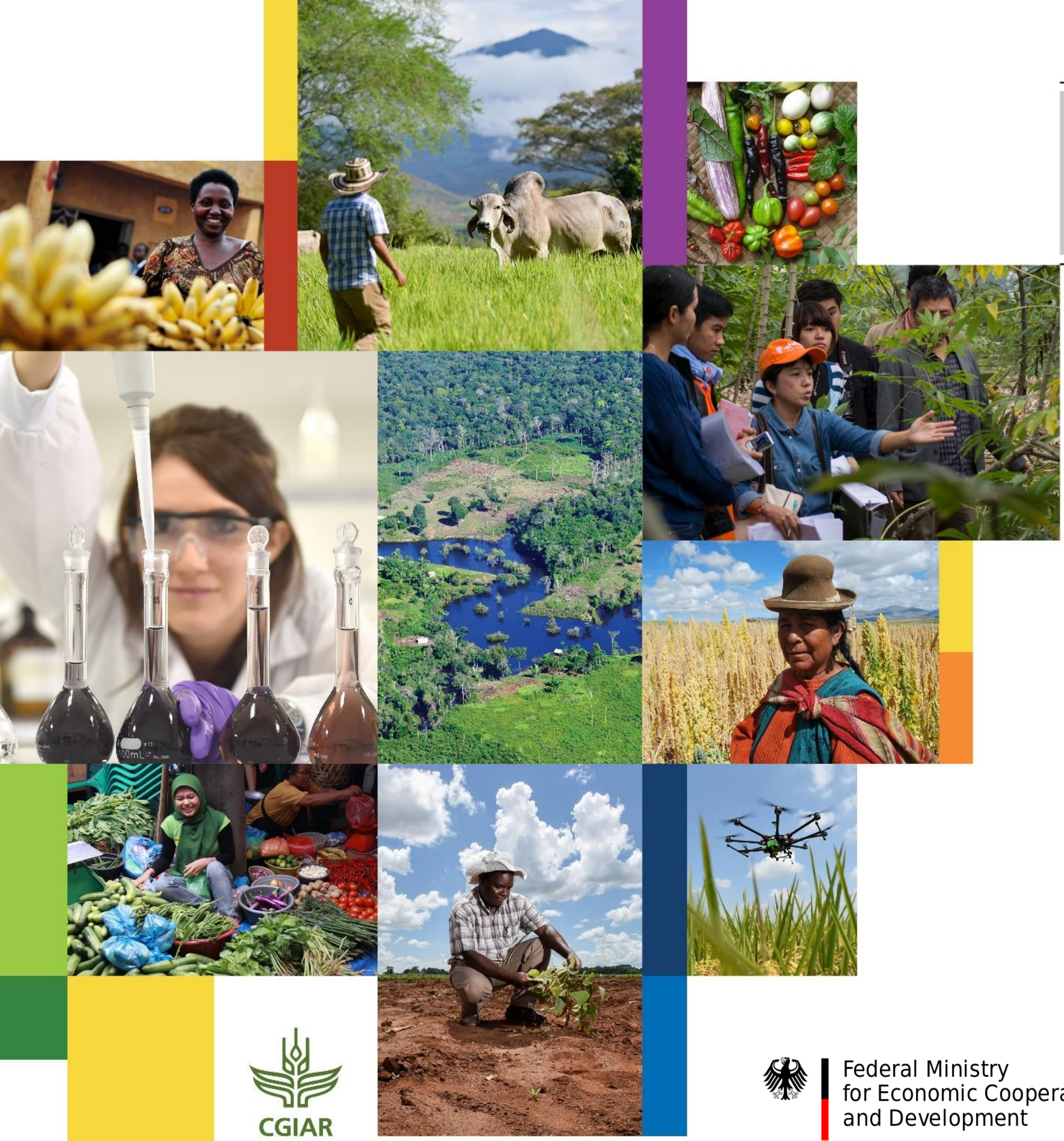
Dataset
Piikki K., Söderström M., Sommer R., Da Silva M. (2019). Physical topsoil properties in Murugusi, Western Kenya. Harvard University, Cambridge, MA, USA, 2019. Link

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Contact:
kristin.piikki@slu.se
mats.soderstrom@slu.se

Acknowledgements
The outputs were developed in collaboration with the projects funded by the AgriFoSe2030 programme, Formas/Sida (contract: 220-1975-2013), Västra Götaland Region and the Swedish University of Agricultural Sciences (contract: RUN 2018-00141). The project was supported by the CGIAR Research Program on Water, Land and Ecosystems (WLE) and CGIAR Fund Donors.





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Estimating spatially distributed SOC sequestration potentials of sustainable land management program of Ethiopia

Wuletawu Abera et al

SLU
Swedish University of Agricultural Sciences

CGIAR

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for Economic Cooperation
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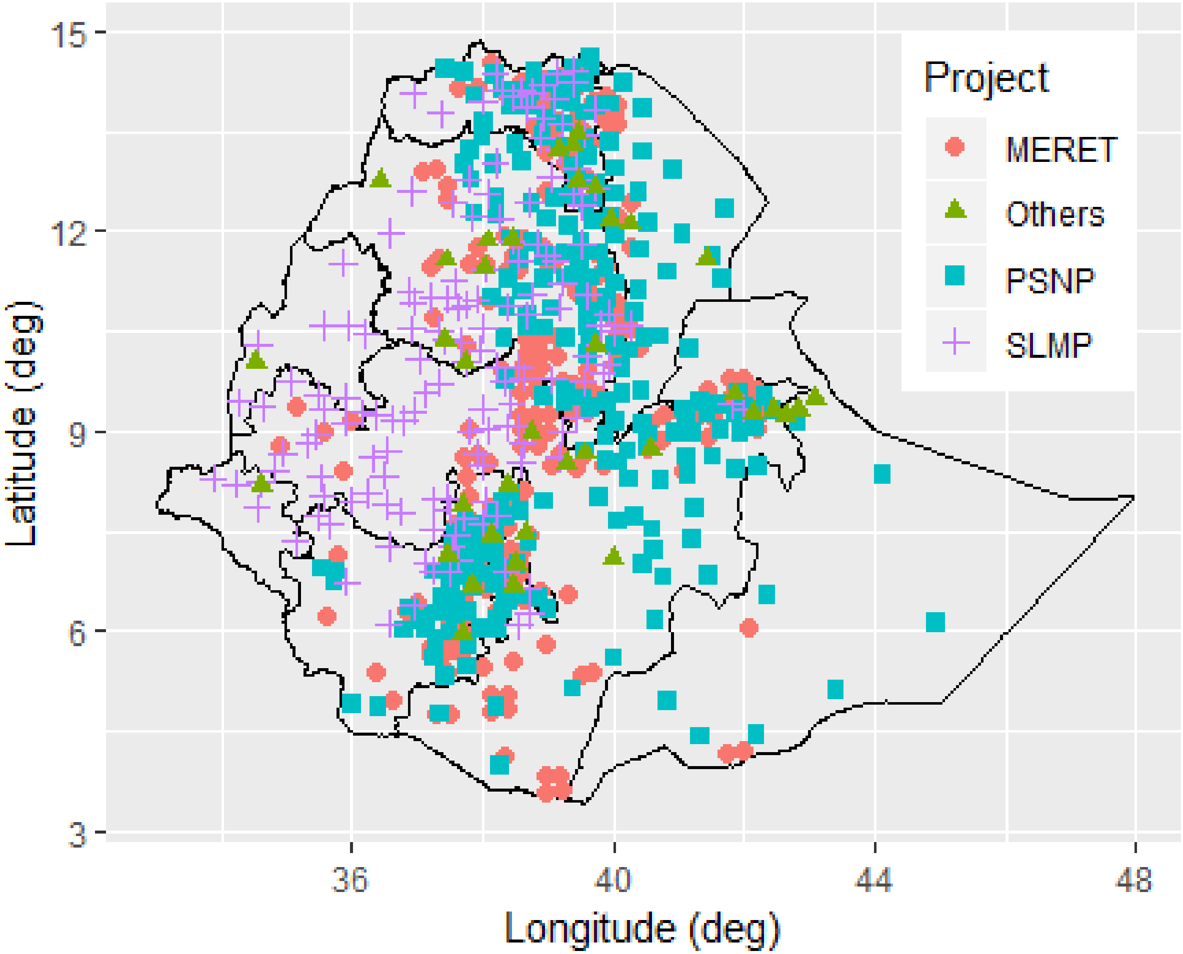
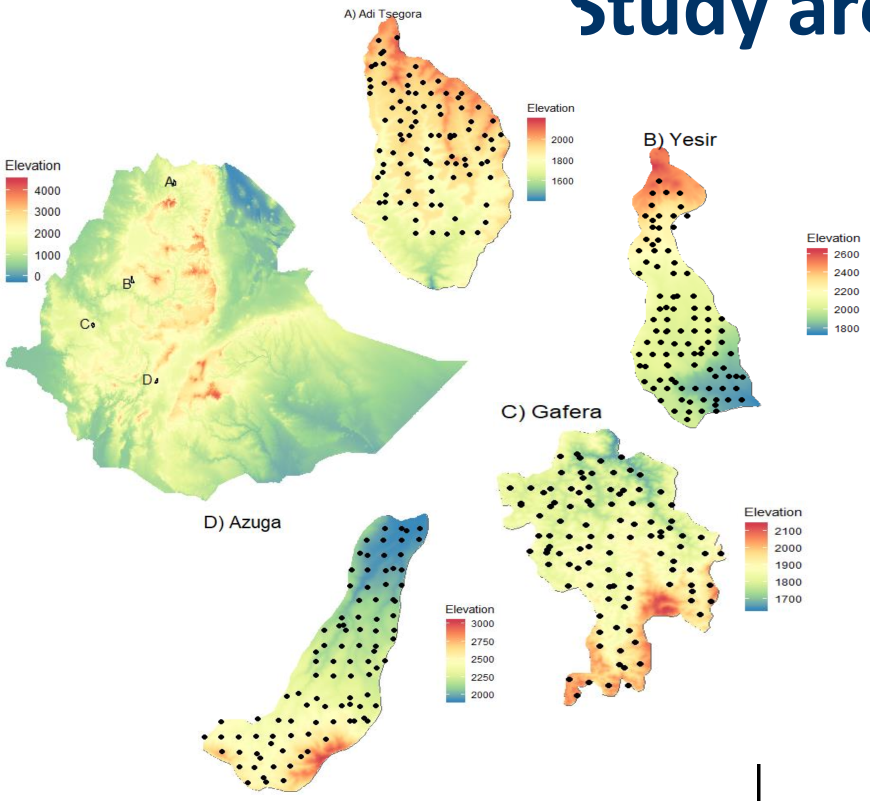
CGIAR
RESEARCH PROGRAM ON
Water, Land and Ecosystems

Land restoration (SLMP/PSNP/MERET)



- **The impacts of land management practices** on sequestration of soil organic carbon (map and hotspots of **SOC sequestration** and **achievable SOC sequestration**)

Study area and approach



Data collected:

- 4 watersheds from 4 regions
- Before SLMP (2010)
- After SLMP (2018)
- 387 Sampling point in each year (x 2 = 774)

Approach:

- ML
- Include topography, soil, climate etc

SOCst_target = f (top, climate, soil, BMP)

Achievable SOCst_seq

SOCst_2018 = f (top, climate, soil,)

SOCst_seq

SOCst_2010 = f (top, climate, soil,)

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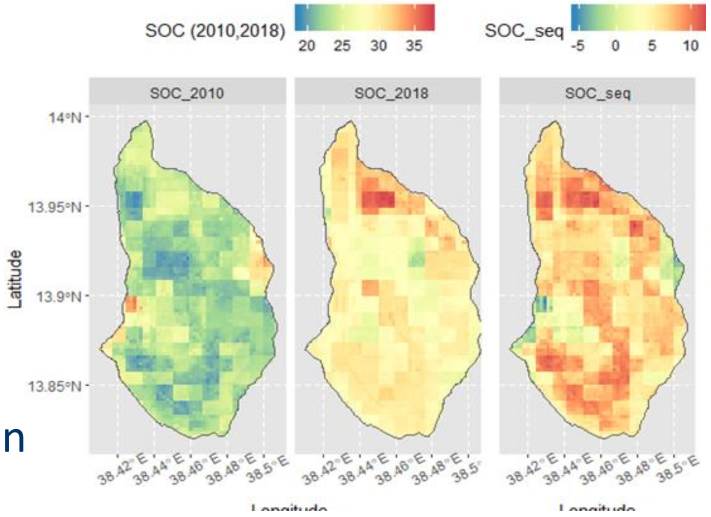
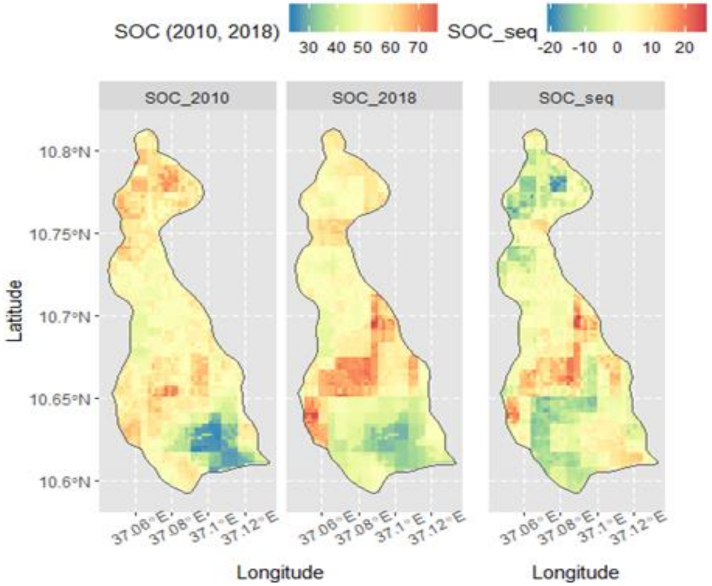
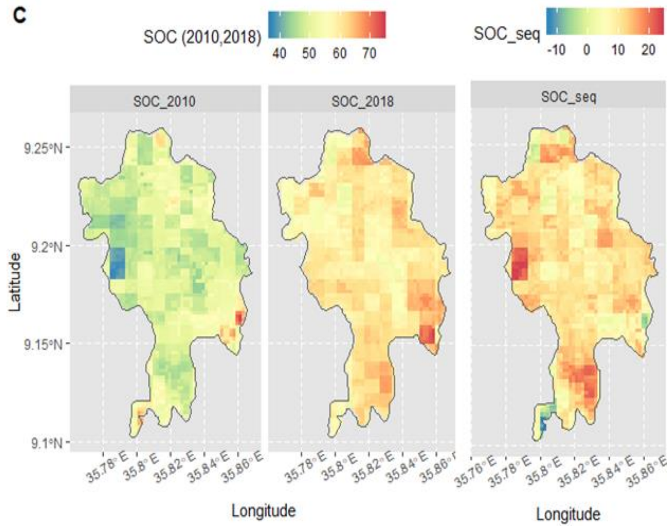
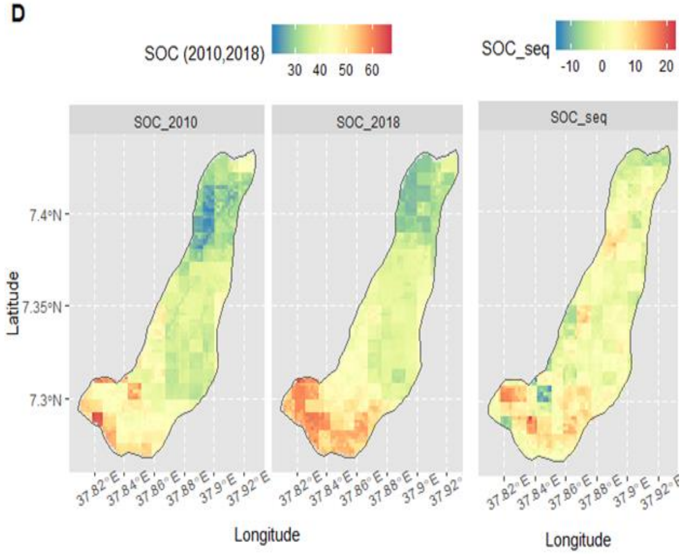
SOC stock and sequestration hotspot mapping

