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Wisdom at the source of the Blue Nile

Impacts of Conservation Agriculture with Small-Scale Irrigation in the Sub-Humid Ethiopian Highlands: An Experiment and Modeling Study

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Innovation Labs: Small Scale Irrigation, Sustainable Intensification

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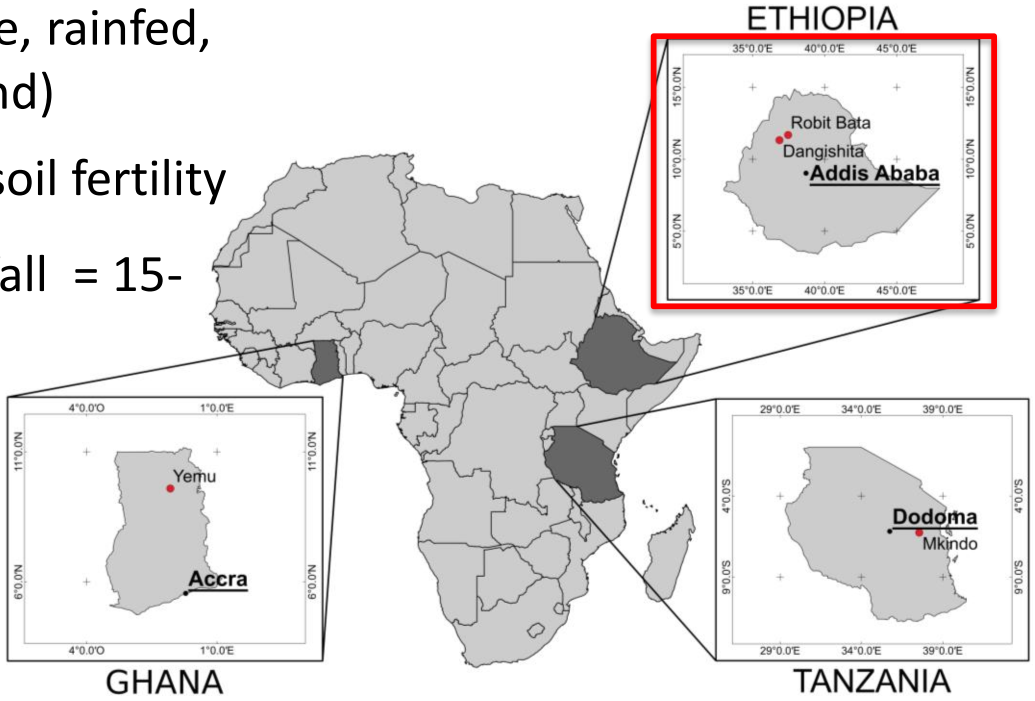
Background

- Agricultural practice: traditional tillage, rainfed, limited irrigation (4-5% of irrigable land)
- Poor rainwater management, loss of soil fertility
- Climate variability is high (CV for rainfall = 15-50%)
- This poses major risk to rainfed crop production, major agricultural practice in the region
- Extensification approach; at the cost of forest and plantation

Population ~ 110 million, 2.5% increase every year



Population ~ 27 million

Population ~ 54 million

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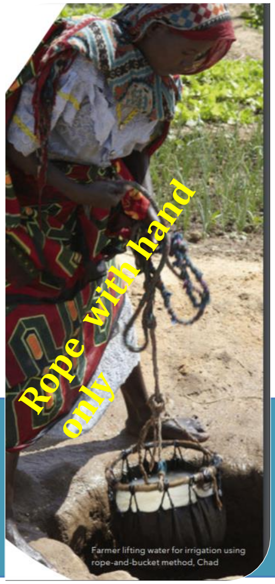
Proposed approach and goals

- Intensification approach: conservation agriculture (CA) and enable small-scale irrigation through user friendly water-lifting technique
- Goals: improve water productivity, soil quality, and crop yield while minimizing the adverse effect of agriculture on the environment

  : scaling-up the intervention and evaluate large-scale impacts



Improve **water-lifting** technique

Improve **agricultural** practice and enable **irrigation**

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Experimental design and site description

