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Feed the Future Innovation Lab for Small Scale Irrigation

Modeling of Small Scale Irrigation (SSI) impacts using the Integrated Decision Support System (IDSS)

Texas A&M AgriLife Research Team, Jan 31, 2018

Texas A&M University

KEY QUESTIONS

- How much water/land is available for irrigation?
- How many farmers/households can it support?
- How sustainable is it?
  - Now into future
- What are the bottlenecks & opportunities?
  - technologies, social/cultural, economics
- What are the optimum mixes of interventions?
- What difference will it make?
  - income, health, and in the lives of people
- What changes in policy, practice and investments are necessary?
  - local, regional, national

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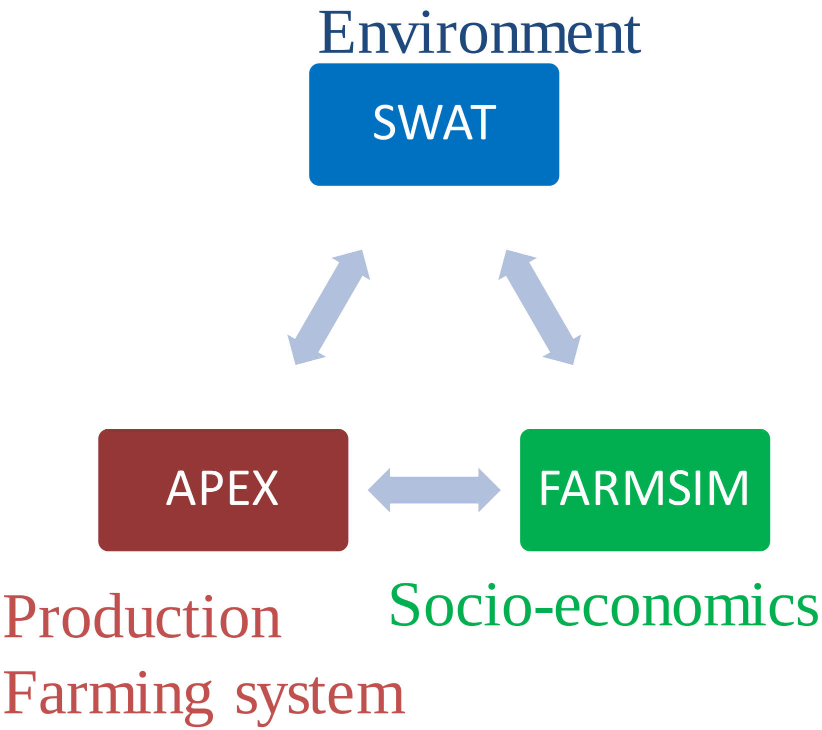
INTEGRATED DECISION SUPPORT SYSTEM (IDSS)



- SWAT – analyze the potentials and impacts of SSI at the watershed scale
- APEX – analyze cropping systems at the field scale, and
- FARMSIM – assess economic & nutritional impacts at household level

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APPLICATIONS OF IDSS?

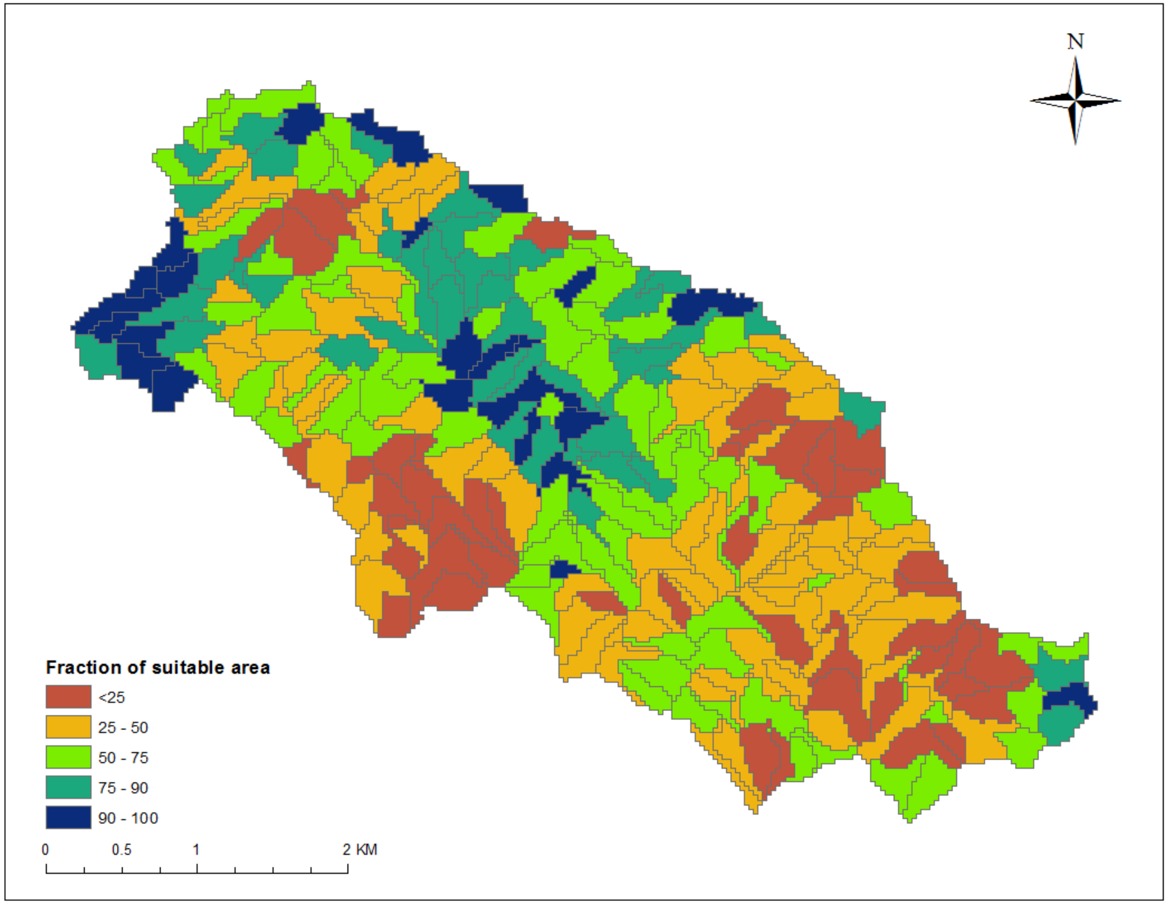
- Ex-ante analysis
  - Relied on existing data from literature and secondary sources
  - Useful to study impacts of SSI
- Ex-post analysis
  - Used field data to fine-tune the ex-ante analysis
  - Helped to understand more on the impacts of SSI
  - Vital for gaps and constraint analysis
- Gaps and constraints analysis to SSI
  - Critical to identify mitigation strategies for the gaps and constraints
- Upscaling analysis
  - Uses data and lessons learned from the ex-post analysis
  - Useful to understand the potentials and impacts of SSI at national level
- Capacity building
  - IDSS models, and other demand-driven tools

EX-POST CASE STUDY: ROBIT SITE

RESOURCE ASSESSMENT AT WATERSHED SCALE: ROBIT CASE, ETHIOPIA

- Average annual rainfall = 1,400 mm
  - → groundwater recharge = 280 mm (~4,000,000 m^3 over the watershed)
  - → surface runoff = 520 mm (~7,000,000 m^3 over the watershed)
- Amount of water required for dry season irrigation for tomato = 1,500,000 m^3
  - → ~40% of the **groundwater recharge**
- At the watershed scale, groundwater recharge can support irrigation for vegetables (in suitable areas) in a sustainable manner.

LAND SUITABILITY FOR IRRIGATION



- ~57% of the watershed is suitable for irrigation.
- Major rainfed crops were maize, teff and finger millet.
- Dry season irrigated crops were tomato and onion.

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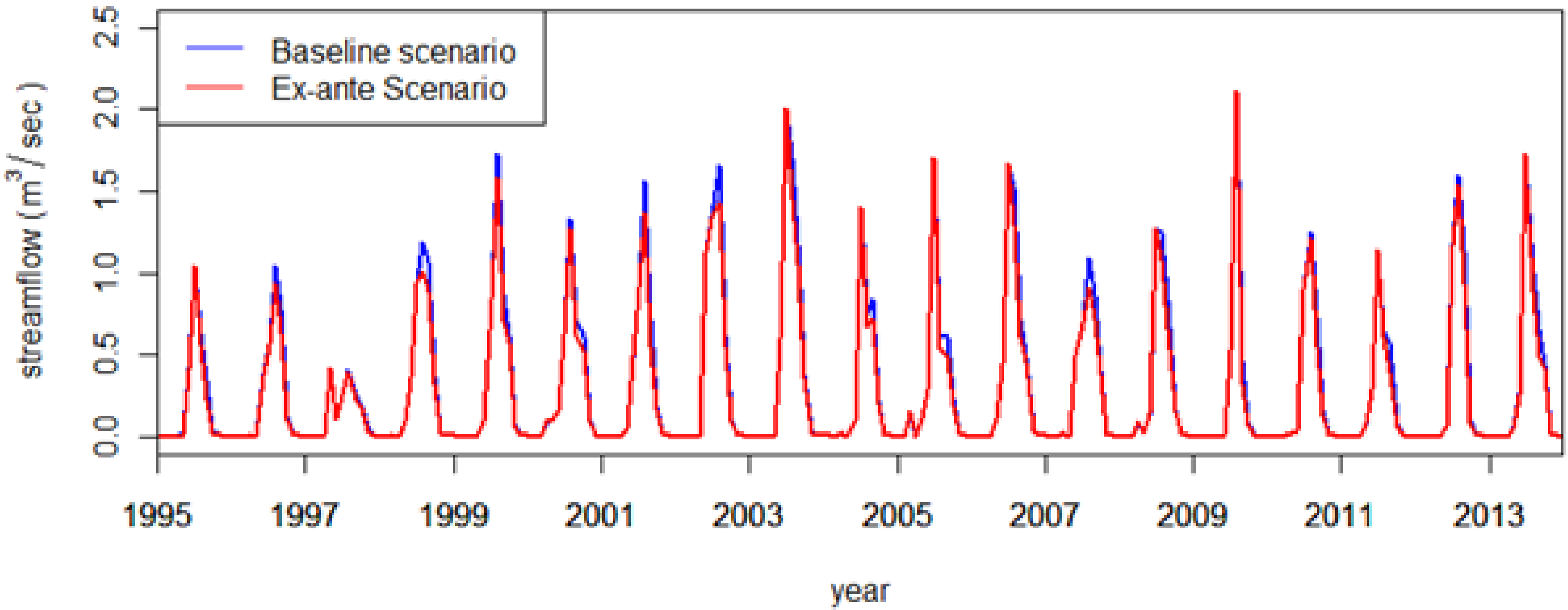
IMPACTS OF SSI AT THE WATERSHED SCALE



- Minor reductions in streamflow amount and timing,
- No major environmental impact such as soil erosion.

