FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

# Potential for upscaling small scale irrigation (IDSS) – constraints and opportunities

Yihun Dile, Texas A&M University

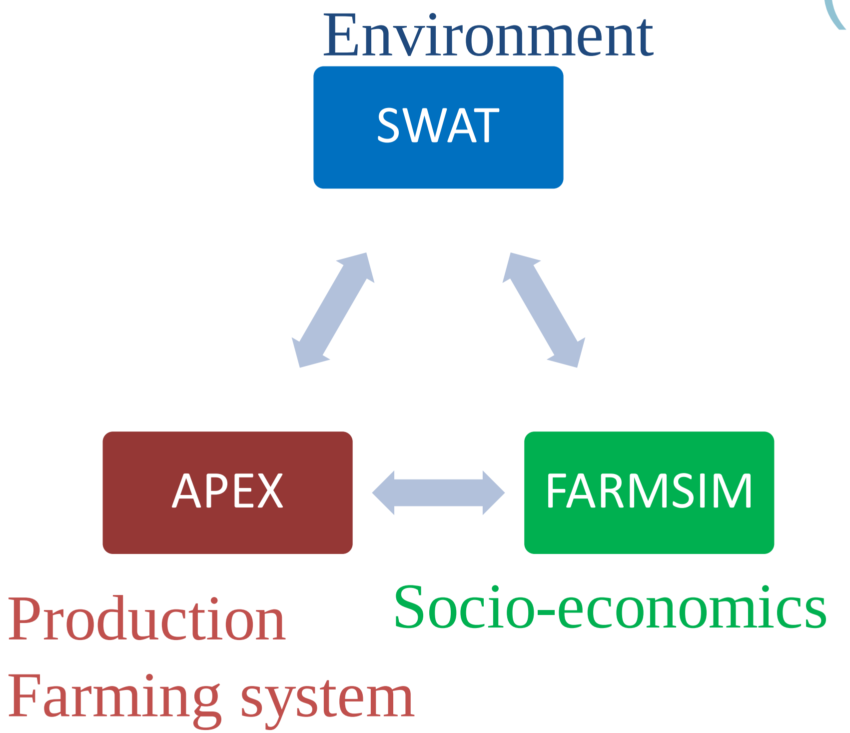
ILSSI Stakeholder Consultation – Dar es Salaam - 17th May 2018

USAID FROM THE AMERICAN PEOPLE | THE BORLAUG INSTITUTE for International Agriculture | TEXAS A&M AGRILIFE RESEARCH | THE TEXAS A&M UNIVERSITY SYSTEM | IFPRI INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE | IWMI International Water Management Institute | ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE | NORTH CAROLINA A&T STATE 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

# 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

# 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

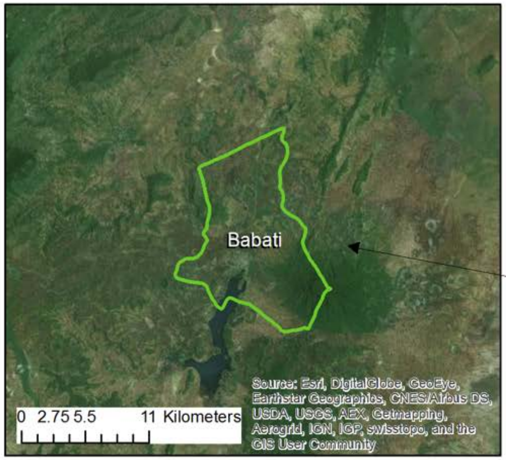
- Gaps and constraints analysis to SSI
  - Critical to identify mitigation strategies for the gaps and constraints

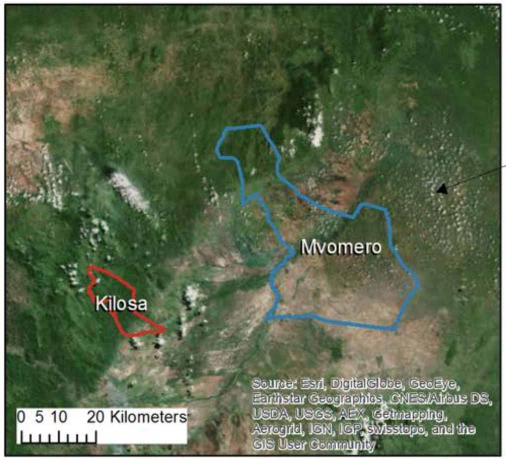
- Upscaling analysis
  - Uses data and lessons learned from the ex-post analysis
  - Useful to understand the potentials and impacts of SSI at national level