- Paired ‘t’ design on a 100 m^2 plot; 50 m^2 is randomly assigned to CA and the other half for conventional tillage (CT); 13 –farmers
- In CA practice farmers put organic mulch (grass) on their plots with no-till practice where as CT is the control (traditional) both with rotation
- Drip irrigation was installed for both CA and CT from groundwater source and stored in tanks (500 L) 1.5 m high for gravity irrigation
- Chromic Luvisols; sandy clay loam (51 % sand, 27% clay), hydrologic group C
- Climate; annual rainfall (1350 – 1750 mm), temperature (8 – 30 ^oC)

CA plot

CT plot

Remark:
CT: Conventional Tillage (50 m^2)
CA: Conservation Agriculture (50 m^2)

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Experimental setup and training


Measurement


Bed preparation


Drip layout


Randomization


Mulch application


Discussion with farmers


On-farm farmers training


On-farm data template


iFarmCA App

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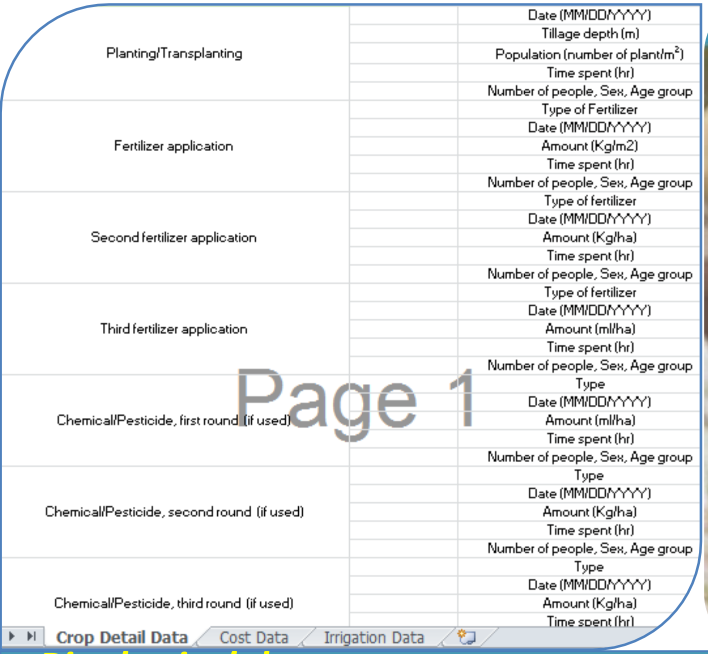
Data collection summary

Data format/template

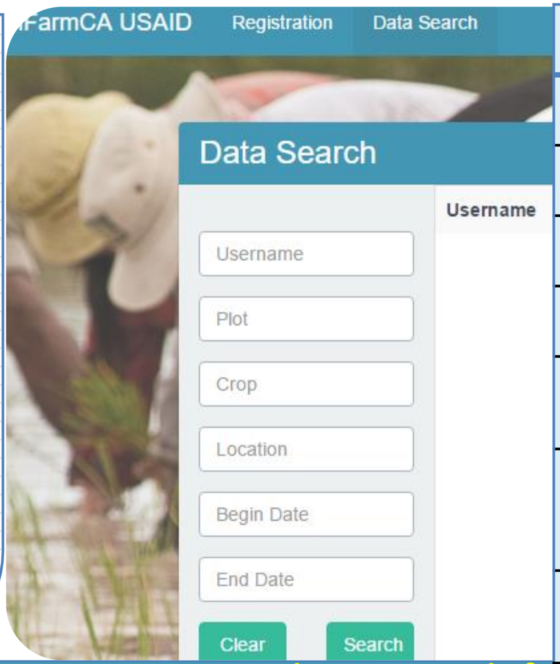


Planting/Transplanting	Date (MM/DD/YYYY) Tillage depth (m) Population (number of plant/m²) Time spent (hr) Number of people, Sex, Age group
Fertilizer application	Type of Fertilizer Date (MM/DD/YYYY) Amount (Kg/m2) Time spent (hr) Number of people, Sex, Age group
Second fertilizer application	Type of fertilizer Date (MM/DD/YYYY) Amount (Kg/ha) Time spent (hr) Number of people, Sex, Age group
Third fertilizer application	Type of fertilizer Date (MM/DD/YYYY) Amount (ml/ha) Time spent (hr) Number of people, Sex, Age group
Chemical/Pesticide, first round (if used)	Type Date (MM/DD/YYYY) Amount (ml/ha) Time spent (hr) Number of people, Sex, Age group
Chemical/Pesticide, second round (if used)	Type Date (MM/DD/YYYY) Amount (Kg/ha) Time spent (hr) Number of people, Sex, Age group
Chemical/Pesticide, third round (if used)	Type Date (MM/DD/YYYY) Amount (Kg/ha) Time spent (hr)