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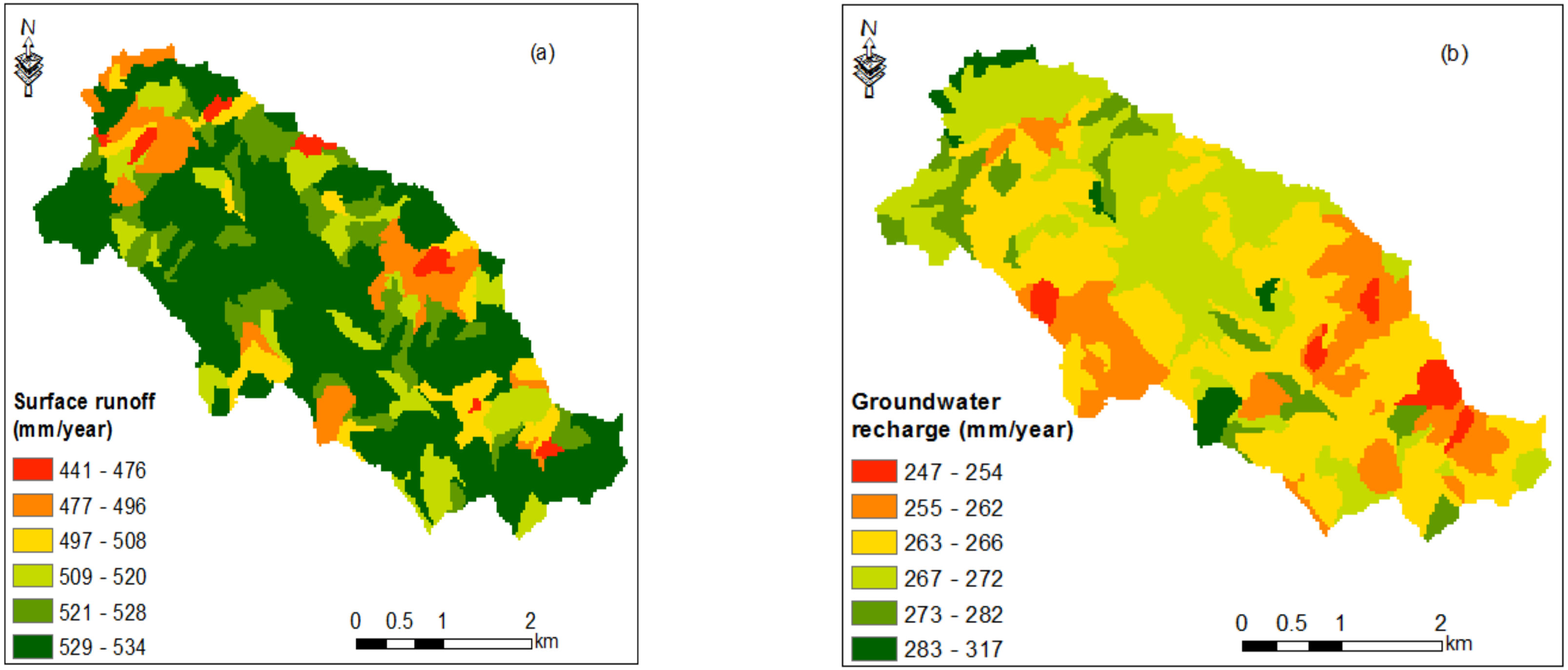
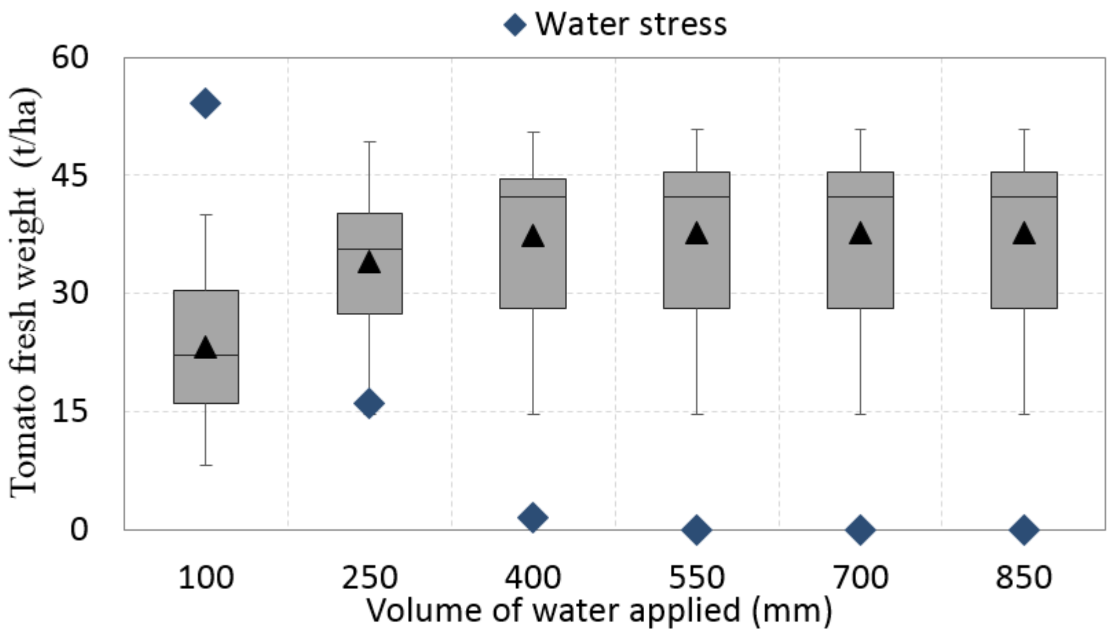
ROBIT SURFACE RUNOFF AND SHALLOW GROUNDWATER RECHARGE



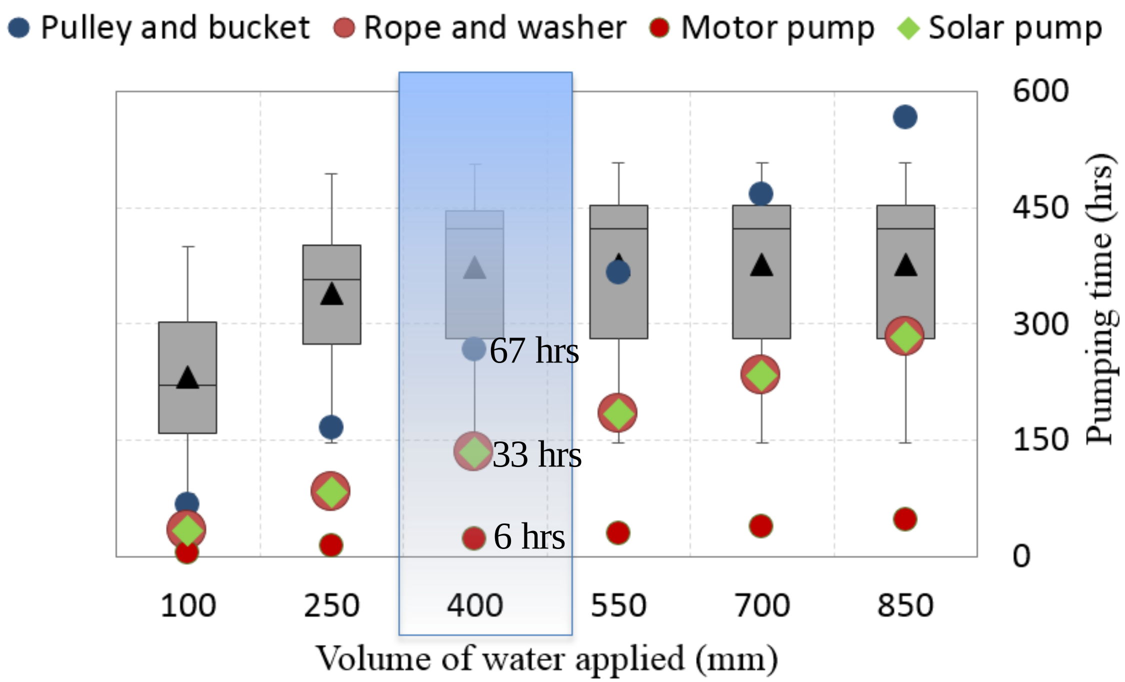
- estimating the water resource potential to determine irrigation potential at watershed scale.

WATER USE FUNCTION OF TOMATO



- Average tomato yield ranges b/n 23-37 ton/ha depending on the irrigation amount
- Optimal water to maximize tomato yield is 400 mm/year, which is higher than the average annual shallow groundwater recharge.
- Water is a constraint if groundwater is the only source of irrigation.