- Spatial variation among the four watersheds was significant,
- Sig. statistical difference between the before and after in Gafera and Adi Tsegora,



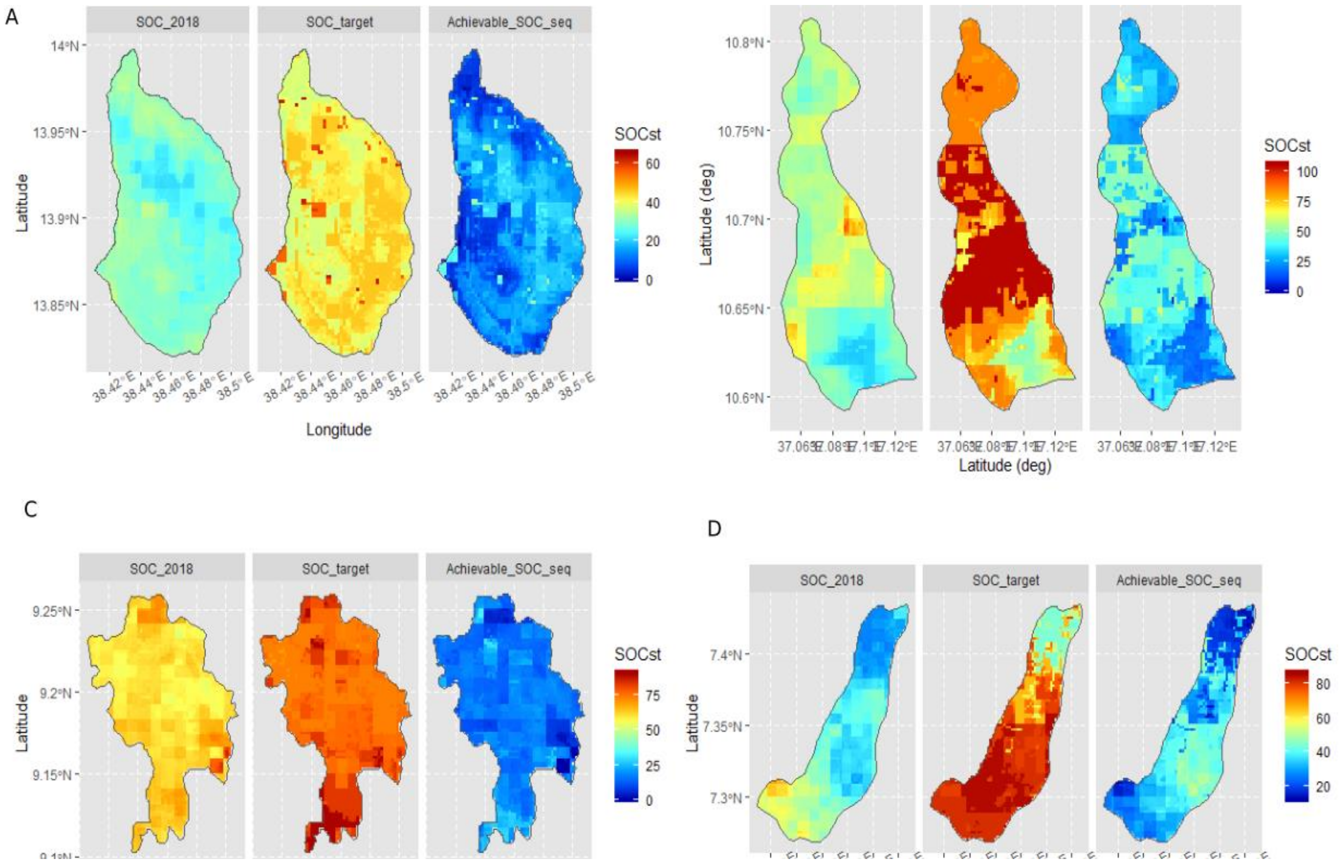


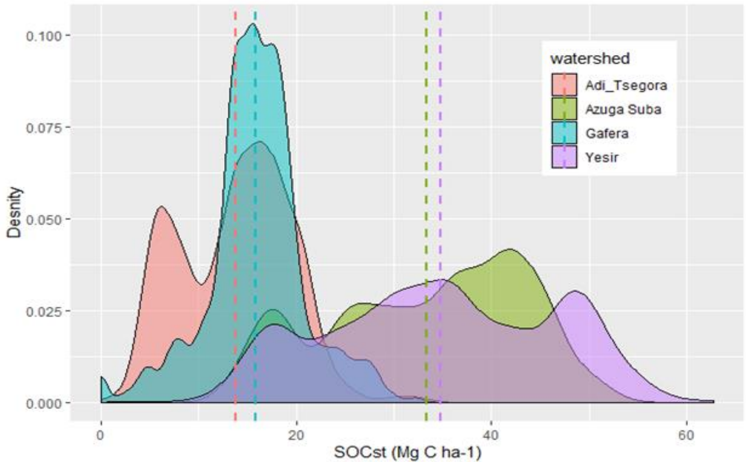




Achievable SOC sequestration mapping

- There is still potential for improvements in terms of retaining more SOC,
- The highest achievable SOCst sequestration is predicted in the Yesir watershed (34.7 Mg C ha−1), followed by Azuga shuba watershed (33.2 Mg C ha−1).





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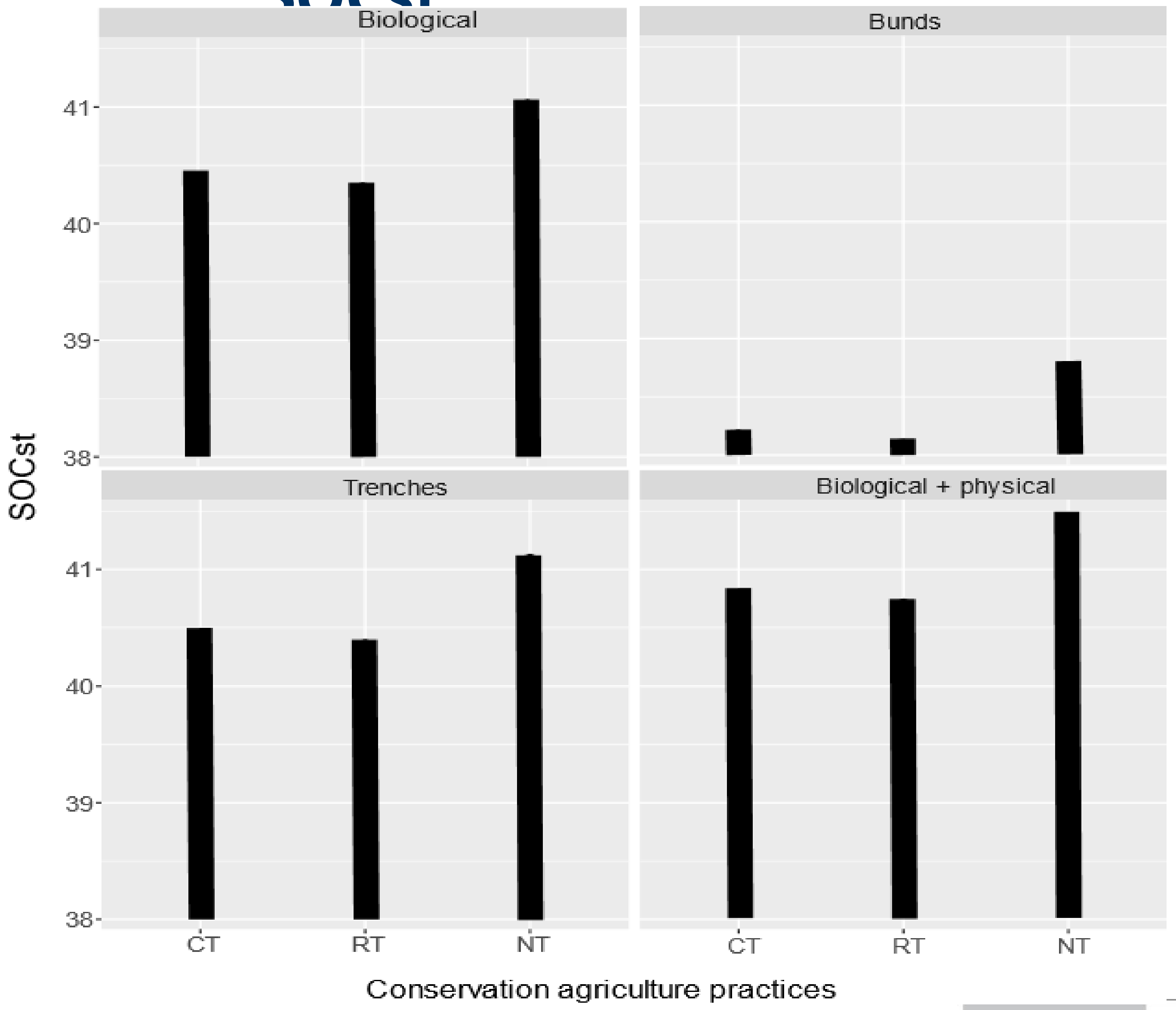
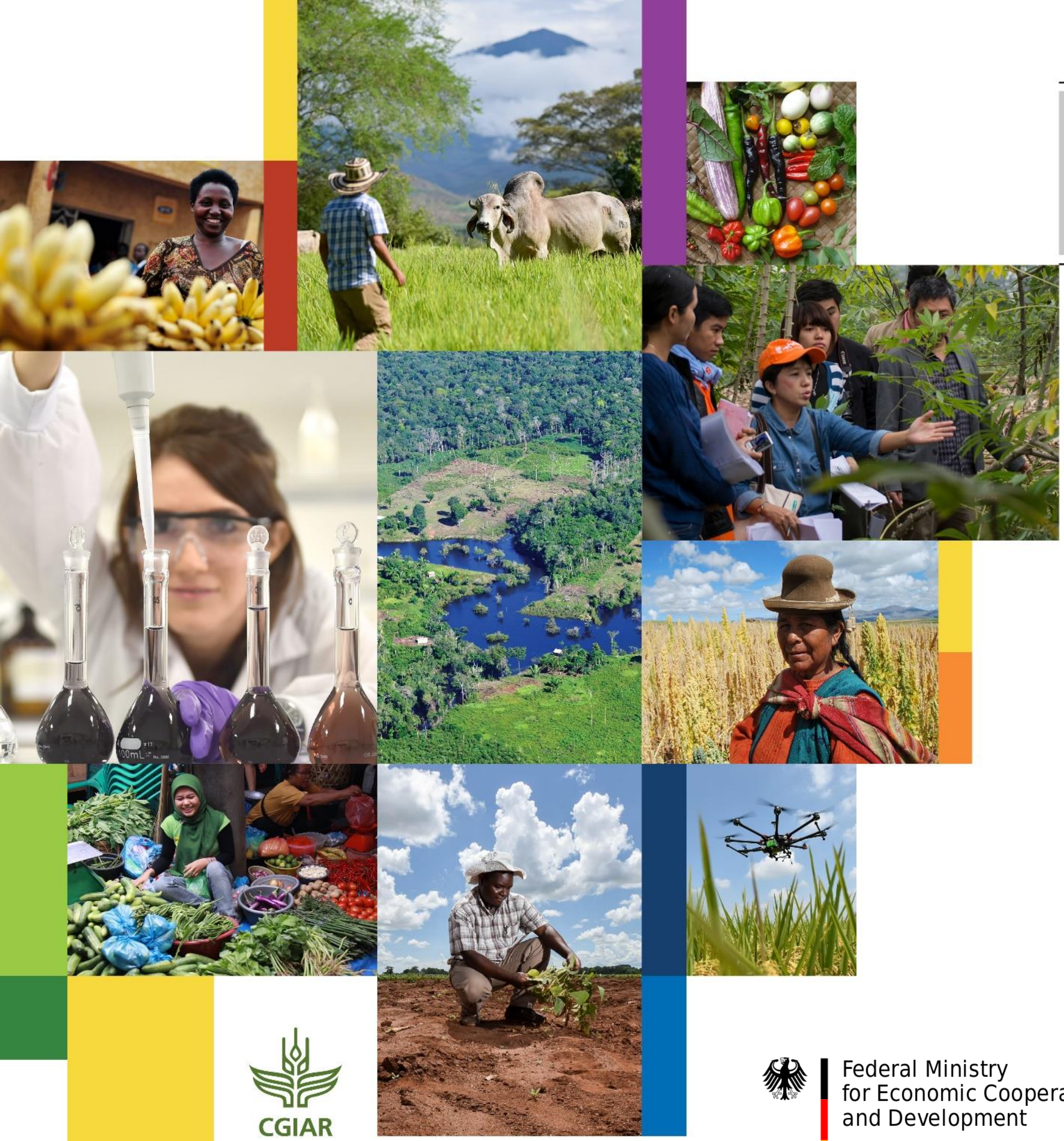
Disentangling the effects of SLM practices on SOCst

- No-tillage (NT) > CT and RT

- Biological + physical > Biological > Trenches > Bunds

- Duration of practices, the nature of the soil, the availability of vegetation cover determine the performances of SLM practices (Luo et al., 2010).