Page 1

Crop Detail Data | Cost Data | Irrigation Data

iFarmCA data upload using iPhone



Other data sources

Data	*Sources*
Land use	World Land Use Database (LADA)
Soil	African Soil Information System (AFSIS)
DEM	United States Geographic Survey (USGS)
Population density	Global Gridded Population Database
MODIS ET	MOD16 Global Terrestrial ET dataset
Borehole yield and groundwater depth	British Geological Survey (BGS)
Climate	Ethiopian National Metrological Agency (ENMA)

Biophysical data: Land preparation, mulch application date/amount (kg/m²), planting detail, plant density, irrigation, fertilizer/pesticides application, mulch application date/amount (kg/m²), harvesting dates, crop yield

Economical data: Labor hour; in planting, harvesting, tilling, mulching, weeding, water-tank fill, fertilizer/pesticide application
Cost data; seed, fertilizer, pesticide

Experiment: one-tailed paired 't' test

- Water productivity: crop yield per cubic metric water consumption
- Hypothesis: $H_1;\ \mu_d > 0\ (water\ productivity\ )$
  : $HO;\ \mu_d = 0$
- One-tailed paired-t test: $t = \frac{\mu_d - 0}{S_d/\sqrt{n}}$ follows t_{n-1} distribution
  $d_i = CA_i - CT_i$
- Significance level: $\alpha = 5\%$
- $t > t_{n-1,\alpha}\ or\ p - value < \alpha\ ;\ Reject\ Ho$

APEX modeling: hydrology (water management) and crop yield

Inputs: **Topography and Soil** | **Weather** | **Land use/cover** | **Tillage schedule** | **Irrigation schedule** | **Conservation practice** | **Nutrient Application** | **Pesticide Application** → **APEX model**

APEX model → **Hydrology** | **Crop** | **Other environmental variables**

Hydrology:
- Runoff
- Evapotranspiration
- Percolation
- Soil water

Tillage:
- No till
- Tillage type and depth

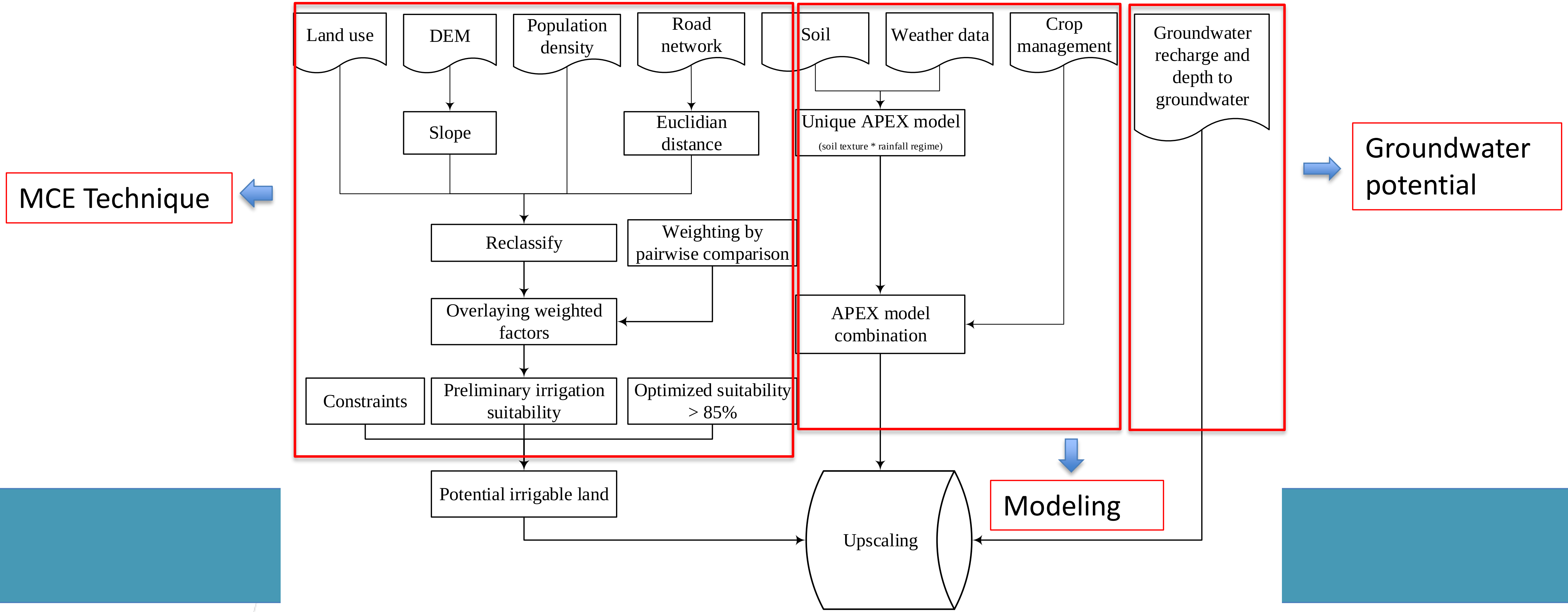
Conservation Practice:
- Addmulch (new subroutine)
- Mulch rate and date