WATER USE FUNCTION AND PUMPING TIME OF TOMATO

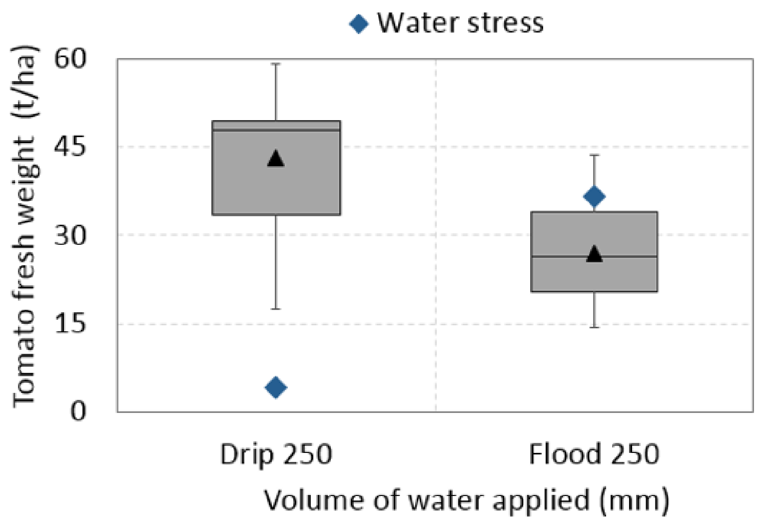


Over-irrigation:

- Costs more time and money
- A threat to irrigation expansion

TESTING IRRIGATION APPLICATION OPTIONS

Crop yield and water stress days of drip and flood irrigation



- Drip irrigation improves crop water productivity, and reduces water loss.

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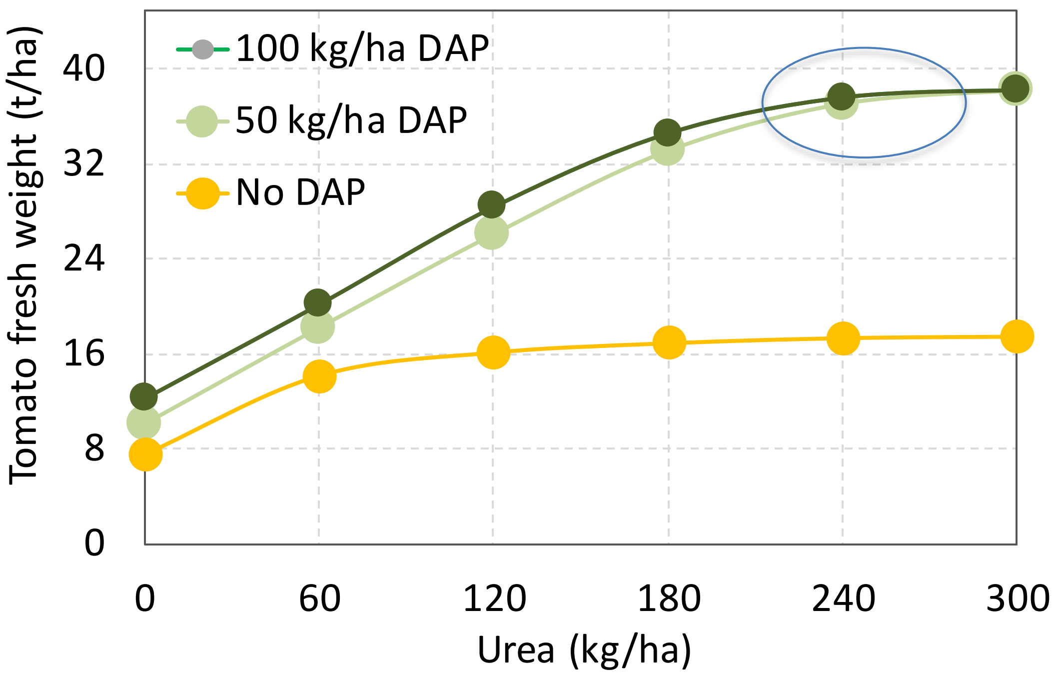
FERTILIZER USE EFFICIENCY OF TOMATO



Urea – nitrogen-based fertilizer, and DAP – phosphorous-based fertilizer

- Optimal fertilizer use is at 200-250 kg/ha Urea with 50-100 kg/ha DAP,
- Farmers' practice is far lower and of different proportional rates.

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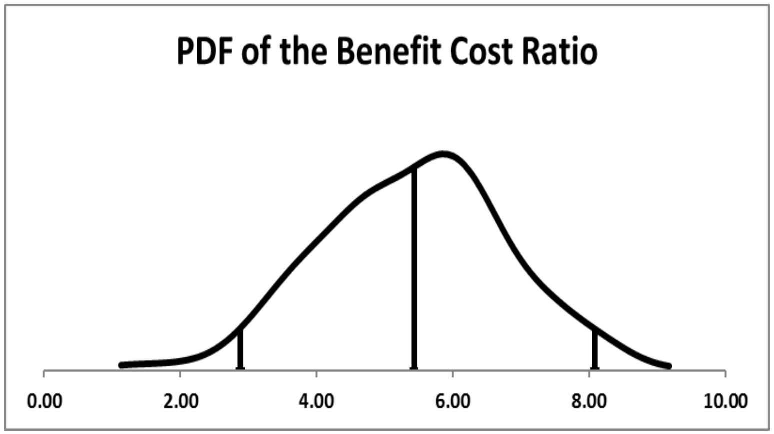
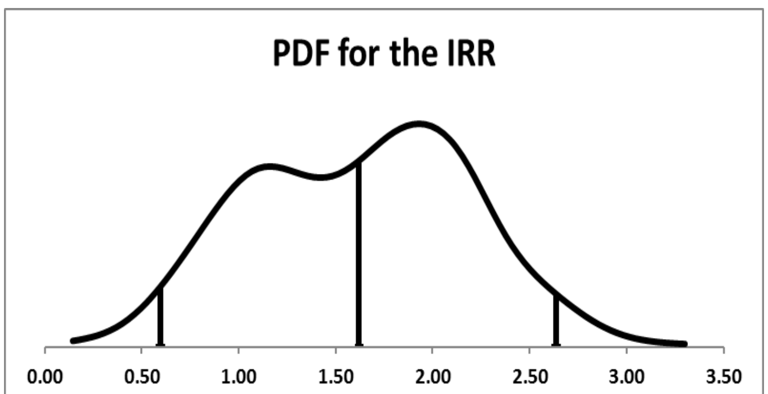
PROFITABILITY OF SSI: COST-BENEFIT ANALYSIS (B/C RATIO AND IRR)



Benefit-Cost (B/C) ratio for Alt. 1 scenario (Pulley/Baseline)

- Average B/C = 5.3 and probability of B/C > 1 is 100%



Internal Rate of Return (IRR) for Alt. 1 scenario

- Average IRR = 1.6 and probability of IRR > 0.1 is 100%

SSI-Pulley is found to be profitable

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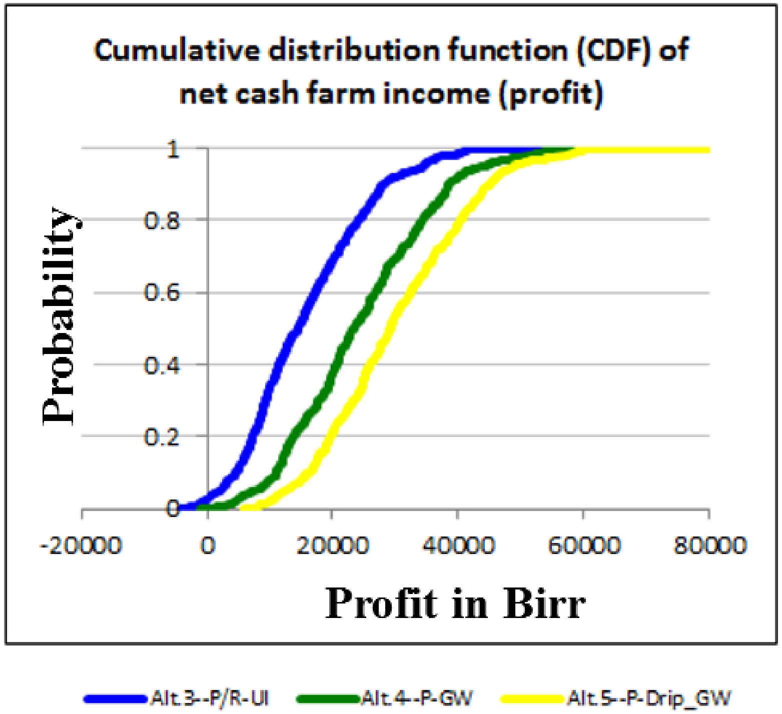
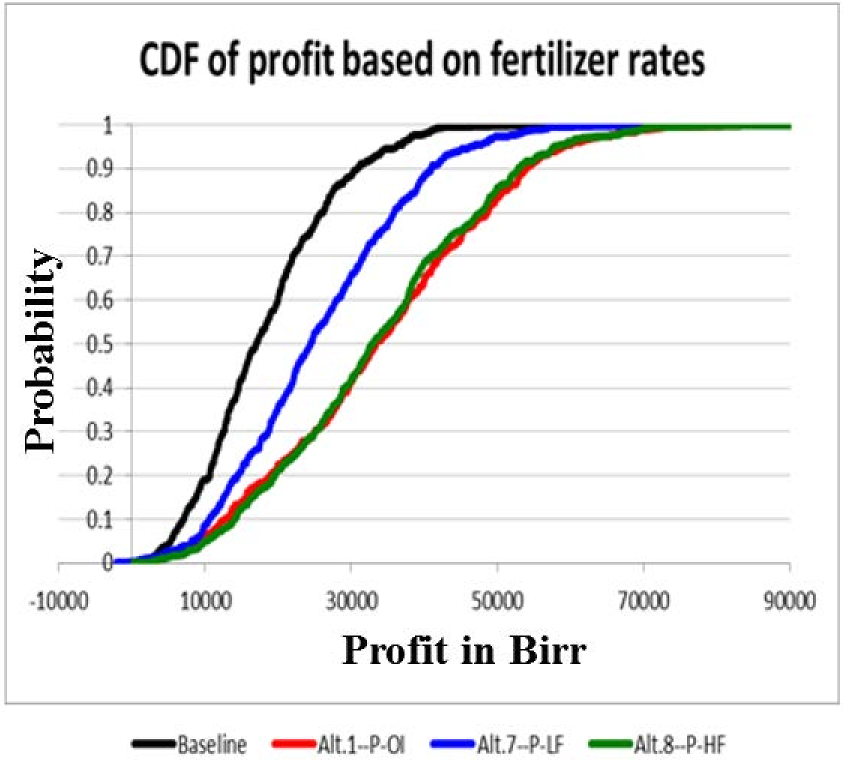
GAP AND CONSTRAINT ANALYSIS: SSI TECHNOLOGY