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Assessment of Farmers' Perceptions, Land Management Preferences and Drivers of Decisions Using the Participatory Tool for Evaluating Land Management Options

Sussy Munialo

PhD Agricultural Resource Management

CGIAR

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CGIAR
RESEARCH PROGRAM ON
Water, Land and Ecosystems

Bioversity International and the International Center for Tropical Agriculture (CIAT) are CGIAR Research Centers.
CGIAR is a global research partnership for a food-secure future.

Introduction

- Evaluating Land Management Options (ELMO) is a participatory tool used to

  - understand the drivers of Land Management decisions
  - the preferences of farmers for different Land Management practices

- The tool uses costs, benefits, advantages and disadvantages associated with the different land management

Materials and methods

- The study investigated farmers' perceptions, preferences and decisions regarding the use and adoption of different land management (LM) practices using the (ELMO).

- This was done using 2 Focus group discussion and 24 key informant interviews in Mukuyu and Shikomoli of Western Kenya

- The participants were drawn from different socio-economic backgrounds, (wealthy, averagely wealth and lowly wealth households) and Gender

- Ranking using a score card was done to identify best LM techniques

Results

BENEFITS

- Crop yield
- Income
- Animal feed
- Soil fertility
- Nutrition

COSTS

- Bought inputs
- Technical know how
- Free inputs
- Own family labor

CONSISTENT LAND MANAGEMENT

Fertilizer use, Manure/compost, Improved seed, Intercropping Crop residue insitu

AGRO-ECOLOGY SPECIFIC LAND MANAMENT

Shikomoli

Terracing, Mixed cropping Crop rotating

Mukuyu

Hole planting

ADVANTAGES

- Lower cost requirement
- Low labour
- Crop health
- Long lasting impact
- Weed free fields
- Reduced wind effect
- Shared knowledge

DISADVANTAGES

- High technical know how
- Soil erosion
- Unreliable inputs
- Risk of pests
- High weed growth

Ranking of Land Management

Shikomoli

Improved seed ↓ Intercropping ↓ Manure ↓ Terraces

Mukuyu

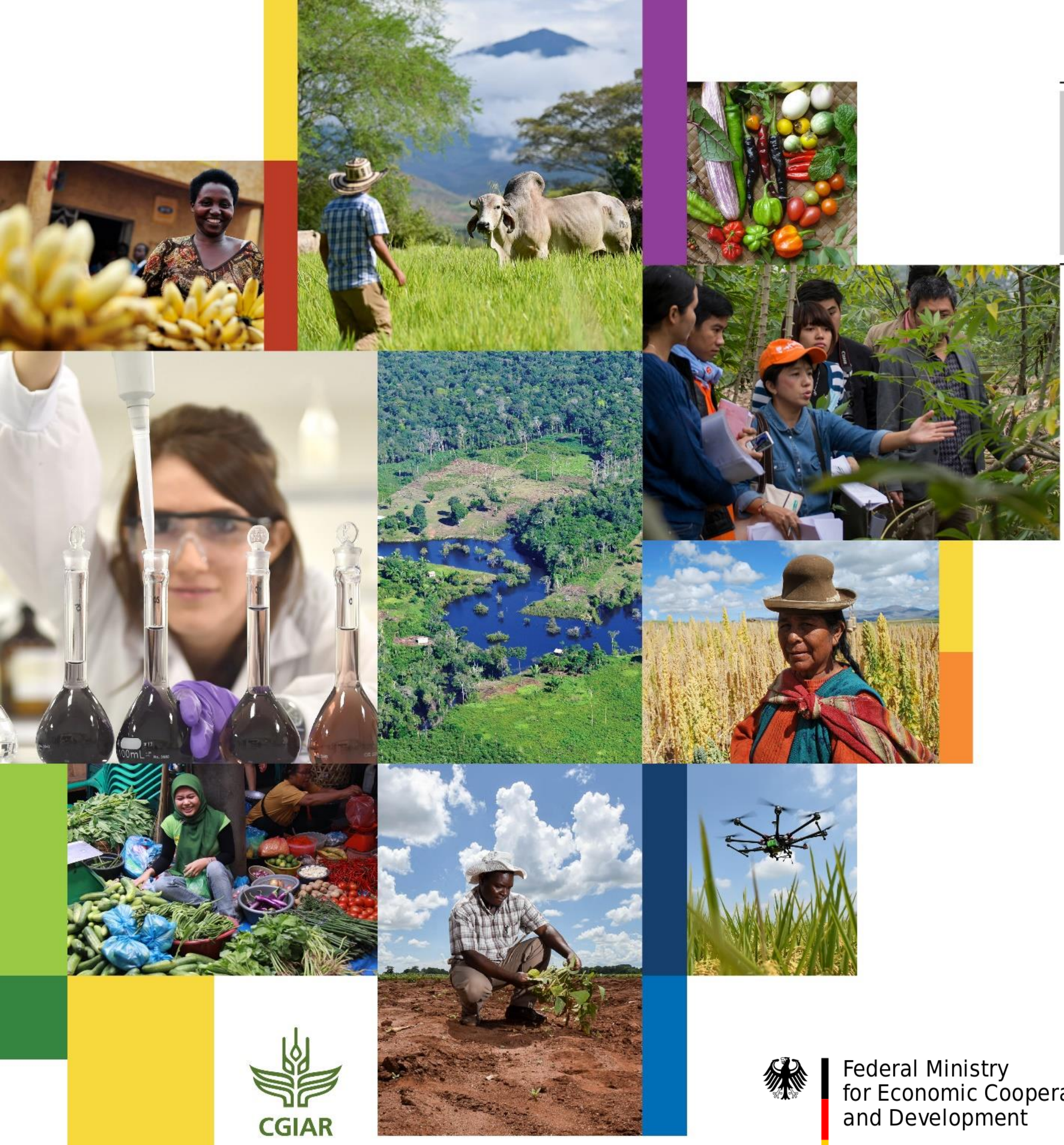
Fertilizer use ↓ Hole planting ↓ Improved seed ↓ Manure

CONCLUSION

- Farmers decisions to use certain LM is based on both direct (increase yields and nutrition) and indirect benefits (improve soil fertility)

- Peer shared knowledge and training was important in transfer of the LM techniques

- Factors considered most important in choosing the LM were; increase in crop yield and improvement in soil fertility



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Analysis of extent and impact of adoption of soil carbon enhancing practices on maize yield among smallholder farmers in kakamega and vihiga counties, kenya

George Magambo

UNIVERSITY OF NAIROBI

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The Motivation for this Research

- Vicious Cycle of Low Productivity:
- What role can Soil Carbon Enhancing Practices play in breaking this Cycle

Small land parcel	Continuous Planting + Mono-cropping	Soil degradation	Low soil fertility
• Less than 2 acres of land. • Smallholder farmers (SHF) account for 75% of Maize production in Kenya • All caused by land fragmentation and high population density	• Most common coping practicing. • Increased emphases to adopt soil carbon enhancing practices: • However low adoption rate. WHY?	• Poor practices results in soil erosion, low soil carbon sequestration and accumulation.	• Manifested by Low yields (Low Productivity)

DATA COLLECTION

Western Kenya:

Kakamega and Vihiga Counties.

5 sub-counties from each county

Sampled 334 household Operating 710 Plots

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Data Analysis

Objective One

Factors influencing the adoption of the soil carbon enhancing practices among SHF.

Multivariate Probit Model

Take into consideration the correlation of error term between the different practices

Objective two:

Factors influencing the extent of adoption of the soil carbon enhancing practices among SHF.

Generalized Ordered Logit Model

Takes into consideration that the probability of adopting an additional practice differs

Objective three:

Impact of adopting soil carbon enhancing practices on maize yield among SHF

Multinomial Endogenous Treatment Effect Model

Is able to calculate the impact of adoption of different practices and their combination

Findings

	Plot Level (n=640)	Household Level n=334
Practice		
Intercropping	48%	75%
Farmyard Manure	42%	49%
Inorganic Fertilizer	74%	93%
Mulching	6%	9%

Adoption Rate

	Mulching	Intercropping	Farmyard Manure	Inorganic Fertilizer
Mulching	1			
Intercropping	0.1791 (0.971)	1		
Farmyard Manure	-0.1125 (0.1051)	0.1529 ** (0.0638)	1	
Inorganic Fertilizer	0.0903 (0.1054)	0.5946 *** (0.0530)	0.2831*** (0.0670)	1

Complementarities

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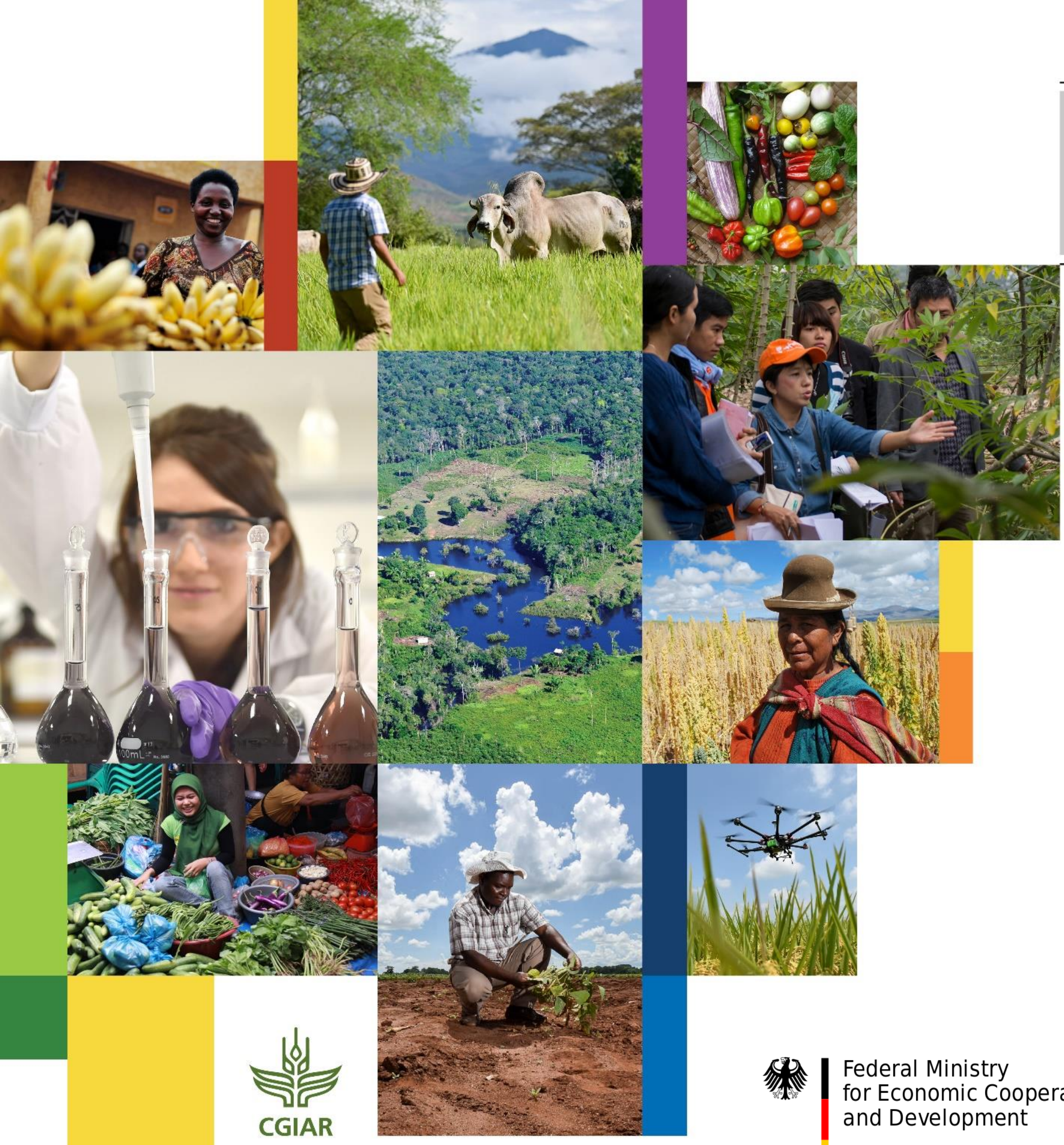
Findings

- Adoption and extent of adoption significantly influenced by:
  - Plot characteristics (number of plot, plots size, soil erosion, slope, distance to plot)
  - Information access variables (agricultural group membership, literacy level)
  - Gender
- Positive Impact on Maize Yields:

Practices	% Change	In Kgs per Acre
Intercropping	35%***	288
Farmyard Manure	18%*	162
Farmyard Manure and Intercropping	33%***	270

Recommendations

- **Access to Information is Important:**
  - Need to strengthen the existing farmers' group, increasing farmers' training frequencies, and on-farm demonstrations.
  - During the Training, farmers can be encouraged to have their soils scientifically tested to enhance adoption of problem-specific technologies at plot level.
  - The training need to be gender inclusive.
  - Lastly, need for collaborative works between developmental agents, county and national government to enhance adoption.