Irrigation schedule:
- Date and amount of water in drip system

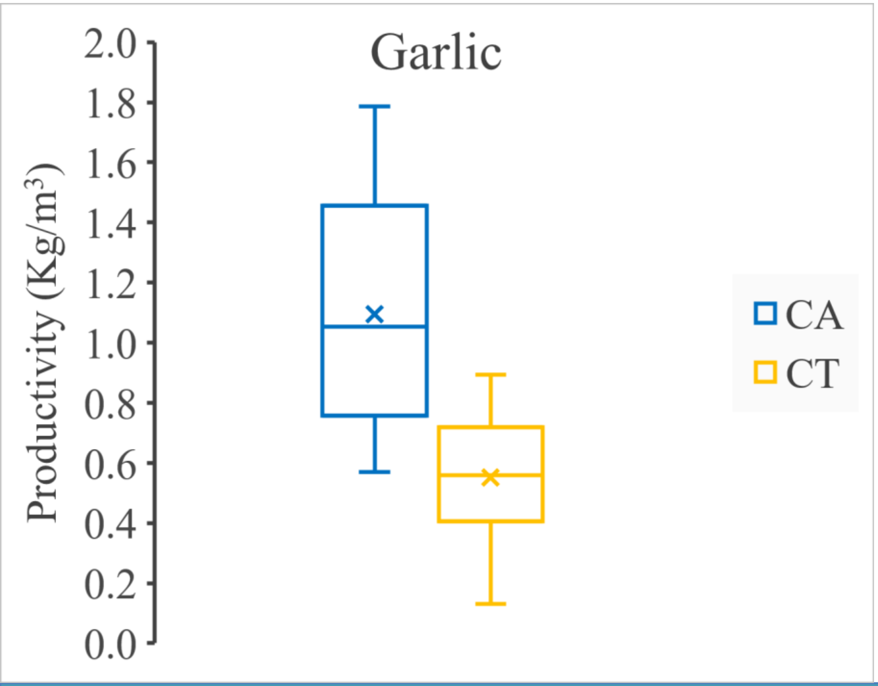
Crop:
- Crop growth/yield

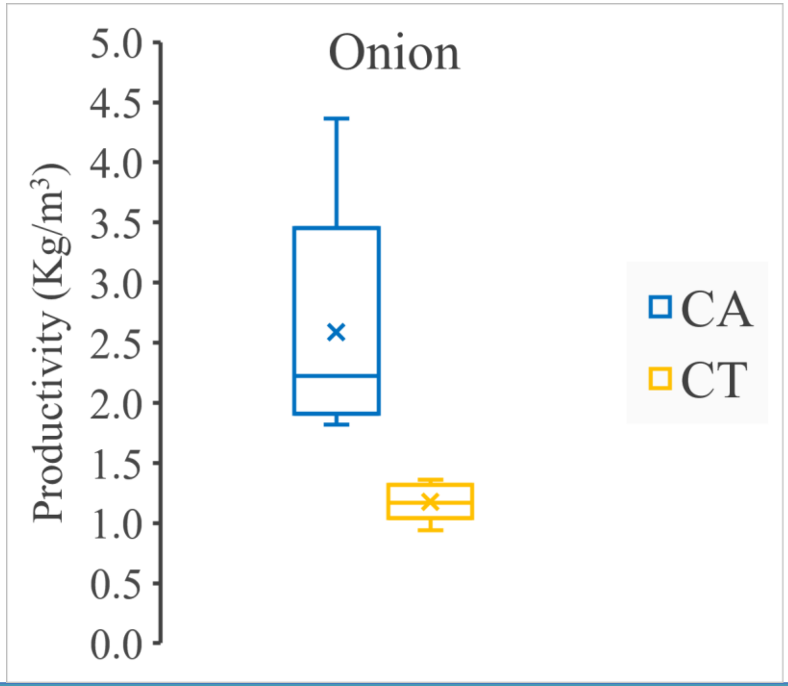
- APEX hydrology and crop yield components were validated using field data (stream flow and crop yield)