- Description of the scenarios
  - **Alt.3--P-UI**: Pulley with 100 mm in furrow irrigation
  - **Alt.4--P-GW**: Pulley with 250 mm in furrow irrigation
  - **Alt.5--P_Drip-GW**: Pulley with 250 mm in drip irrigation

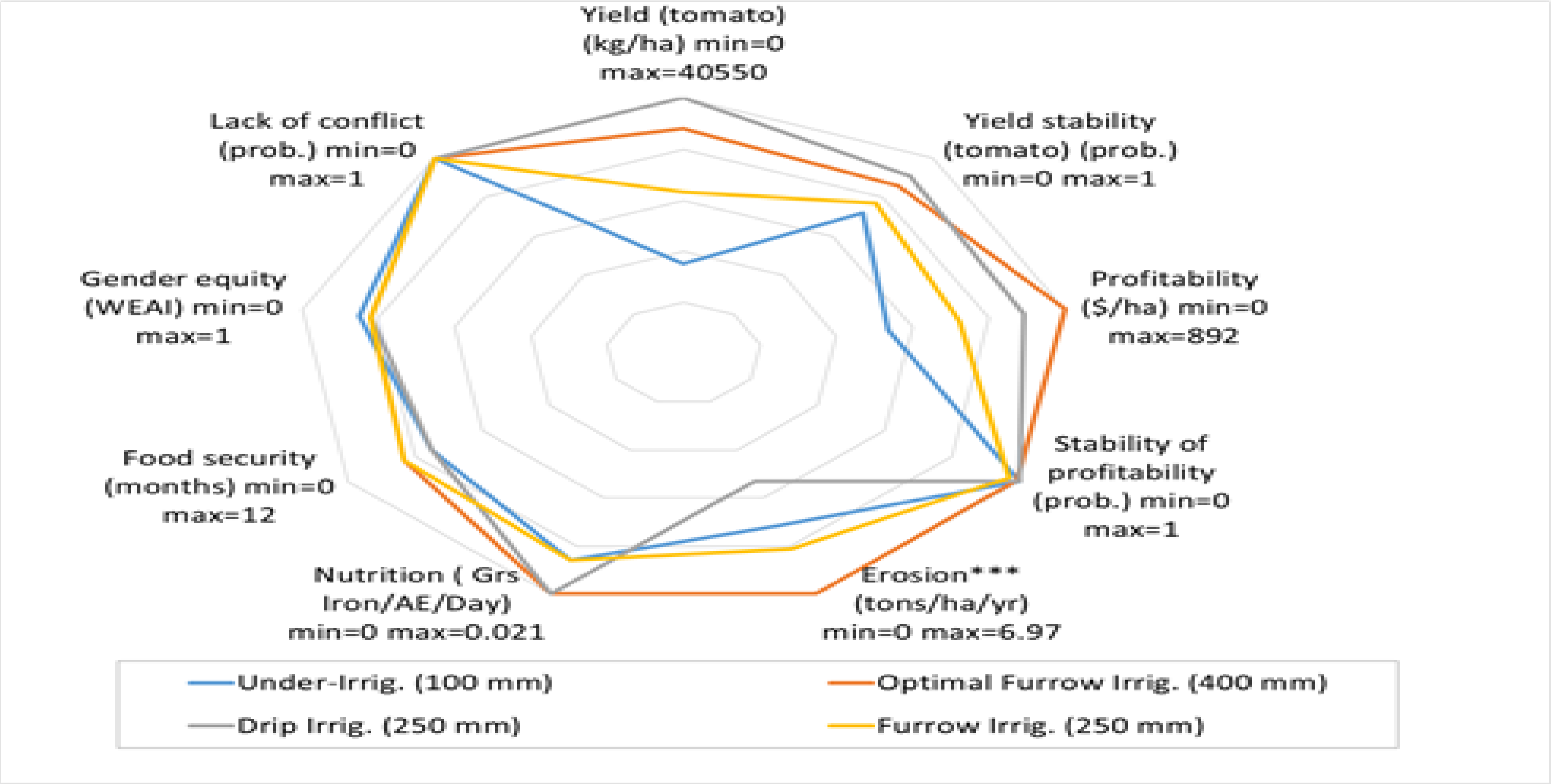
- Alt. 5 is more profitable and efficient in water limited situation
- Alt.3 (in extremely dry situation) is lowest ranking in profitability

GAP AND CONSTRAINT ANALYSIS: FERTILIZER TECHNOLOGY



- Description of the fertilizer scenarios:
  - **Baseline**: current fertilizer rates
  - **Alt. 1**: application of optimal fertilizer rates (Urea-DAP): 240-100 kg/ha
  - **Alt. 7**: application of 50-120 kg/ha (lower than optimal)
  - **Alt. 8**: application of 300-100 kg/ha (higher than optimal
- All the 3 alternative scenarios are profitable compared to the baseline.

SYNERGIES AND TRADEOFFS OF INTENSIFICATION OF SSI



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CONCLUSIONS AND IMPLICATIONS

- Use of a pulley for vegetable/fodder irrigation showed profitability,
- Drip irrigation showed higher profitability and also water use efficiency compared to furrow irrigation,
- Impact to the environment was minimal,
- Higher economic profit was obtained with optimal fertilizer rates,
- Daily minimum nutrition requirement were met with alternative scenarios except for fat and calcium.

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Planning and evaluation of Small Scale Irrigation at national scale

Farms to Nations using models

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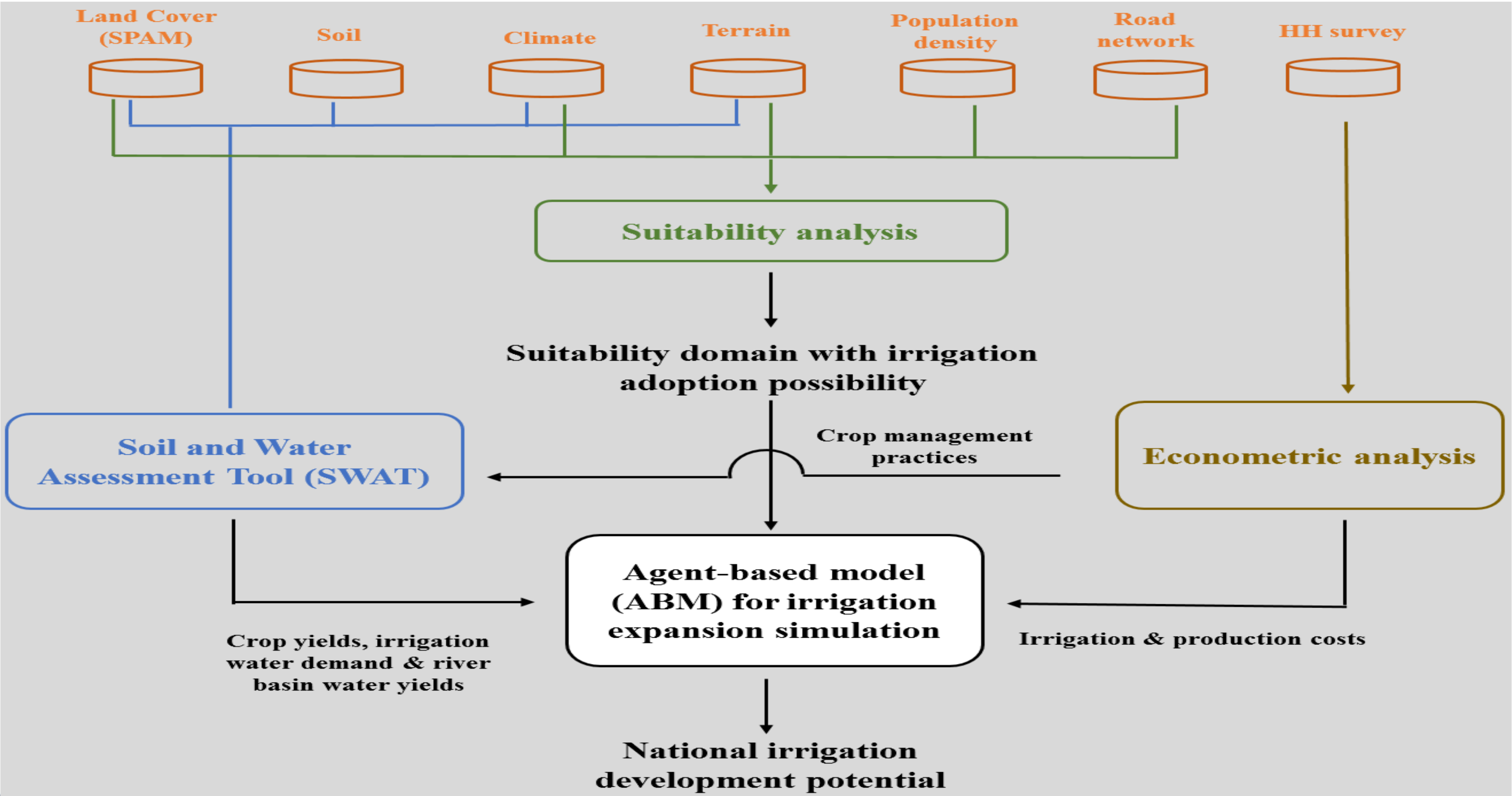
UPSCALING ANALYSIS, WHY?