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Factors affecting the adoption of soil organic carbon enhancement technologies and their spatial distribution among small-scale farmers in Kenya and Ethiopia.

Wilson Nguru

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The Motivation for this Research

- There has been a continuous depletion of soil organic carbon which forms the basis of soil fertility due to land degradation.
- Efforts to resuscitate the productivity of farmlands have been made by the stakeholders promoting the adoption of soil organic carbon enhancing technologies (SOCETs).
- Little has been undertaken to enlighten these institutions on the extent to which SOCETs have been implemented in these countries and the factors constraining this adoption.
- There exists spatial relationships between the adoption of SOCETs and the factors that affect farmers' adoption of SOCETs and therefore their influences on the farmers' choices to adopt.
- Farmers are influenced by the behavior of neighboring farmers, opportunities provided by the enabling environment or by agro-ecological characteristics as they try to make decisions on whether to adopt to a technology or not.
- Therefore, ignoring spatial heterogeneity can lead to obtaining biased or inefficient results.

Data collection

Study Areas

Western Kenya – Vihiga and Kakamega counties.

Ethiopia- SNNP and Amhara regions

Sample sizes

Western Kenya - 334 households.

Vihiga and Kakamega counties

Sample sizes

Ethiopia - 381 households.

Angacha (Azuga suba watershed)

Bure (Yesir watershed

Dependent and explanatory variables

SOCETs (Dependent variables)

Manure	Agroforestry
Crop rotation	Grass strips
Intercropping	
Fertilizer use	
Residue management	

Factors affecting adoption (Explanatory variables)

Plot level variables

- Slope (degrees)
- Tenure security of the plot
- Soil erosion perception
- Plot size (acres)
- Distance to plot (minutes)
- Plot fertility perception

Socioeconomic variables

- Education level of household head (grade/level)
- Livestock ownership
- Household head years in farming
- Household size
- Distance to urban market (minutes)

Institutional characteristics

- Credit access
- Access to extension
- Group membership

Climatic characteristics

- Annual precipitation (mm)

Data analysis

Probit Model

Relationships between each SOCET and the explanatory variables.

Prediction of factors affecting adoption.

Random forest model

Predict adoption of each SOCET across space at a fine resolution.

Maps

Geographically weighted regression

Predict the effect of each explanatory variable on the adoption of SOCETs

Manure adoption example

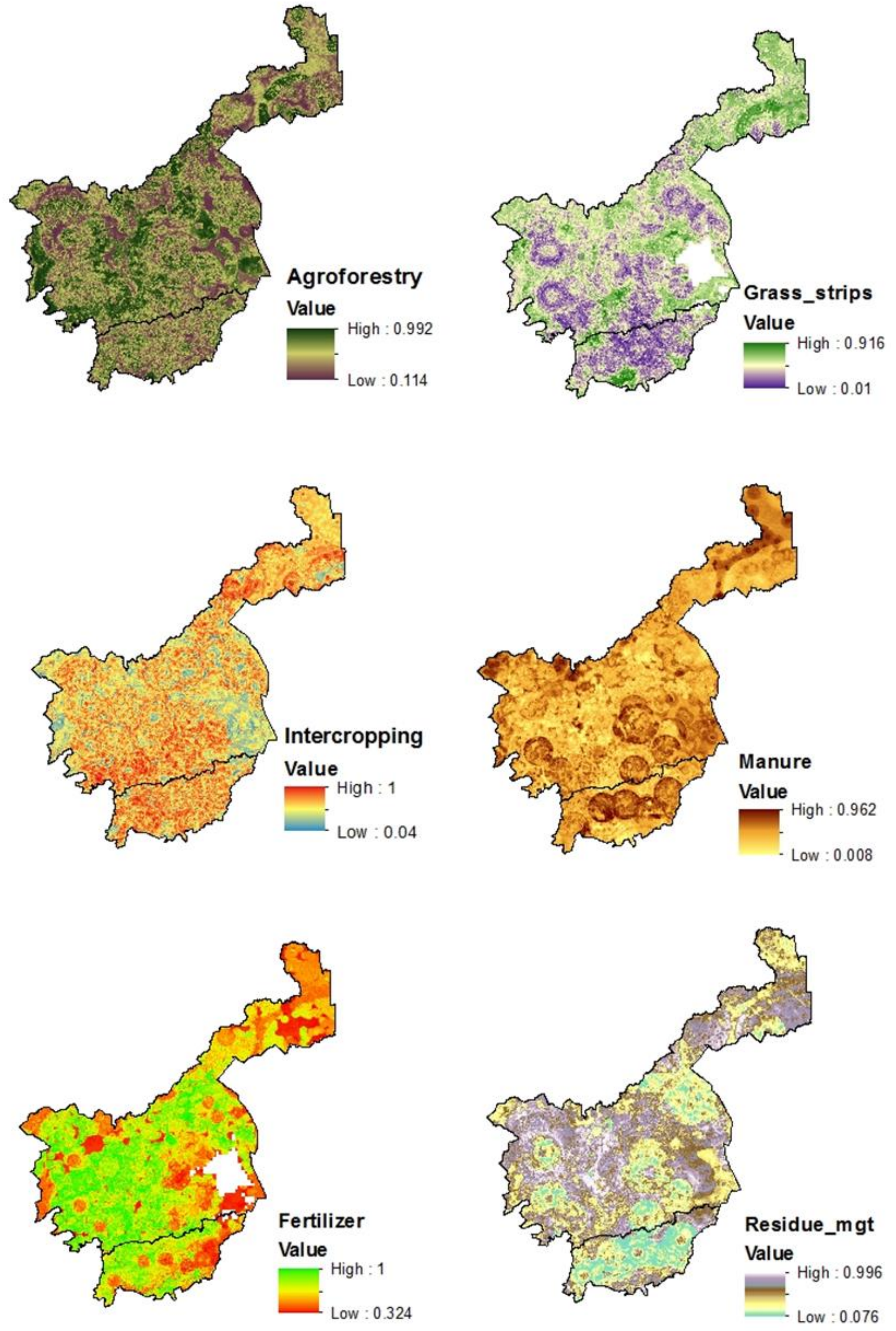
- Done at ward level in Kenya and Kebele level in Ethiopia. In some of these small admin locations adoption will be insignificant.
- Kenya – Kakamega county

	Affect positively	Affect negatively
Kisa west	Tenure security	Plot size
	Plot fertility	Extension
Butsotso S	Education	
	HH size	Plot fertility
	Farming experience	Distance to the market

- Ethiopia Yesir and Azuga watersheds

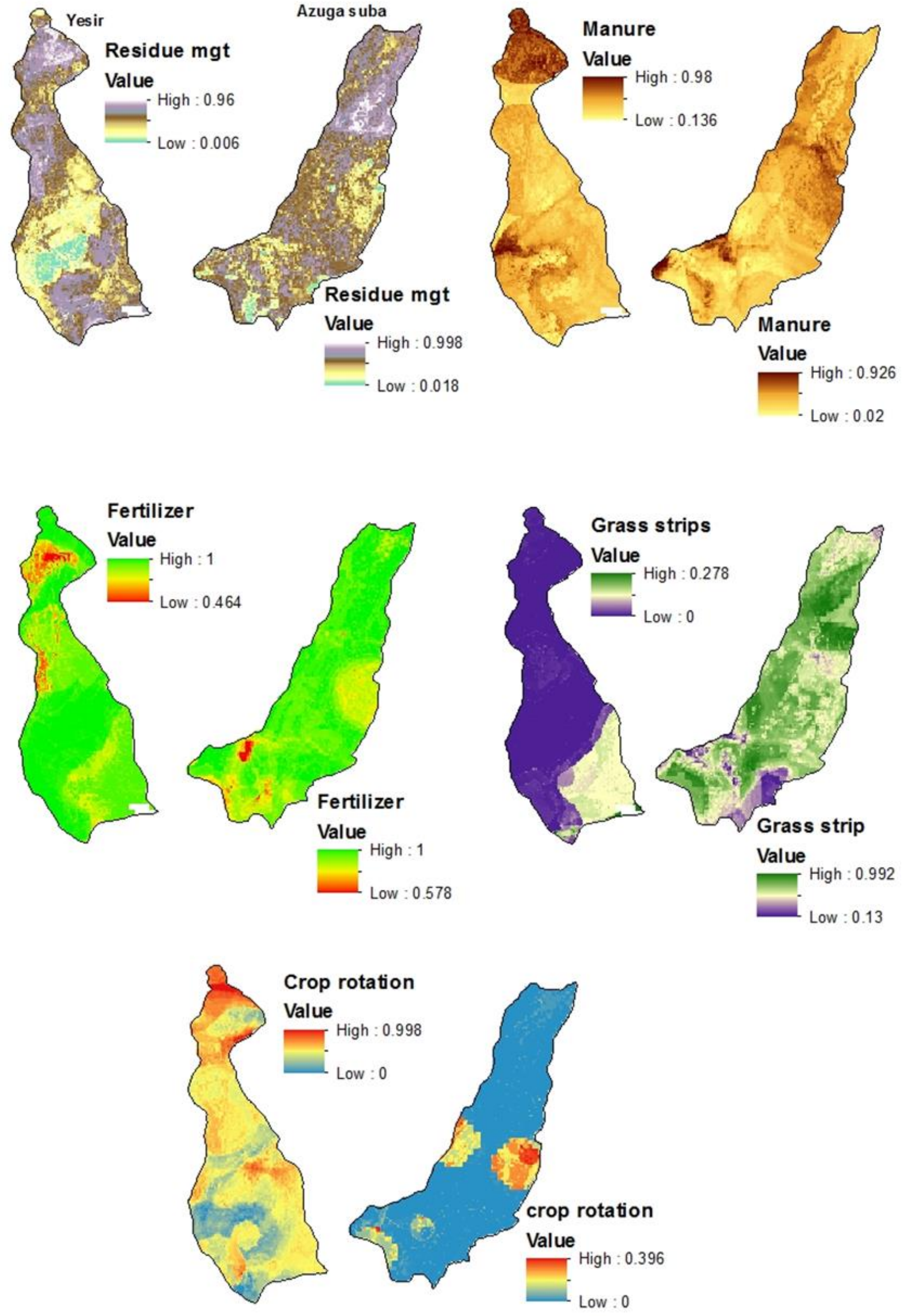
	Affect positively	Affect negatively
Bucha	Rainfall	Distance to plot
		HH size
		Plot fertility
Jib Gedel	Tenure security	Group membership
	Distance to plot	Soil erosion
	Livestock ownership	Plot sizes