Scaling-up CA with drip irrigation: APEX model, MCE-GIS based technique



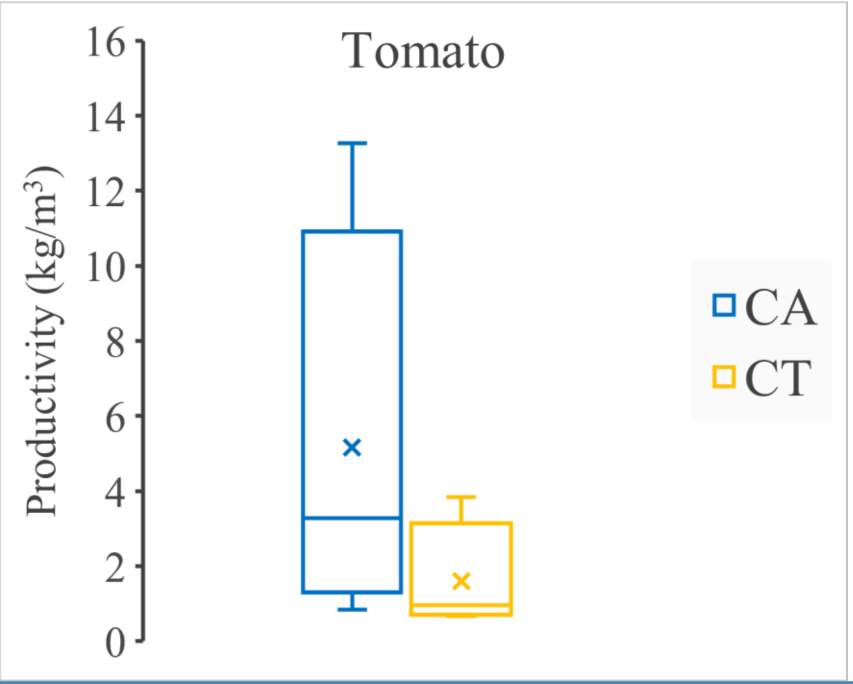
Experiment results: Water Productivity at Dangishita

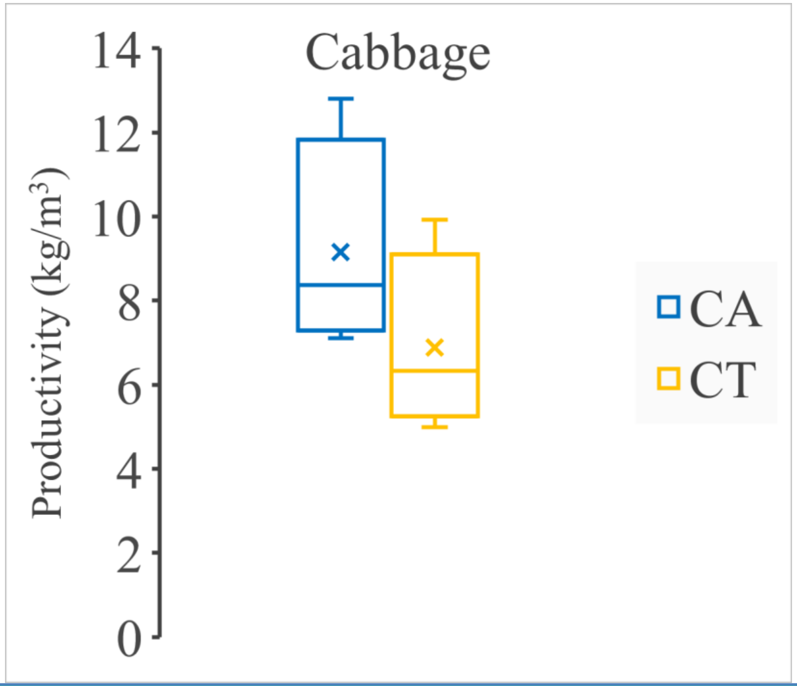




- Water productivity significantly increased (α = 0.05) under CA in Dangishita
  Garlic ~ 100% increase
  Onion ~ 120% increase