- ILSSI research showed SSI improves agricultural production, environmental sustainability and household income & nutrition **at the household level**. The main questions though are:
  - What is the scale of investment for expanding SSI?
  - Where are strategic investment potential areas? and
  - What are the environmental and socio-economic impacts?
- Upscaling instrumental to address these and other questions.

UPSCALING ANALYSIS FRAMEWORK



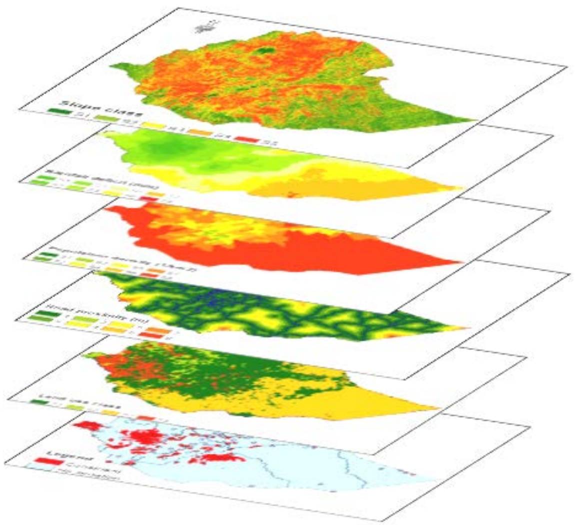
SPATIALLY EXPLICIT ESTIMATION

- Spatial Production Allocation Model (SPAM) to disaggregate the land use data into different crop types for SWAT,
- SWAT to estimate spatially explicit water availability, water consumption, crop yields, and environmental impacts, and
- ABM to estimate economic-cost benefit and water balance.

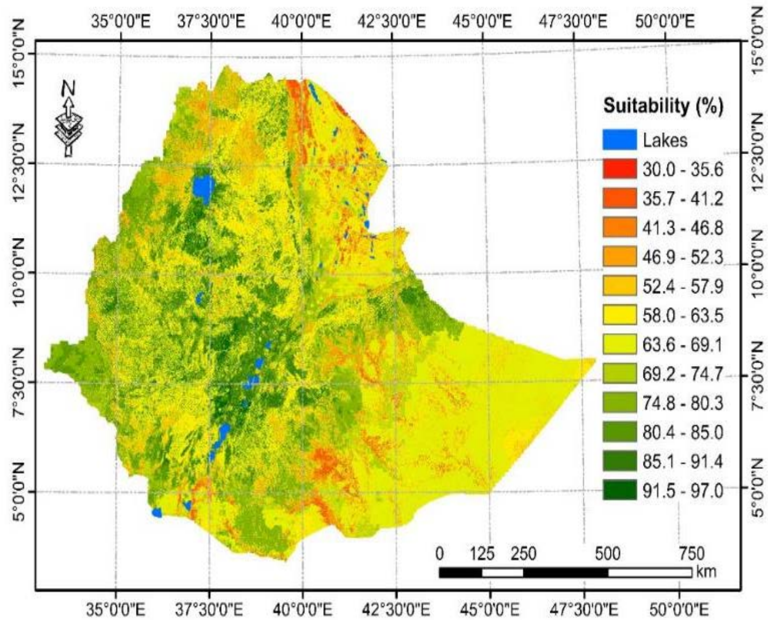
AGENT-BASED MODEL (ABM) OUTPUT

- Adoption probability and area of SSI in each geographic domain across the country,
- Environmental risk of water scarcity due to the adoption,
- Economic benefit for irrigators from the adoption, and
- Number of beneficiary population.

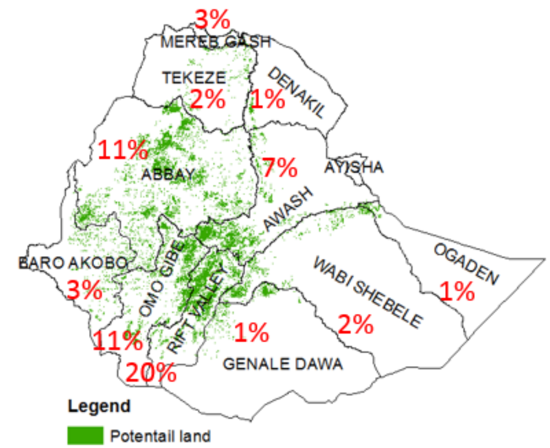
SUITABLE IRRIGABLE LAND



Overlay analysis

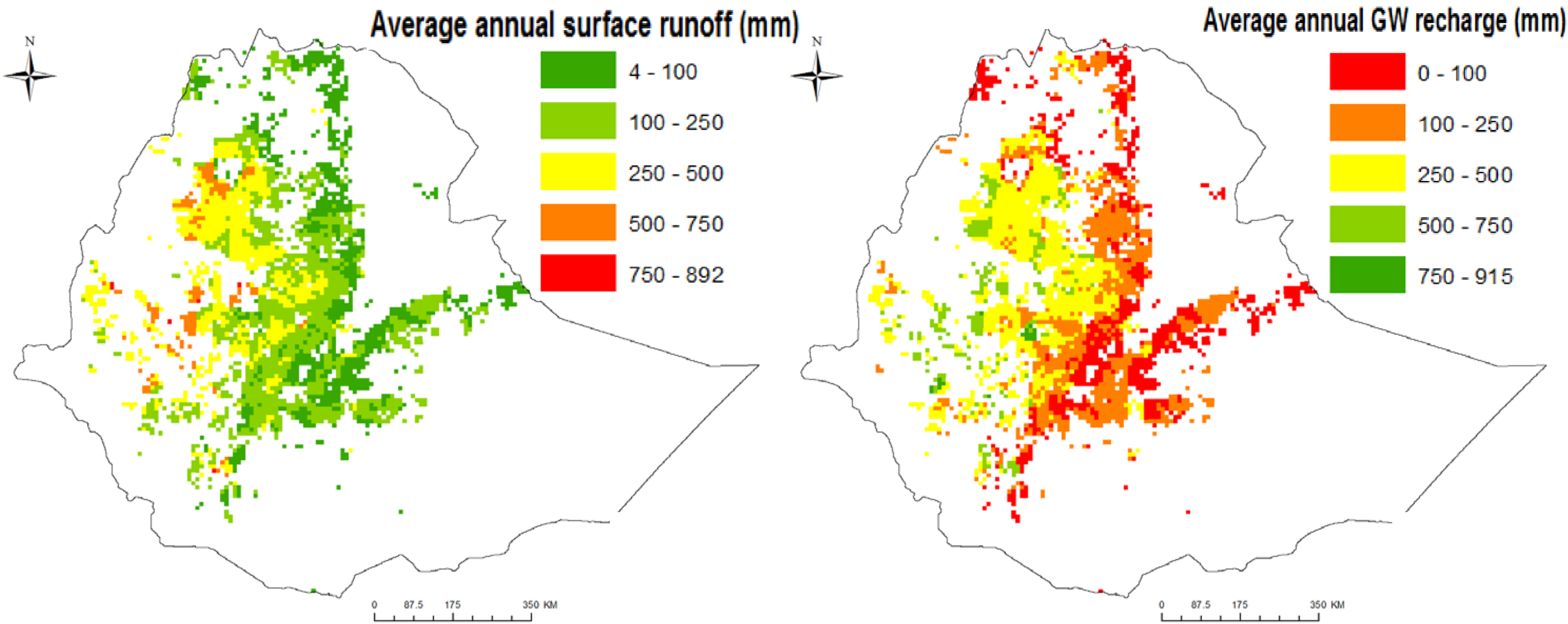


Preliminary Suitability Map
12% rainfed land = 6.0 million ha



8% of the suitable land could be irrigated with the shallow groundwater

WATER RESOURCES POTENTIAL



- A significant amount of surface runoff and groundwater recharge available across the country to expand SSI.