Probit model



Findings

Random forest



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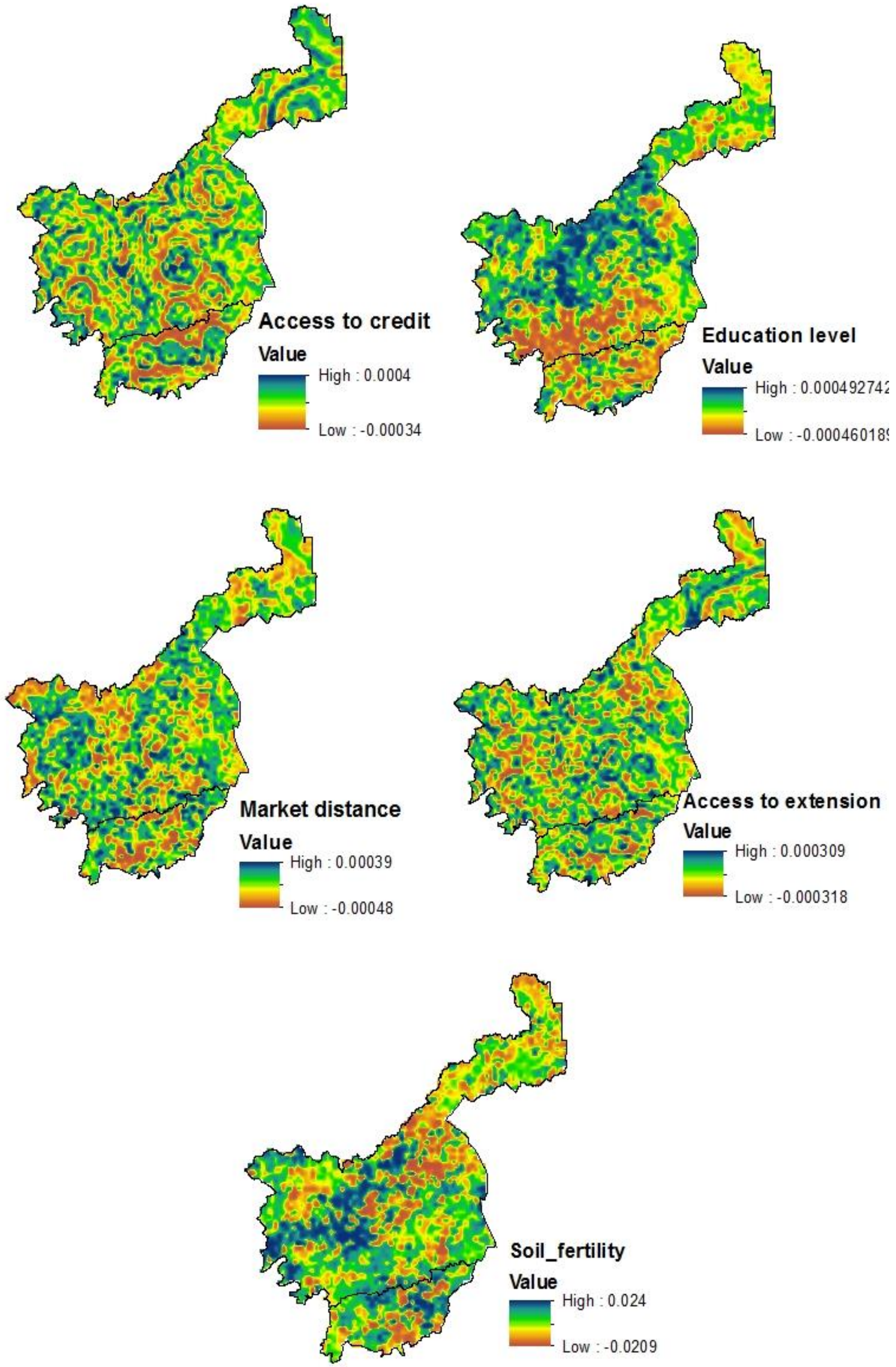
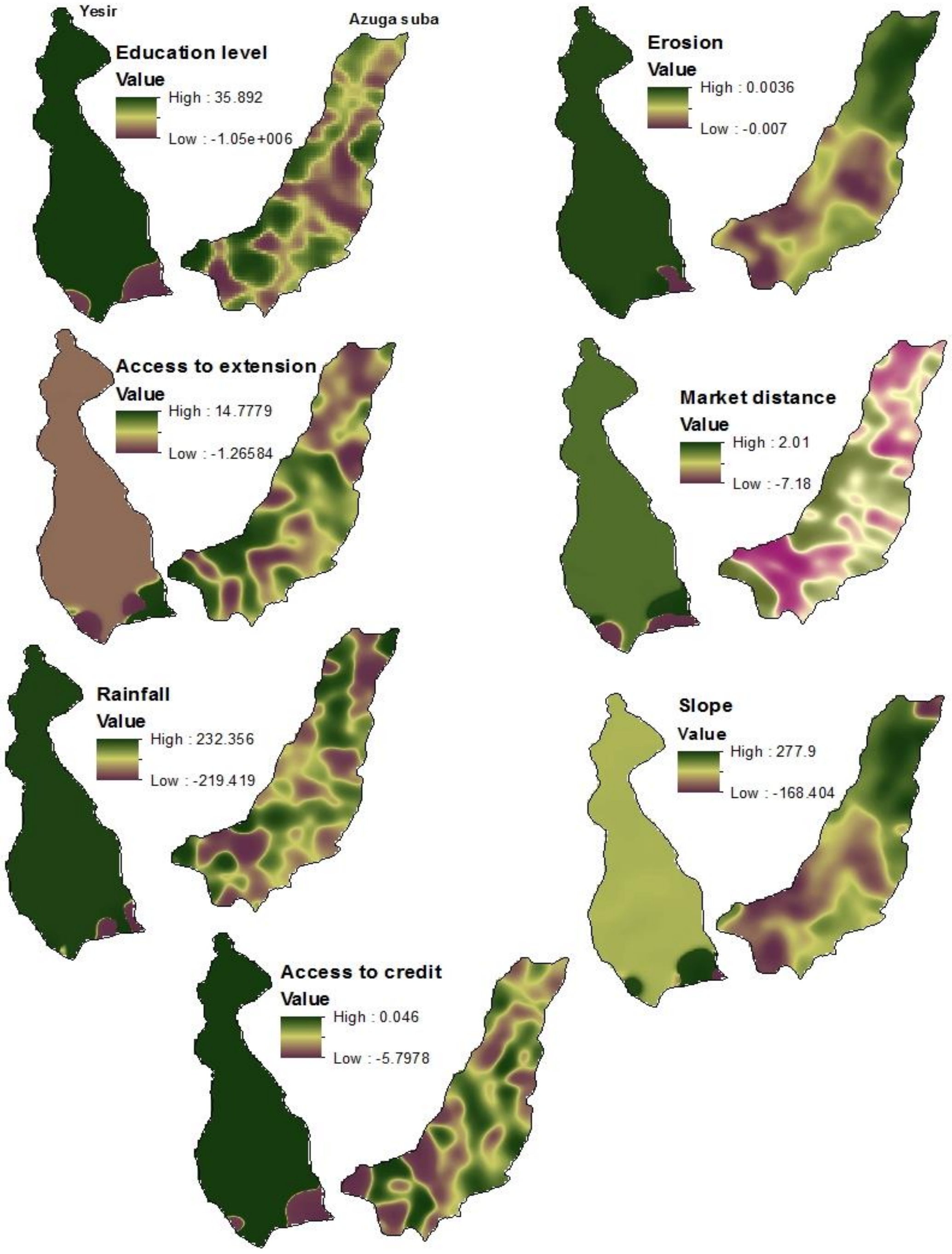


Findings

Geographically weighted regression

Manure (Kenya)



Findings

Geographically weighted regression

Manure (Ethiopia)

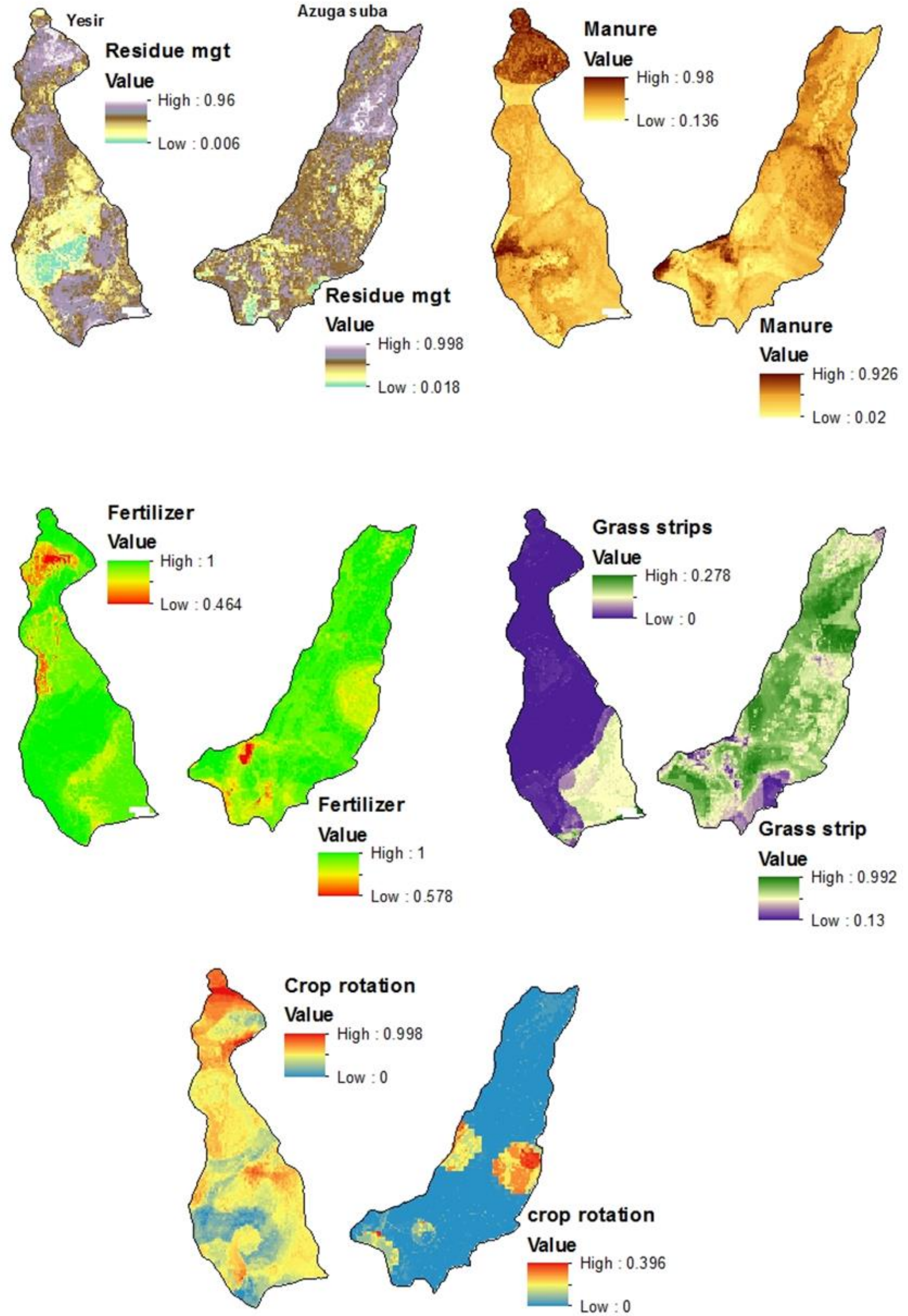
Conclusion

- The influence of factors affecting the adoption of SOCETs vary greatly across space with one factor affecting adoption in one part of the study areas at a high impact to the positive while at the same time the same factor affecting another part of the area mildly positive, mildly negative or highly negative.
- This is due to the fact that areal characteristics vary across geographical areas. The areas will have different socioeconomic and biophysical factors affecting farmers' adoption of SOCETs and this will result into different choices to the adoption of SOCETs.

Recommendations

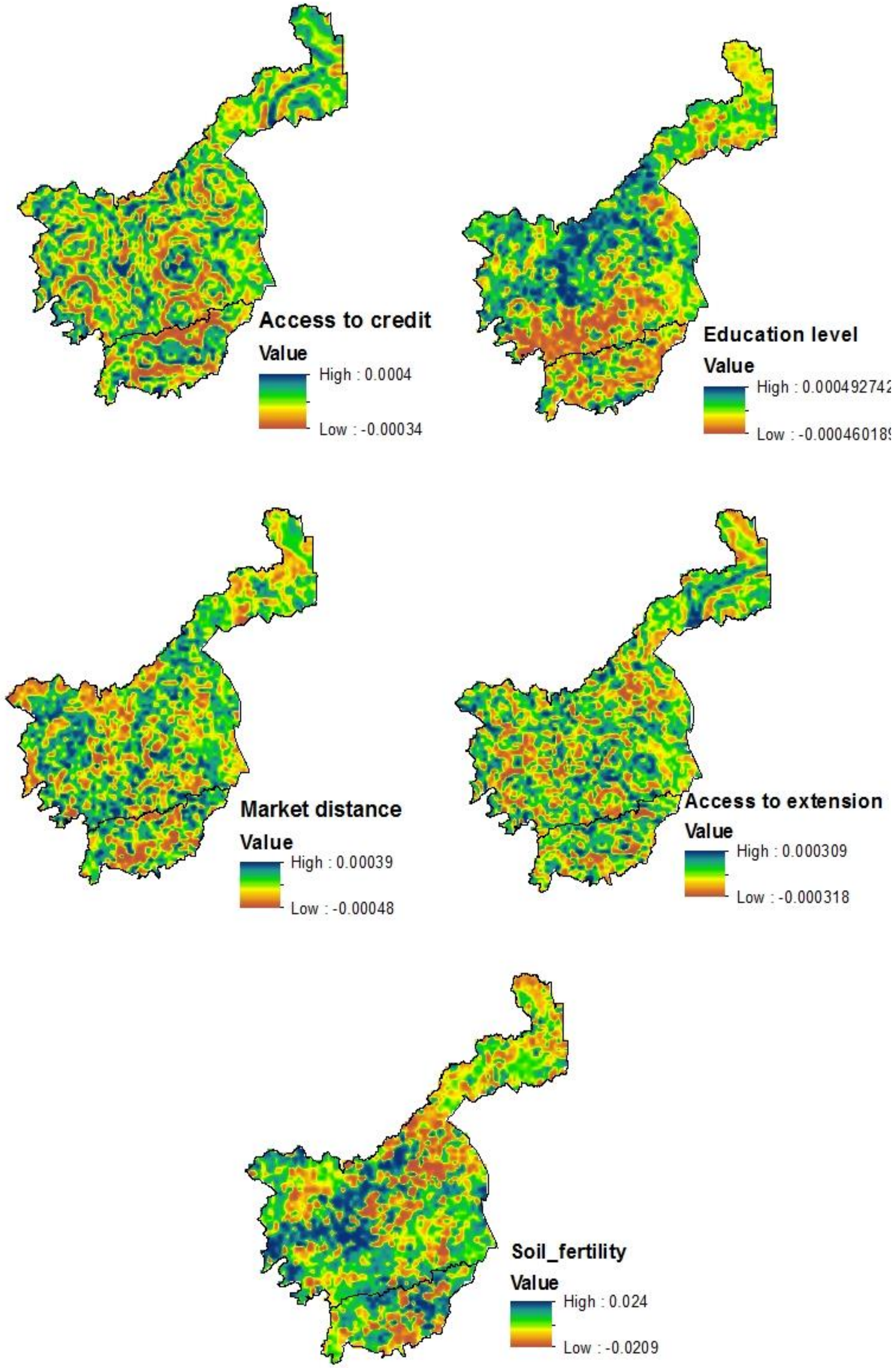
- Encouraging farmer education so as to promote sustainable soil fertility management can help target sustainable land management interventions aimed at enhancing SOC more appropriately.
- This will be enhanced by providing resources such as access to credit and affordable inputs.
- Incorporating the geographical aspect research. This is because the magnitude and direction into which these factors affect the choices of farmers vary spatially.