Experiment results: Water Productivity at Robit





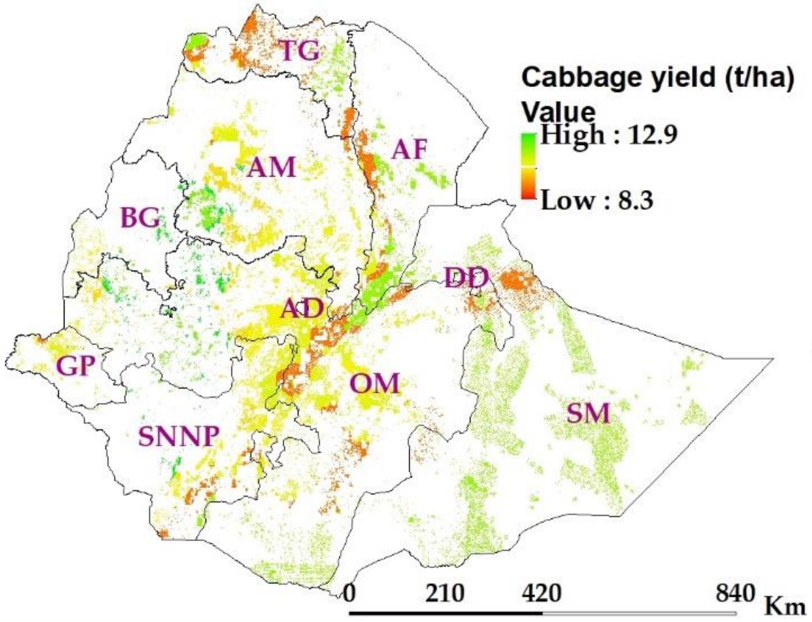
- Water productivity significantly increased ($\alpha = 0.05$) under CA in Robit
  Tomato ~ 222% increase
  Cabbage ~ 33% increase

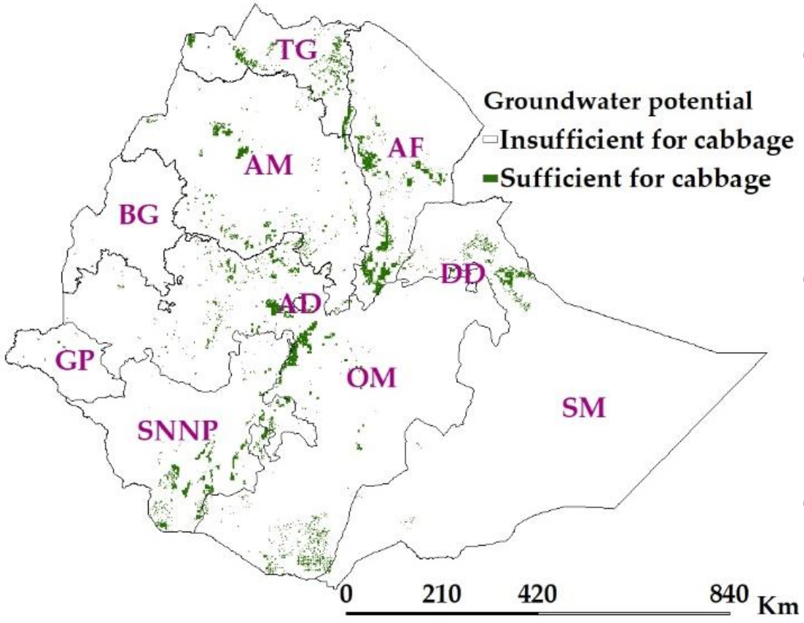
Modeling Results: Impacts of CA on hydrology/water management