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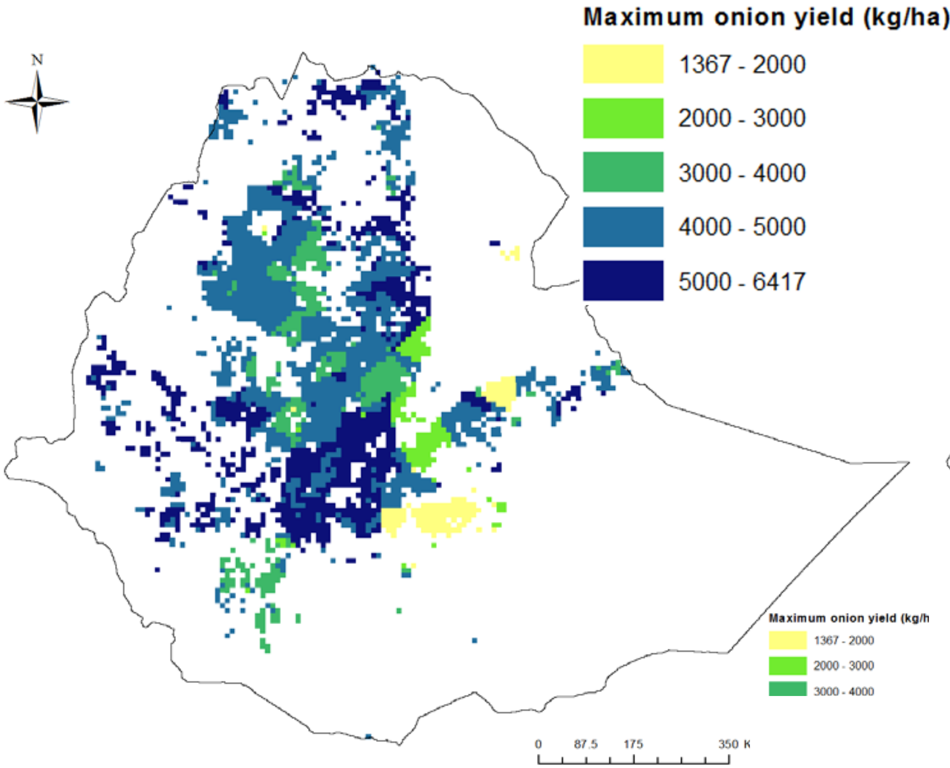
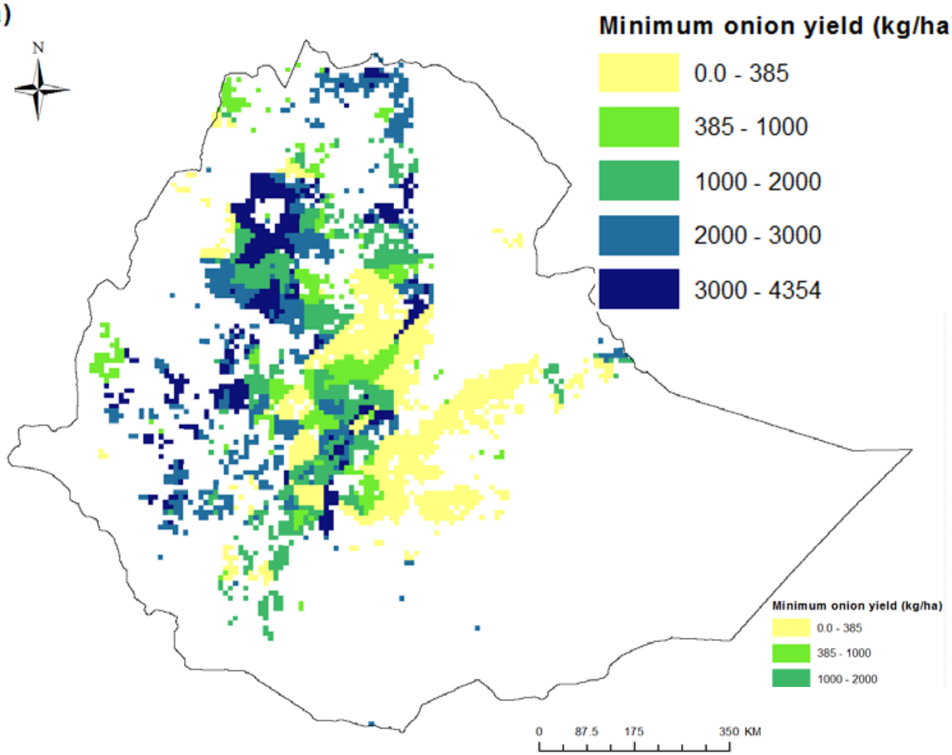
POTENTIAL FOR VEGETABLE PRODUCTION





- A large part of the country, productive for producing vegetables and fodder during the dry season

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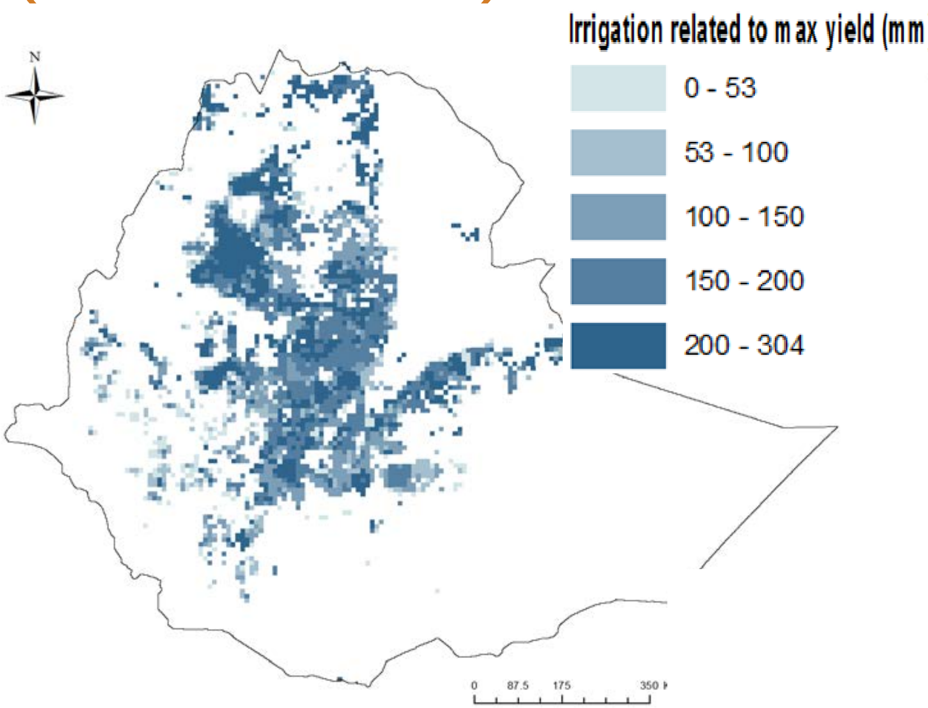
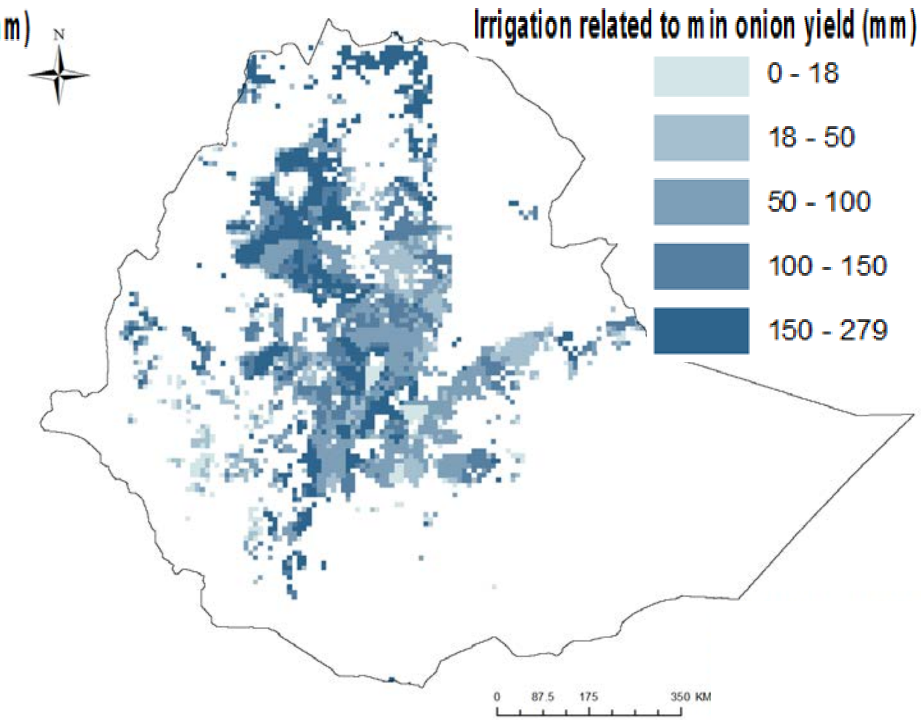
IRRIGATION FOR DRY SEASON CROPPING (E.G. ONION)





- Only modest amount of irrigation needed to produce significant amount of vegetable and fodder during the dry season.

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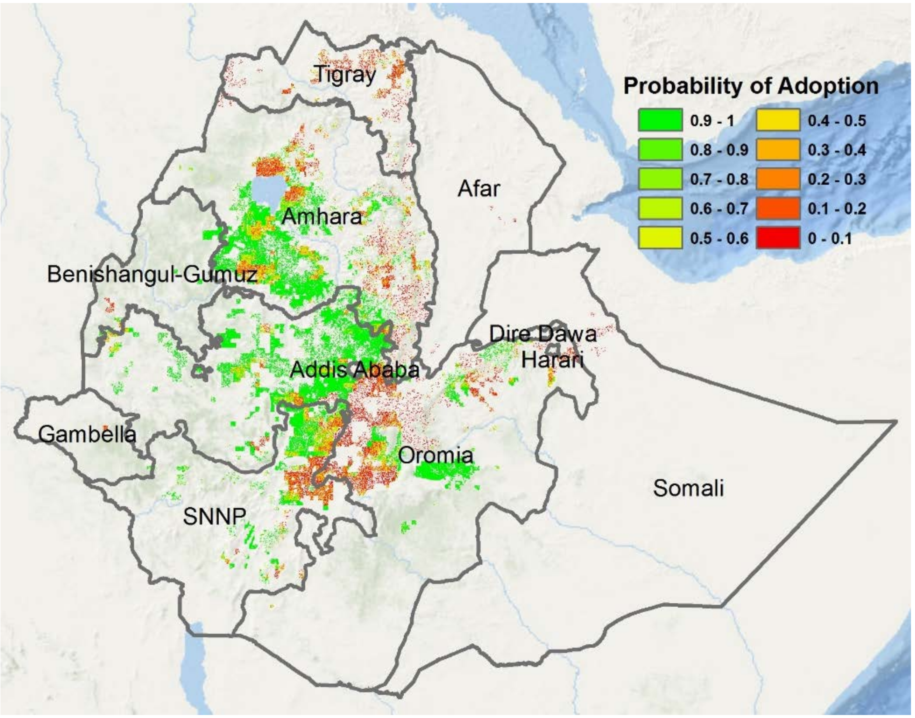
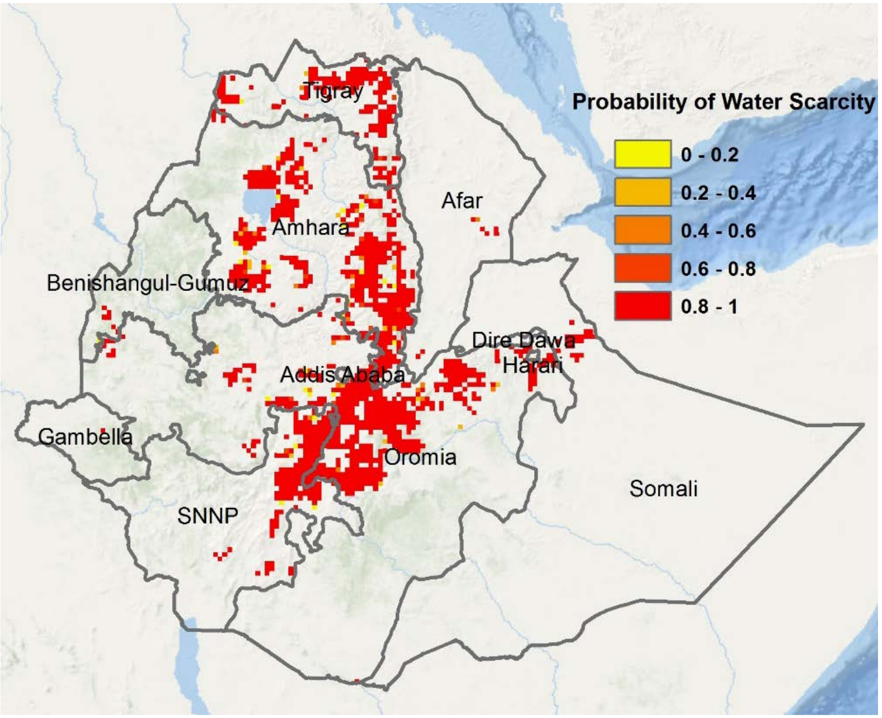
PROBABILITY OF IRRIGATION ADOPTION AND WATER SCARCITY