Thank You



Findings

Random forest



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Geographically weighted regression

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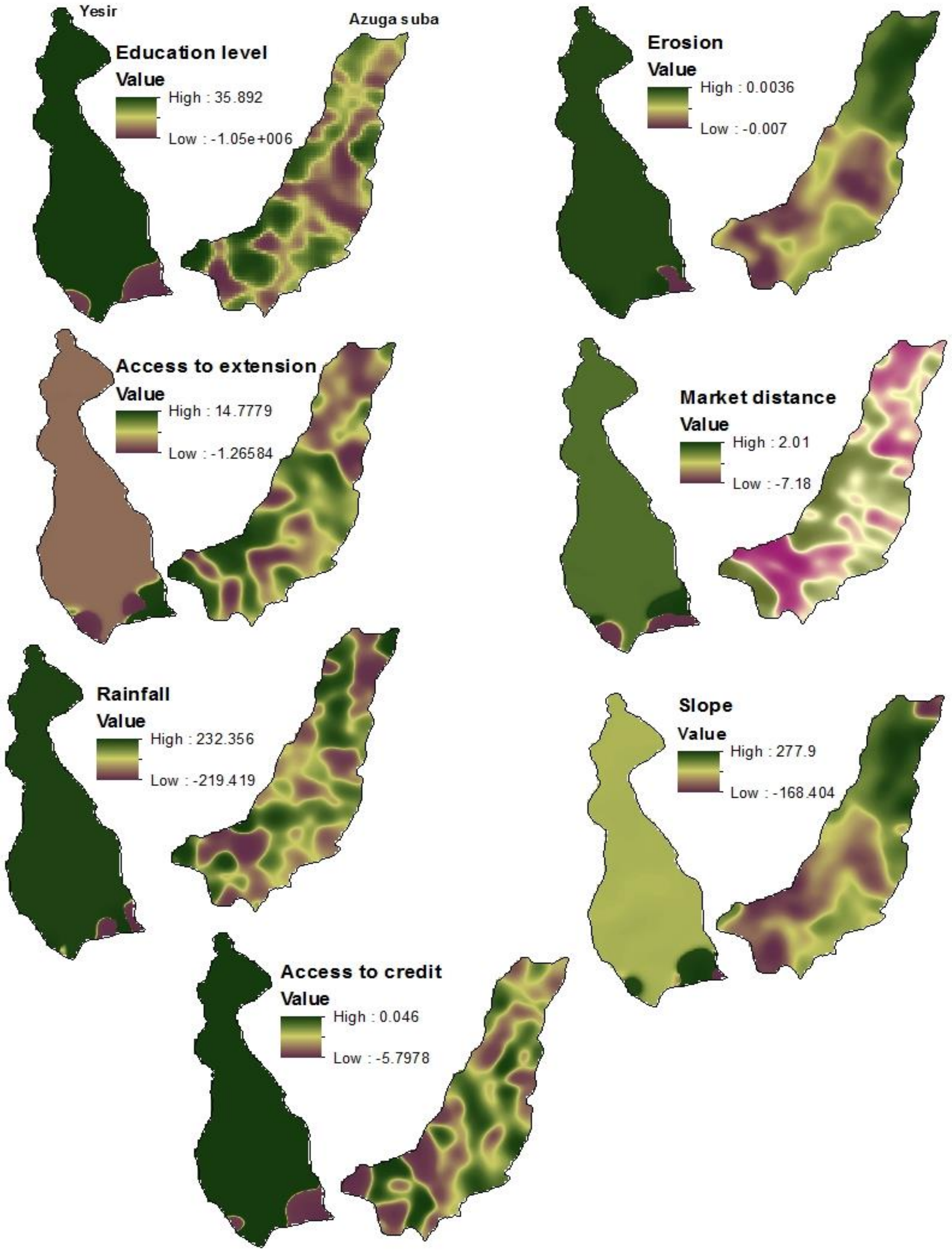

Findings

Geographically weighted regression

Manure (Ethiopia)

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- This is due to the fact that areal characteristics vary across geographical areas. The areas will have different socioeconomic and biophysical factors affecting farmers' adoption of SOCETs and this will result into different choices to the adoption of SOCETs.

Recommendations

- Encouraging farmer education so as to promote sustainable soil fertility management can help target sustainable land management interventions aimed at enhancing SOC more appropriately.
- This will be enhanced by providing resources such as access to credit and affordable inputs.
- Incorporating the geographical aspect research. This is because the magnitude and direction into which these factors affect the choices of farmers vary spatially.

Karlsruhe Institute of Technology

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IMK-IFU: Atmosphärische Umweltforschung

Modelling impacts of agricultural management on crop ecosystems in Eastern Africa

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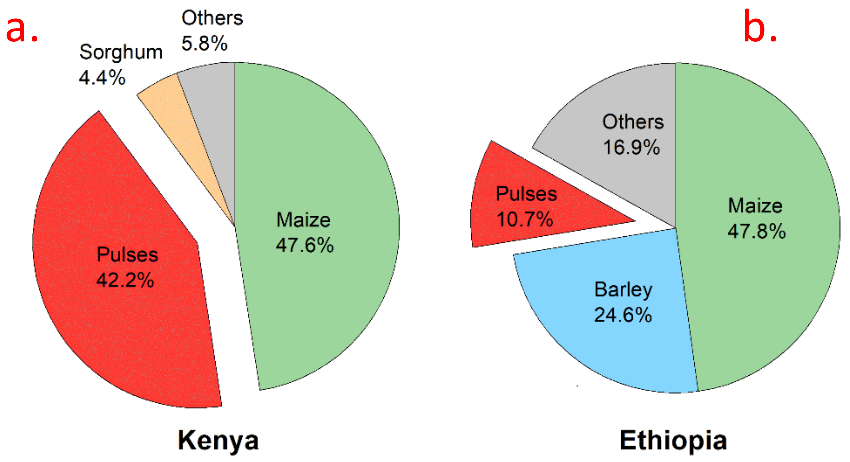
Tool used for research: LPJ-GUESS

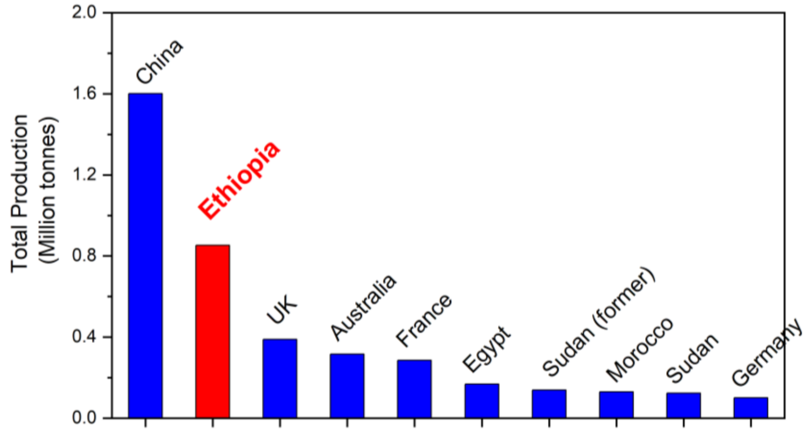
- LPJ-GUESS
  - ✓ a process-based dynamic global vegetation model
  - ✓ to simulate global and regional dynamics and composition of vegetation and ecosystems
  - ✓ to detect the response to environmental changes (e.g. climate and land management)
- New incorporation of legume crops with BNF into model
  - ✓ Soybean
  - ✓ Faba bean
  - ✓ Kenya white clover

    (*Trifolium semipilosum*)



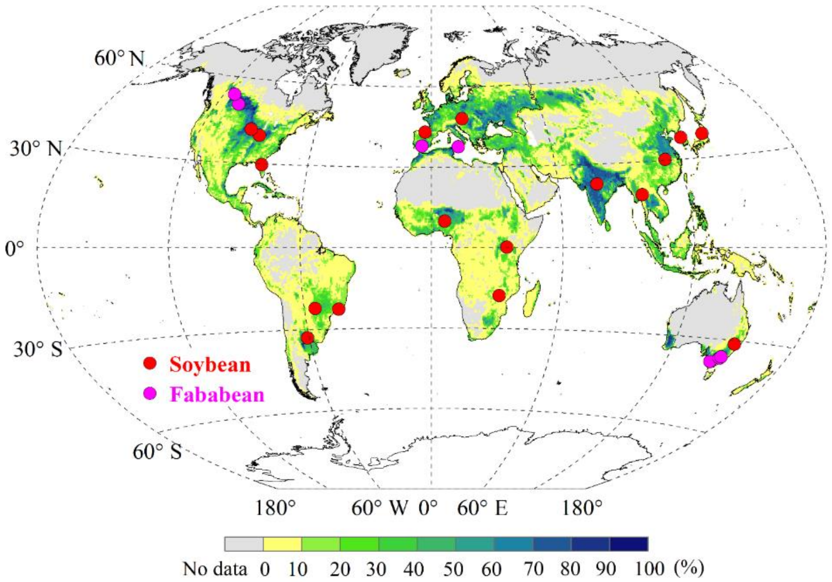
Cultivated area of major grain in 2014

Top10 faba bean producer countries
2009-2018 average (FAOSTAT)



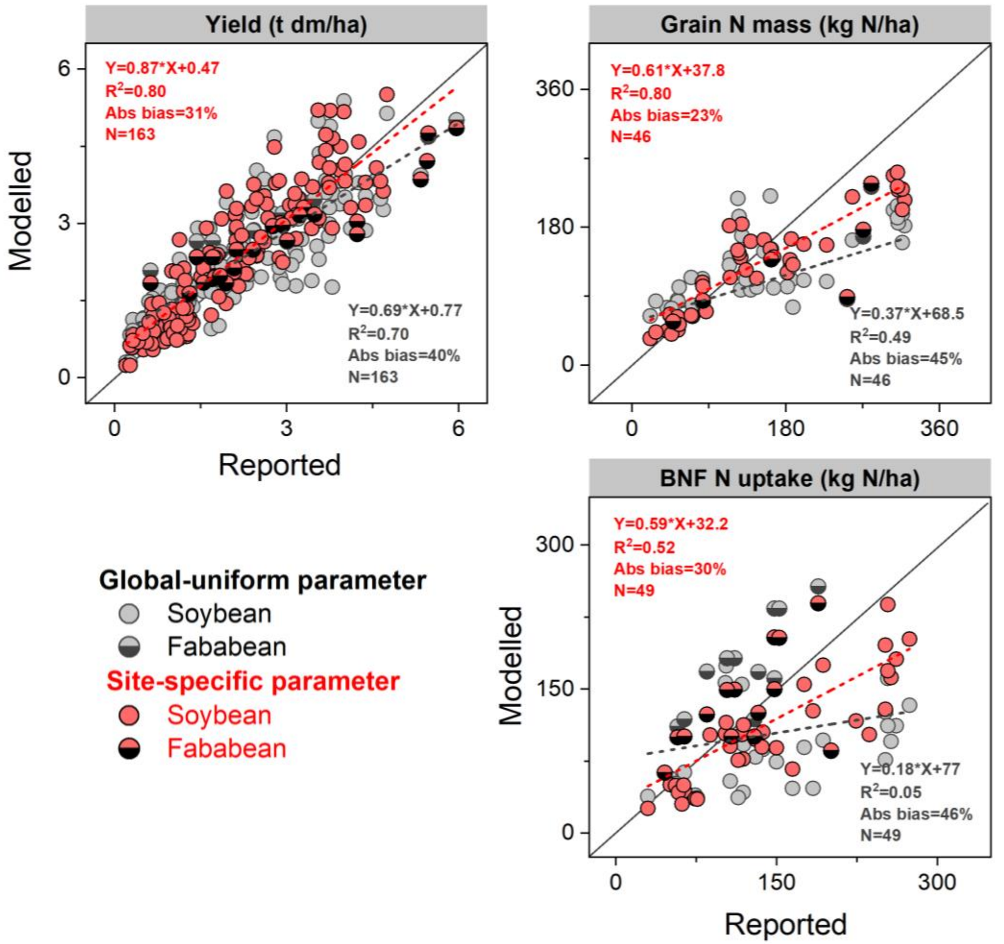
Model evaluation

- At site scale



Soybean (17) and faba bean (7) sites used for BNF evaluation globally

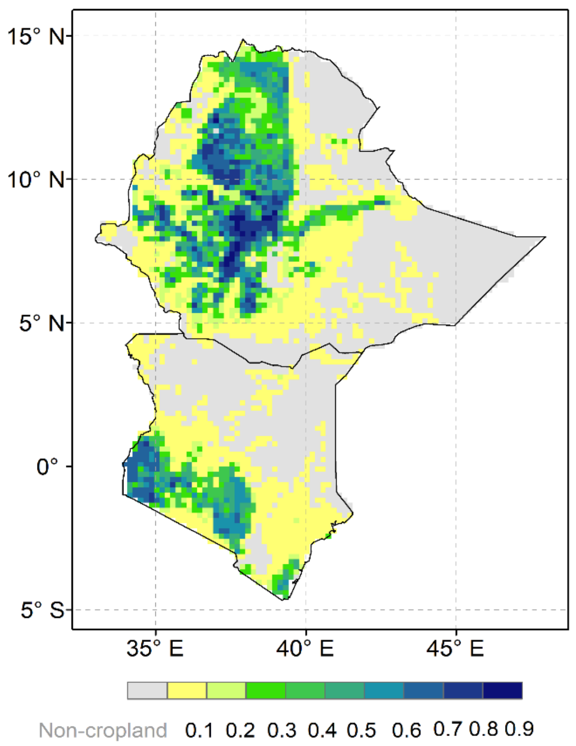
The map background is crop fraction (%) averaged over 1996-2005 from LUH2 dataset



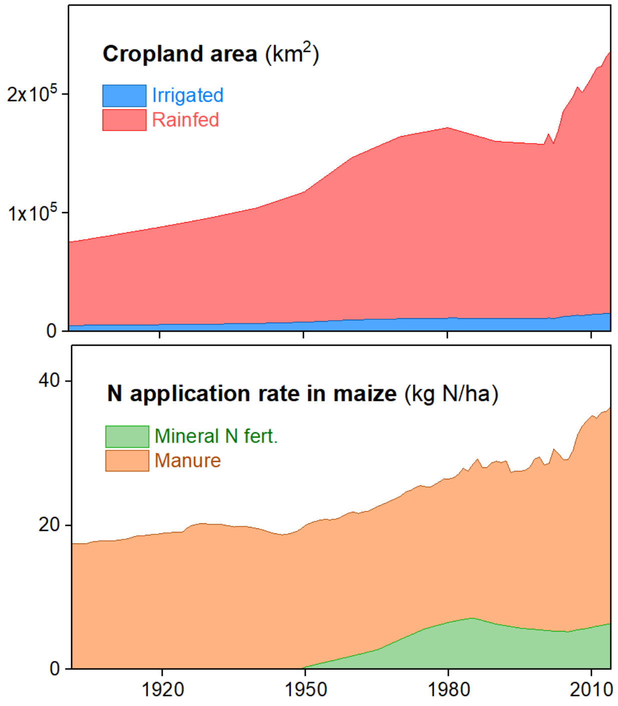
Comparison of modelled and observed yield, grain N mass, and BNF N uptake at harvest across all soybean and faba bean sites

Model input data

a.



b.