Hydrology	Dangishita, Ethiopia (% change in CA)	Robit, Ethiopia (% change in CA	Significance (α = 0.05) P(T<=t)
Evapotranspiration	-33 - 49	-28 - 44	0.0004
Runoff	-17-54	-34 - 62	0.039
Irrigation	-15 - 44	-18 - 34	0.0001
Percolation	+173 - 231	+52 - 312	0.009
Soil water content	+12- 15	+12 - 28	0.0004

if the impacts of CA varies based on crop type, weather, water input, etc

Modeling Results: Impacts of CA on hydrology/water management





Note: Administrative regions (TG- Tigray, AM – Amhara, AF – Afar, BG- Benshangul Gumaz, AD- Addis Ababa, DD- Dire Dawa, GP-Gambela Peoples, SNNP- Southern Nations, Nationalities and Peoples, SM- Somali)

- Significant crop yield increase; 8.3 – 12.9 tha^{-1} under CA with drip versus 7.9 tha^{-1} national average under CT
- Groundwater could supply 1.4 – 3.5 Mha under CA; 17% of the irrigable land (18.7 Mha) versus 0.6 Mha in CT
- Oromia and Amhara states constitute about 61% of the nation's groundwater potential.

Conclusions/Lessons/

- **Crop yield** significantly improved under CA; garlic (+46 to 56%), onion (+44%), tomato (+184%), and cabbage (+9%); and **irrigation water** use reduced by 15 to 44%
- **Water productivity** significantly (α = 0.05) increased under CA when compared to CT; 33 to 222 %
- **Agricultural water management** was substantially improved under CA; evapotranspiration (- 28 to 49%, runoff (- 17 to 62%), percolation (+52 to 312%, and soil moisture (+12 to 28%)
- **Groundwater** significantly improved; 1.4 to 3.5 Mha in the nation if CA with drip irrigation practiced (versus 0.6 Mha with tilled system); crop yield improved for instance cabbage, 8.3 – 12.9 tha^{-1} versus 7.9 tha^{-1}
- **CA with drip irrigation is found to be an ideal approach for sustainable intensification**
- **Competitive use of mulch** is a limiting factor to expand CA practice

Research outputs/publications/

- **Tewodros Assefa**, Manoj Jha, Manuel Reyes, Abeyou W. Worqlul, Luca Doro, and Seifu Tilahun (2019). Conservation agriculture with drip irrigation: Effects on soil quality and crop yield in Sub-Saharan Africa. (Accepted 09/2019, Soil and Water Conservation)
- **Tewodros Assefa**, Manoj Jha, Abeyou W. Worqlul, Manuel Reyes, and Seifu Tilahun (2019). Scaling-Up Conservation Agriculture Production System with Drip Irrigation by Integrating MCE Technique and the APEX Model. Water 11(3)
- **Tewodros Assefa**, Manoj Jha, Manuel Reyes, Seifu Tilahun, and Abeyou W. Worqlul (2019). Experimental Evaluation of Conservation Agriculture with Drip Irrigation for Water Productivity in Sub-Saharan Africa. Water 11(3)
- Seifu A.Tilahun, Sisay A. Belay, Belaynew Belete, Getnet Awoke, **Tewodros T. Assefa**, Yonas Mitiku, Sisay G Gebeyehu, Petra Schmitter, Manuel R. Reyes, and Tammo S. Steenhuis (2019). Testing Maji solar pump for irrigation by smallholder farmers in sub-humid Ethiopia. July 7-10, 2019, Boston, Massachusetts, USA
- **Tewodros Assefa**, Manoj Jha, Manuel Reyes, Abeyou W. Worqlul (2018). Modeling the Impacts of Conservation Agriculture with a Drip Irrigation System on the Hydrology and Water Management in Sub-Saharan Africa. Sustainability 10(12)
- **Tewodros Assefa**, Manoj Jha, Manuel Reyes, Abeyou W. Worqlul (2018). Assessment of Suitable Areas for Home Gardens for Irrigation Potential, Water Availability, and Water-Lifting Technologies. Water 10(4)
- **Tewodros Assefa**, Manoj Jha, Manuel Reyes, Keith Schimmel, Seifu Tilahun (2017). Commercial Home Gardens under Conservation Agriculture and Drip Irrigation for Small Holder Farming in sub-Saharan Africa. Conference proceeding. July 16-19, 2017, Spokane, Washington, USA

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If you are a modeler, go to the field and feel the difference!!!

Thank You

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