- High adoption probability for SSI at Lake Tana and Ethiopian Great Rift Valley areas, and
- SSI development may pose widespread water scarcity.

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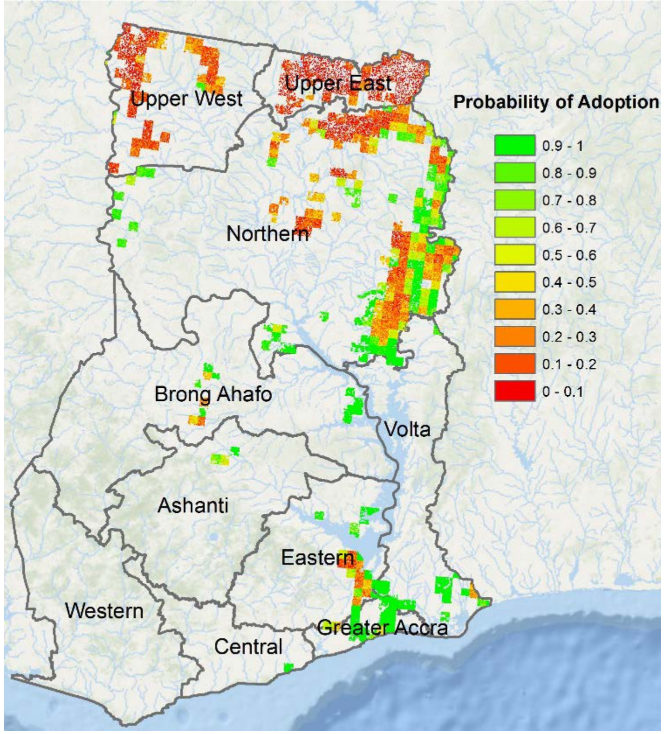
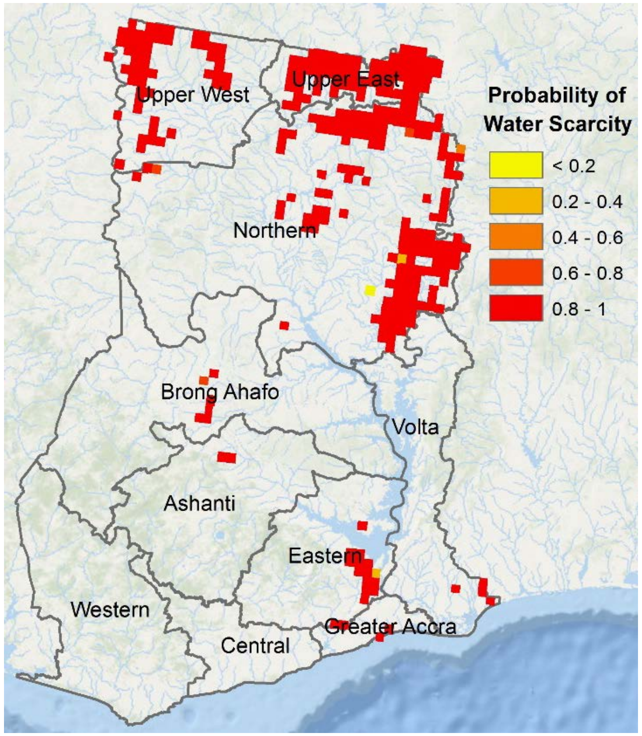
ESTIMATED SMALL-SCALE IRRIGATION ADOPTION POTENTIAL IN ETHIOPIA

	Vegetables & pulses (ha)	Fodder (ha)	Total (ha)	Profits (Million USD/yr)	Number of beneficiaries (Thousand People)
Addis Ababa	0	0	0	0	0
Affar	51	14	66	0.1	0.4
Amhara	314,394	141,047	455,440	1,066	2,581
Benishangul-Gumuz	15,861	259	16,120	37	91
Dire Dawa	0	51	51	0.08	0.3
Gambella	594	0	594	2.3	3
Harari	0	46	46	0.2	0.3
SNNP	77,602	40,569	118,171	399	670
Tigray	5,686	6,596	12,282	45	70
Oromiya	261,401	172,218	433,619	1,041	2,457
Somali	27	219	245	1	1
Total	675,642	361,021	1,036,663	2,593	5,874

- A net income of **~2.6 billion USD/year** from the SSI adoption,
- Amhara, Oromia and SNNPR having the highest SSI adoption potential.

SMALL-SCALE IRRIGATION DEVELOPMENT POTENTIAL IN GHANA





Potential area

210,572 ha

Profits

285 million USD/yr

Number of beneficiaries

0.68 million people

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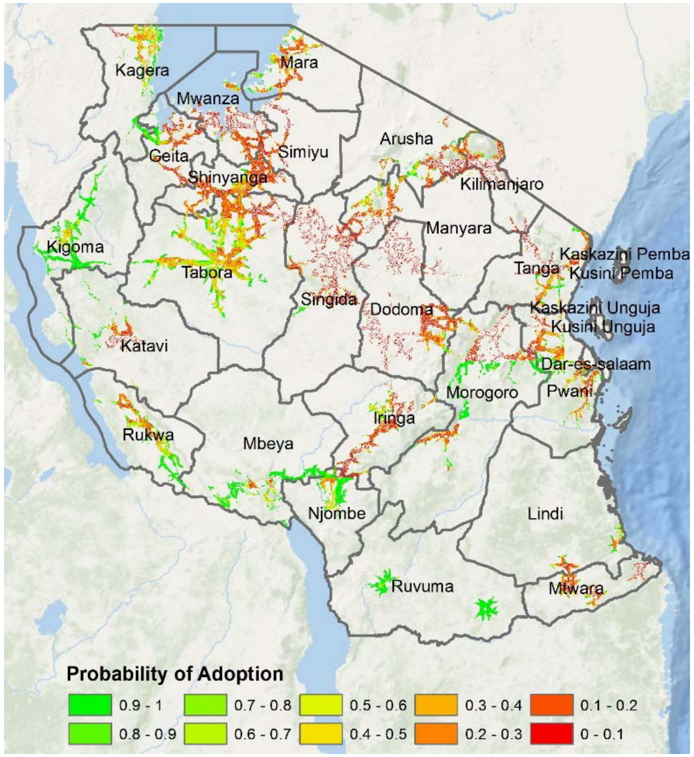
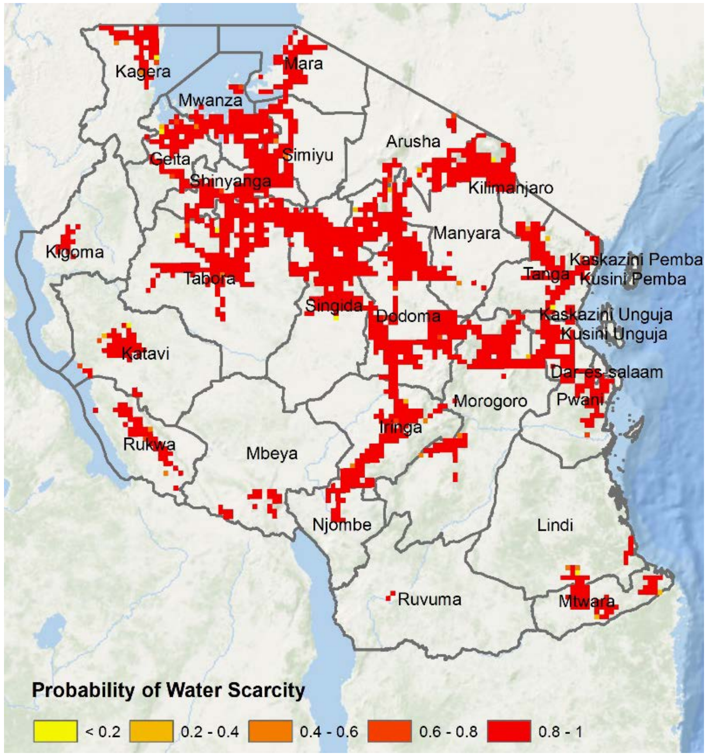
SMALL-SCALE IRRIGATION DEVELOPMENT POTENTIAL IN TANZANIA