GCMs Climate and climate-related forcing data [a]

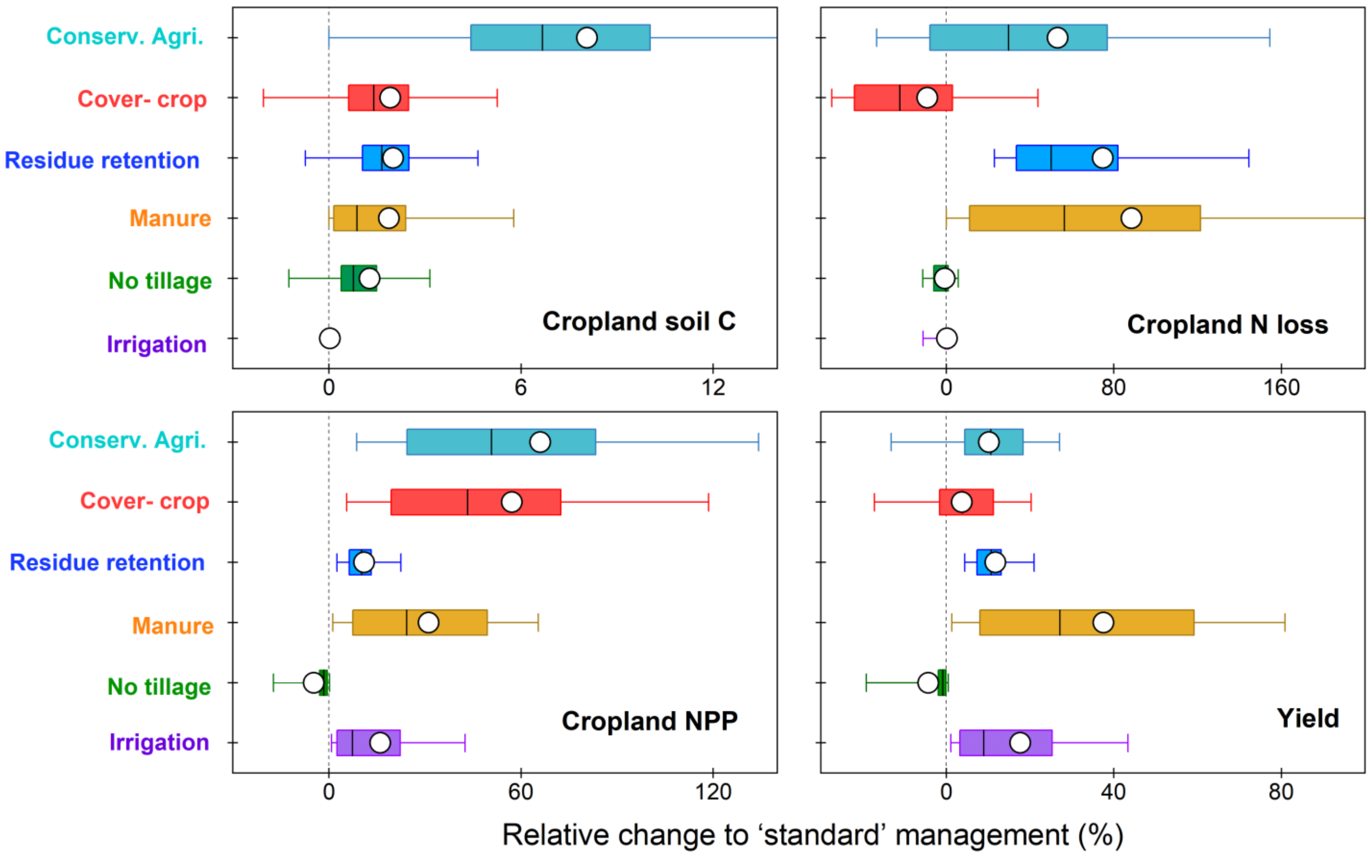
Title	Institution	Original resolution
GFDL-ESM4	National Oceanic and Atmospheric administration, Geophysical Fluid Dynamics Laboratory, Princeton, USA	288×180
UKESM1-0-LL	Met office Hadley Center, Fitzroy Road, Exeter, Devon, UK	192×144
MPI-ESM1-2-HR	Max Planck Institute for Meteorology, Hamburg, Germany	384×192
IPSL-CM6A-LR	Institut Pierre Simon Laplace, Paris, France	144×143
MRI-ESM2-0	Meteorological Research Institute, Tsukuba, Japan	320×160

a: 5GCMs with 3 SSP future scenarios are used as climate forcing, which is bias-corrected and downscaled to 0.5° × 0.5° from original resolution.

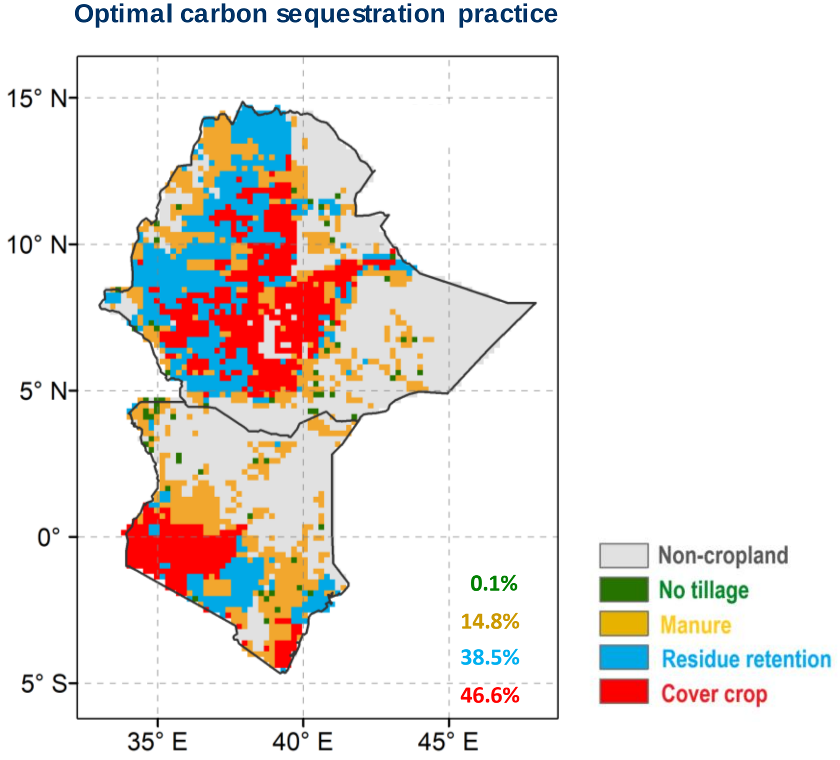
10-mins historical (a) cropland-related input data and 0.5° future climate forcing (b) from 5 GCMs and 3 SSP scenarios used for eastern Africa runs.

Historical runs

a.

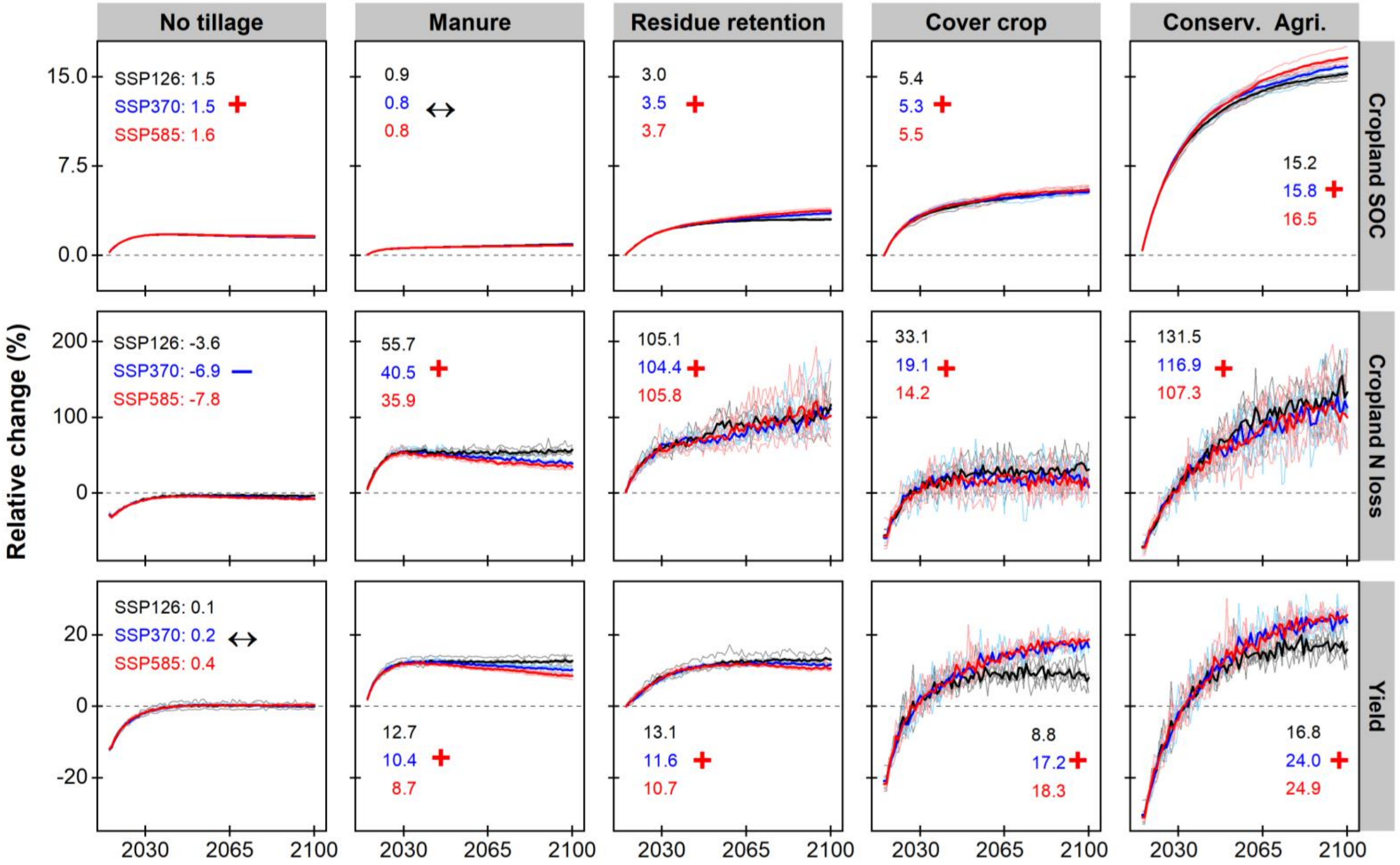


b.



Modelled relative response of SOC, N loss (gaseous N and leaching), NPP and yield to alternative managements (a), and optimal carbon sequestration practice (b) across EA. Statistical box denotes the 25th and 75th percentile; whisker represents the 5th and 95th percentile; white dot is the average over all gridcells; The alternative practice (irrigation, no tillage, manure, residue retention, cover crop) that yields the largest soil carbon increase was chosen as the optimal management;

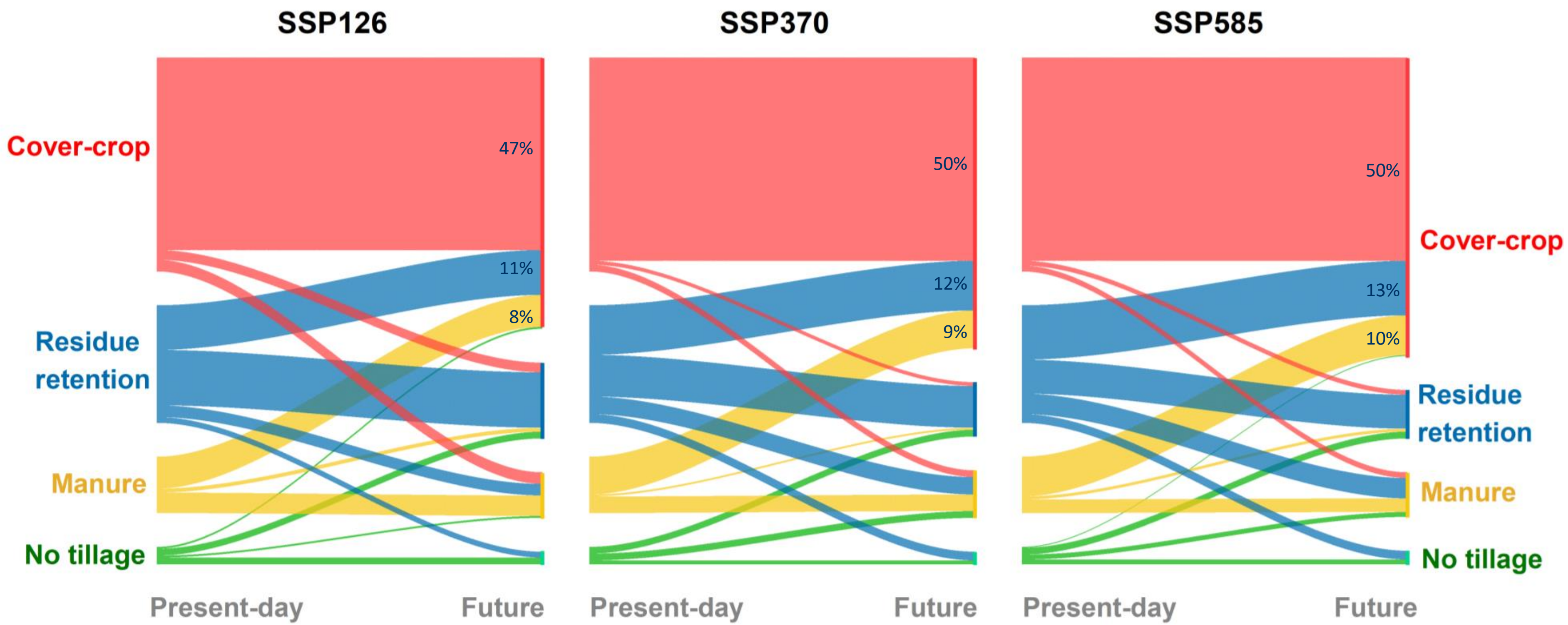
Future projection



- **To enhance SOC**: cover crop > residue retention > no tillage > manure;
- **To reduce N loss**: no tillage > cover crop > manure > residue retention;
- **To increase yield**: cover crop > residue retention > manure > no tillage;
- Cover crop with BNF is the best practice to enhance SOC and yield, with lower environmental cost of increased N loss;

The simulated response on C in cropland soil, N loss and yield with management options implemented in LPJ-GUESS relative to standard set-up in future. Light color line denotes each GCM result, dark color is 5GCMs average. Number in plots is the average over 2091-2100.

Future projection



Relative to present-day, **~32%, 35%, 37%** cropland grid cells regarding optimal carbon sequestration practice would change under future SSP126, 370 and 585 scenario, respectively.

The potential transition of cropland grid cells regarding management practice optimal from a carbon sequestration perspective, comparing the highest SOC for present-day and for future (2091-2100) SSP126, 370 and 585.

Thanks for your attention!

Alliance

Bioversity International

CIAT
International Center for Tropical Agriculture
Since 1967 *Science to cultivate change*

Cost Benefit Analysis of different soil fertility management practices

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11/12/2020

CGIAR

Bioversity International and the International Center for Tropical Agriculture (CIAT) are CGIAR Research Centers.
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CGIAR RESEARCH PROGRAM ON Water, Land and Ecosystems

Background and purpose

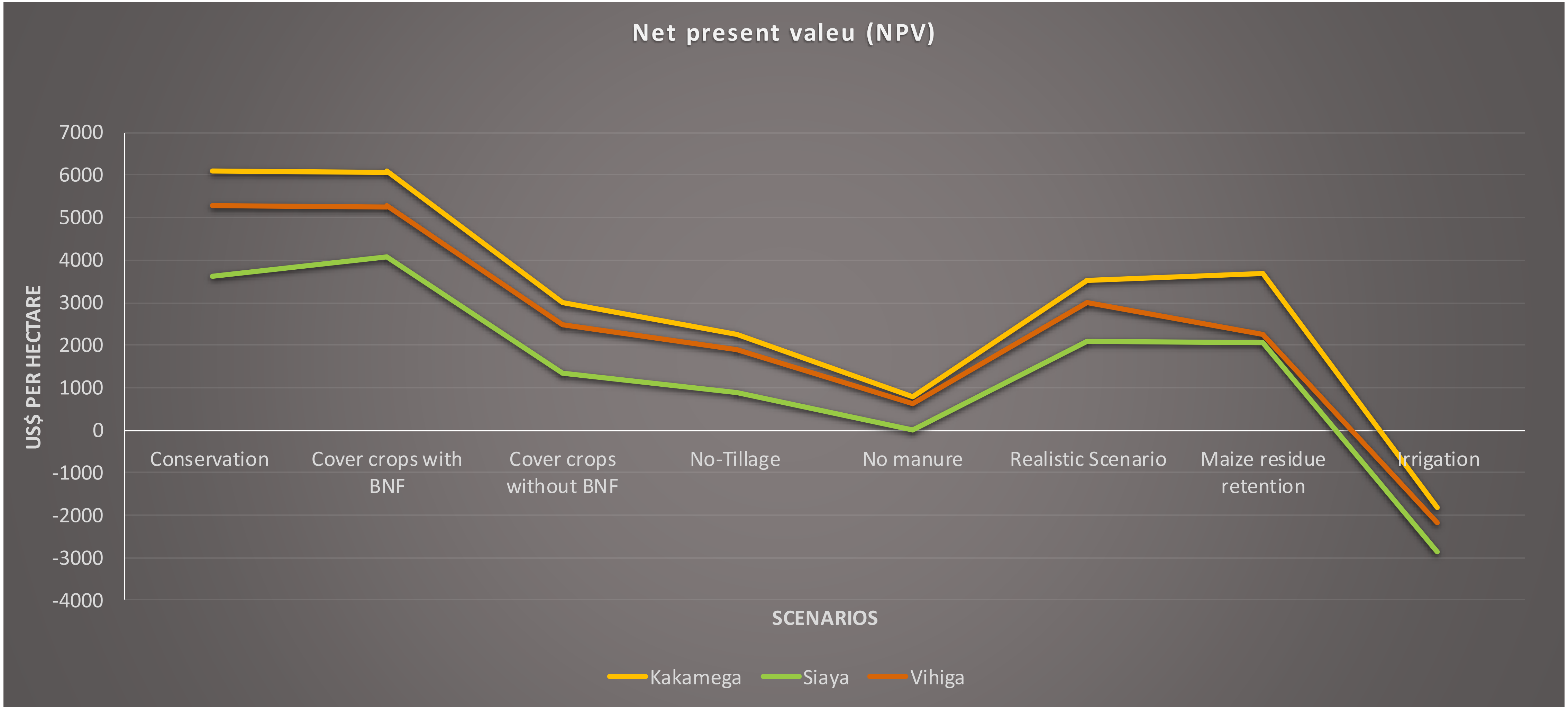
- **Background**: Eight scenarios based on yield and soil fertility management practices were identified through modelling in Kenya
- **Purpose**: Compared the eight scenario, relative to baseline practices
- These scenarios – are mutually exclusive

Codes	FCC	FNT	FRR	FNman	FMineral-N	FConserv	FIrri	FReal
Scenarios full description	*Cover-crops with BNF*	*No tillage*	*Maize residue retention*	*No-manure*	*Mineral N fertilizer replacement*	*Conservation*	*Irrigation*	*Most realistic*
Cover crops	Yes	No	No	No	No	Yes	No	No
Tillage	Yes	No	Yes	Yes	Yes	No	Yes	Yes
Residual removal	90%	90%	0%	90%	90%	0%	90%	90%
Manure N	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Mineral N	Yes	Yes	Yes	YES	YES	Yes	Yes	Yes
Irrigation	No	No	No	No	No	No	Yes	No

Analysis Methods and Assumptions

- Incremental values of management scenarios per household per hectare compared to business as usual (BAU)
- Implementation, maintenance and operation cost per ha based on survey data (2016) collected from 96 respondents.
- Net present values (NPVs) at 17% real discount rates (after inflation)
- Time horizon: life of practice for financial analysis (45 years)
- Economics associated with social cost of net greenhouse gas emissions (not included)
- Economic analysis scaled up to county level (an example with conservation agriculture scenario in three counties – Kakamega, Siaya and Vihiga)

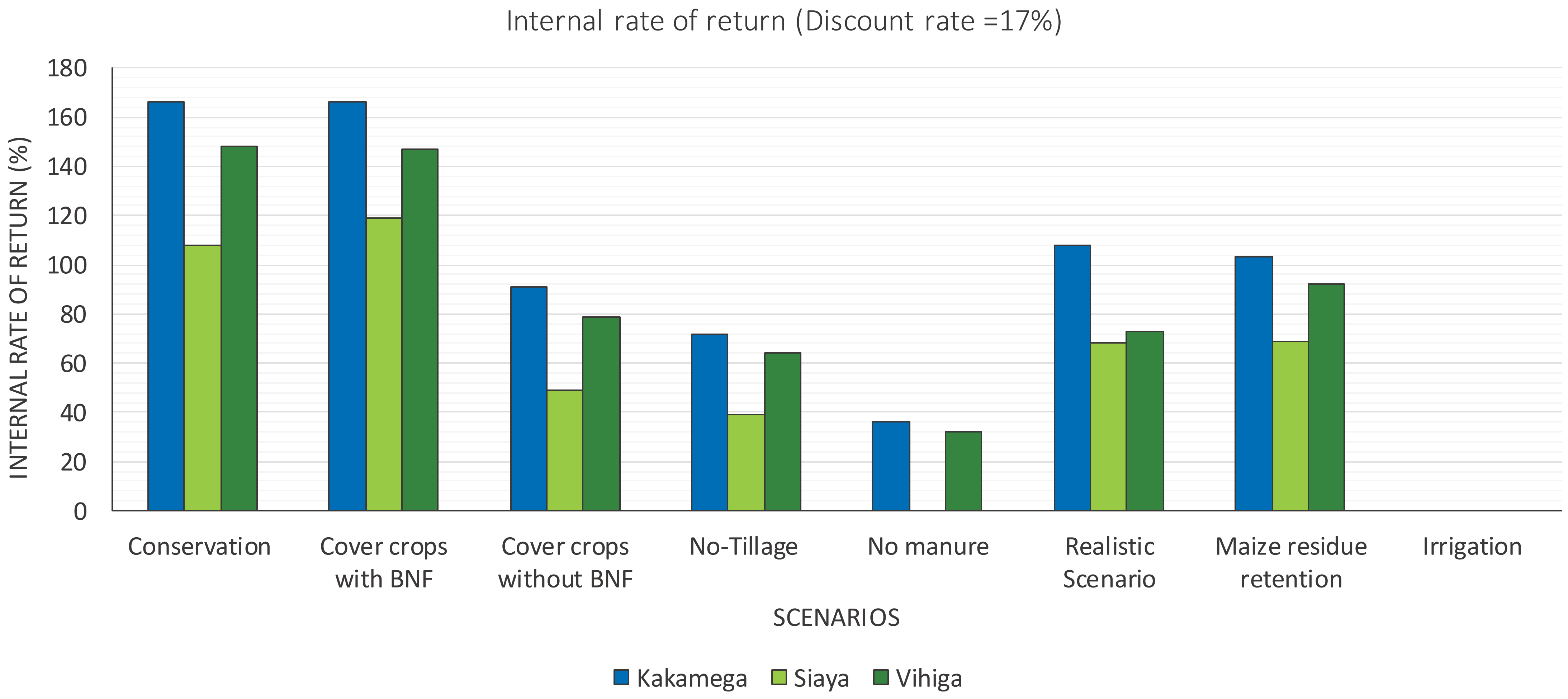
Profitability of different management scenarios



Financial NPVs of the Scenarios, at 17% Discount Rate

- **NPVs High:** for conservation agriculture, cover crops with biological nitrogen fixation (BNF) and maize residue retention when compared with the most realistic scenario
- **NPVs low:** cover crops without BNF, No-tillage and the scenario with no manure when compared with the most realistic scenario
- NPV is Negative for irrigation scenario

Is it profitable to invest in different MGT practices?

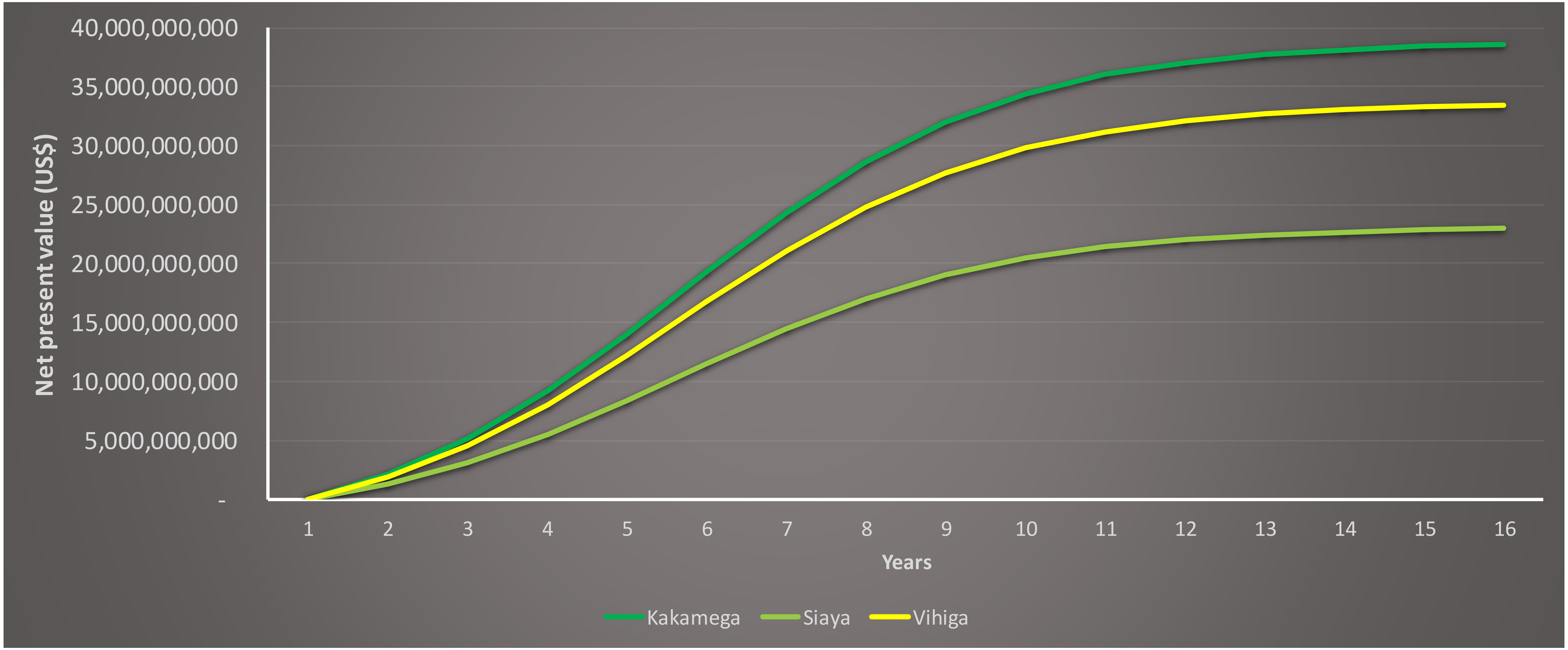


Economic Impact at the county level (Conservation agriculture)

- Assumptions (for modelling impact):

1. Diffusion start year 1 (just following the introduction of the practice in the area)
2. Length of prediction 15 years (i.e., period which adoption will be taking place)
3. Estimated diffusion ceiling (K) 70% (maximum number of household adopting)
4. Proportion of adoption at the starting point (4% of the entire farmers in a county)
5. Proportion of adoption at mid-point (50%)
6. Total number of farmers in each county (100,000)
7. The average land size per farmer under conservation agriculture (1ha)

Aggregate economic impact of adopting conservation agriculture



Conclusions on the Cost-Benefit Analysis

- If the irrigation scenario data was correct, this practice NPV is negative unless the discount rate 3% or less
- Seven fertility management/scenarios were financially beneficial
- Except, no-tillage scenario, all the scenarios require large up-front investments – a big challenge for low-income farmers
  - Therefore, for upscaling and broad adoption, **financing would be needed**
- Increasing access to markets may improve the financial profitability associated with the practices and motivate farmers to adopt more efficient land use management practices

Thank you!

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