Potential area

573,886 ha

Profits

1,310 million USD/yr

Number of beneficiaries

2 million people

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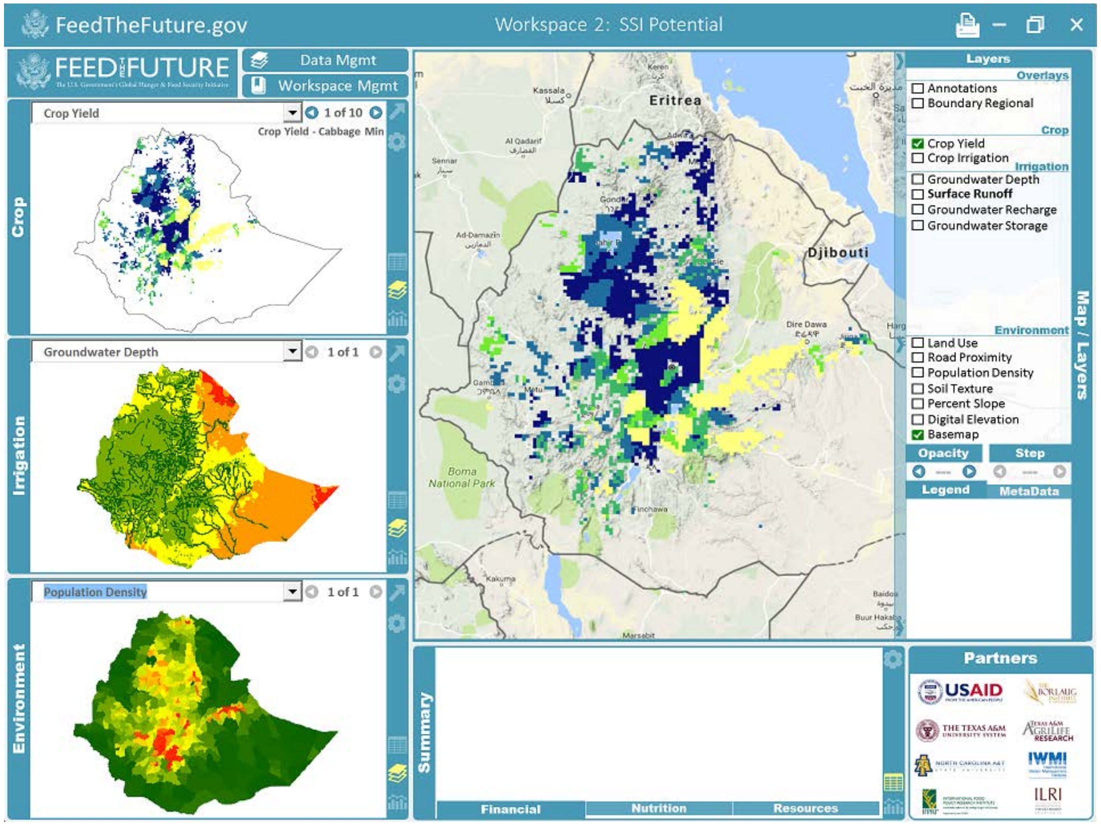
DEVELOPMENT OF DASHBOARD TO HARNESS THE POWER OF IDSS

- Alleviating end-users from being an expert in any specific models but to leverage from obtained results
- Planning and evaluation of SSI at multiple levels of scale
- Support analysis for expanding SSI and its impacts, and identification of strategic investment areas
- Targeted end-users include:
    - Farmers and farmer organizations
    - Agents/practitioners that provide education and outreach



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CONCLUDING REMARKS

- Ample land and water resources available in Ethiopia for SSI expansion,
- More than 0.8 million ha of land is economically and biophysically suitable for SSI expansion generating ~2.6 billion USD/year, and
- SSI development may pose widespread water scarcity.

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CAPACITY DEVELOPMENT WITH IDSS

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ILSSI APPROACH TO CAPACITY DEVELOPMENT

Continuous
- Seasonal or bi-annual
- Repeated and cumulative

Multiple levels
- Farm/Local
- National research institutes, university, planning

Methods
- IDSS – SWAT, APEX, FARMSIM - Decision support tools and analysis
- Survey
- Field/action research

Special subjects
- Gender
- FEAST
- Irrigated fodder, forages, including dairy cow health
- Irrigation scheduling and tools
- Conservation agriculture
- Microfinance for irrigation technologies

FARM/LOCAL TRAINEES – ALL COUNTRIES

Year	Producers	Civil servants	Private sector	Civil society	M/F
1	63	-	-	-	41/22
2	260	26	5	2	203/90
3	356	28	1	76	349/112
4	259	61	30	115	314/151
ALL	**938**	**115**	**36**	**193**	**907/375**

FARMER AND FIELD LEVEL

Subject	Target group(s)	Frequency	Countries
Water and soil management	Farmers, Extension	Each irrigation season	All
Irrigation scheduling	Farmers, Extension	Each irrigation season	Ethiopia, Ghana
Post-harvest handling and marketing	Farmers	Each irrigation season	Ghana
Farmer forums and exchanges – consolidate learning, build networks	Farmers	After each irrigation season	Ethiopia, Ghana
Conservation agriculture	Farmers, Extension	Start of irrigation season	All
Savings and credit trainings cooperatives	Farmers, Finance cooperative	Start of field trials	Ethiopia
Improved forage development, irrigation, dairy health	Farmers	Start of field trials and refresher trainings	All
Intercropping grasses, forage legumes under SSI, dairy cow management	Farmers, Extension, Subject experts	Start of field trials and refresher trainings	All

STUDENT RESEARCH/MENTORING IN FIELD STUDIES

- Graduate students (26) and Honor's Undergraduate students (10)
- Capacity development and mentoring:
  - Matched with home university faculty and IWMI researcher
  - Mentored through proposal, research design, field work, data collection, analysis, writing and presenting
- Financial support for field work, data collection, lab analysis
- Results:
  - 22 theses papers (as of September 2017)
  - 1 awarded outstanding thesis for MSc economics (Ethiopia)
  - 3 international conference papers accepted
  - 14 students to complete theses in final project year

CAPACITY BUILDING ON IRRIGATION-GENDER LINKAGES

- > 150 national experts with a focus on irrigation / gender participated in **gender and irrigation capacity building and knowledge exchange events** Ethiopia, Ghana, and Tanzania
- Resources from the workshops are available online
- Blog on WLE Thrive
- ILSSI Project Note, based on workshop discussions, identifies key concepts, opportunities, and constraints to Promoting Gender Equality in Irrigation and other publications
- Insights were used by WARIDI, a large integrated wat res man project in Tanzania for their gender strategy
- Insights were used by Ethiopia ATA in their work on ensuring gender-sensitivity of irrigation

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CAPACITY DEVELOPMENT FROM IDSS

- Graduate professional training in U.S. institutions (2-3 years)
- Extended training for graduate students and university faculty from project countries (90-day)
- Regular workshops (5-day)
- Institutionalization of IDSS (long term commitment)
- Continued support to stakeholders, graduate students, and CG systems (long term commitment)

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IDSS TRAINING: DEMAND DRIVEN AND SOURCE OF INPUT TO ILSSI

- Based on user demand, the content of the training have been updated and additional workshop packages have been included, e.g.
  - IDSS-clinic,
  - Advanced SWAT Training, and
  - Ethiopian Agricultural Transformation Agency (ATA) tailored IDSS training for irrigation planning
- The workshops were important venue to exchange data and receive feedbacks on SSI practices in the project countries

INSTITUTIONALIZING IDSS

- **Universities** included IDSS models in their curricula to train the next generation scientists and professionals, e.g.
  - Addis Ababa University and Bahir Dar University, Ethiopia
  - Sokoine University of Agriculture, University of Dar es Salaam, and Nelson Mandela African Institute of Science and Technology, Tanzania

- **Government Institutions** use IDSS for planning and evaluation of government initiatives, e.g.
  - Ethiopian Agricultural Transformation Agency (ATA),
  - Abay (Blue Nile) Basin Authority – Ethiopia,
  - Water Research Institute, Ghana

- **CGIAR centers, NGOs and Private sector** for environmental analysis and engineering design
  - CIAT, IWMI, Ethiopian Construction Works Design and Supervision Enterprise (ECWDSE) and various private agencies

ALL IDSS TRAINING

Ethiopia		Tanzania		Ghana		Total		Grand Total
M	F	M	F	M	F	M	F	
327	41	128	42	100	30	555	113	668

A total of 10 training workshops in Ethiopia, Ghana and Tanzania

OVERALL OUTPUTS

- More than 50 reports and scientific articles produced - individual model per site, integrated site, and country reports, as well as scientific articles on the three ILSSI countries.
- Data for all the reports were shared to partners including through the Texas A&M University Library Dataverse. The data include:
  - Model outputs from SWAT, APEX and FARMSIM, which aid planning of SSI adoption,
  - Map for potential land suitability for SSI, and
  - Groundwater depth, Digital Elevation Model (DEM), high resolution soil and land use.
- Tools and models
  - SWAT/APEX/FarmSIM models, and QSWAT and Win-APEX interfaces
  - SSI Dashboard SSI for planning and evaluation at multiple levels of scale
  - Land suitability mapping tool, and
  - Weather data bias correction tool

OVERALL OUTCOMES

- IDSS – helpful tool to identify strategies to mitigate gaps and constraints of SSI
- SSI and application of optimal fertilizer rates increased agricultural production and economic outcome
- The source of the water, and the most profitable technology were site specific
    - Solar pumps – economical and workable
    - Labor – a major limitation on using low cost technology
- Minimal to modest environmental impacts due to adoption of SSI
- Substantial potential for scaling SSI nationally, e.g. more than 4.5 million people benefited and more than 2.6 Billion USD/year generated using SSI in Ethiopia
- Key personnel trained with IDSS application, and IDSS institutionalized to educate the next generation scientists and professionals to scale up SSI
- A dashboard developed for planning and evaluation of SSI

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