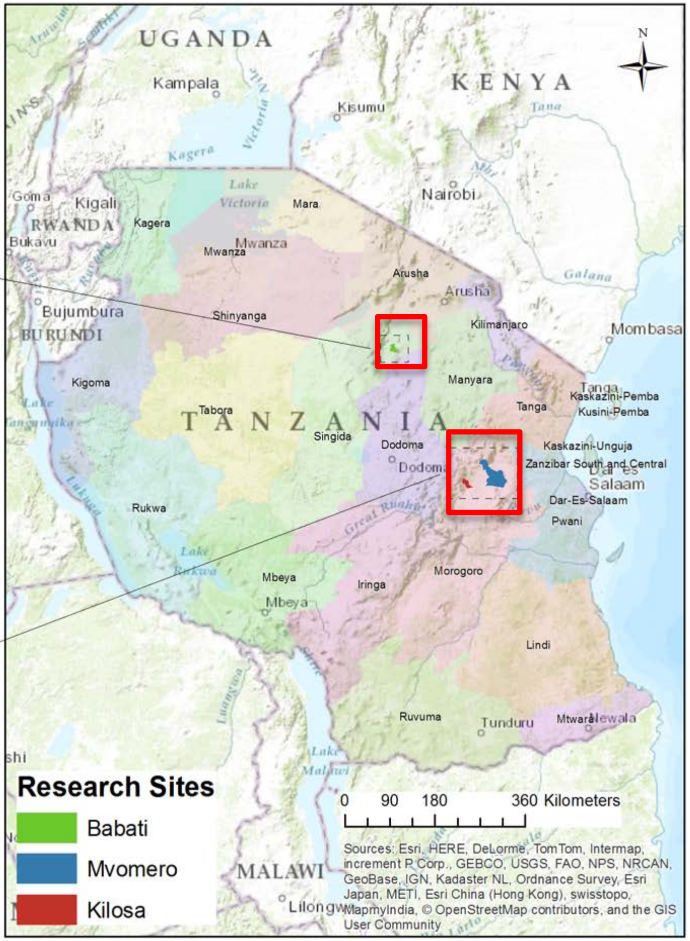
- Capacity building
  - IDSS models, and other demand-driven tools

FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

# ILSSI RESEARCH SITES IN TANZANIA

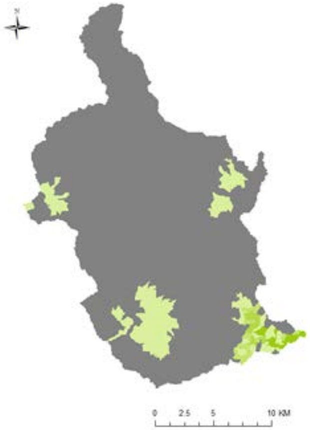


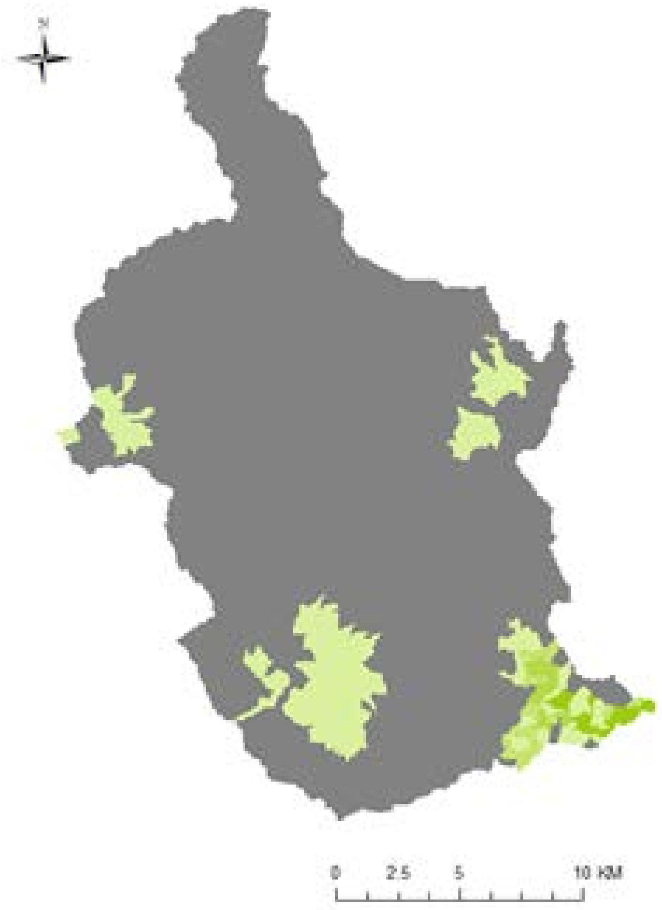

# EX-POST CASE STUDY:

# RUDEWA-KILOSA SITE




USAID FROM THE AMERICAN PEOPLE · THE BORLAUG INSTITUTE for International Agriculture · TEXAS A&M AGRILIFE RESEARCH · THE TEXAS A&M UNIVERSITY SYSTEM · IFPRI INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE sustainable solutions for ending hunger and poverty Supported by the CGIAR · IWMI International Water Management Institute · ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE · NORTH CAROLINA A&T STATE UNIVERSITY

# LAND SUITABILITY FOR IRRIGATION




- A large part of the watershed land use is either forest or bushland
- Major rainfed crops were maize, and rice.
- Dry season irrigated crops were tomato and eggplant.
- Irrigation was implemented on ag. land, and part of the pasture land for tomato and fodder production (ca. ~2%)
- Streamflow was used for irrigation

# RESOURCE ASSESSMENT AT WATERSHED SCALE

- Average annual rainfall = 680 mm (260 million $m^3$)

  → groundwater recharge
  (~30 million $m^3$ over the watershed area of 387 $km^2$)

  → surface runoff
  (~22 million $m^3$ over the watershed)

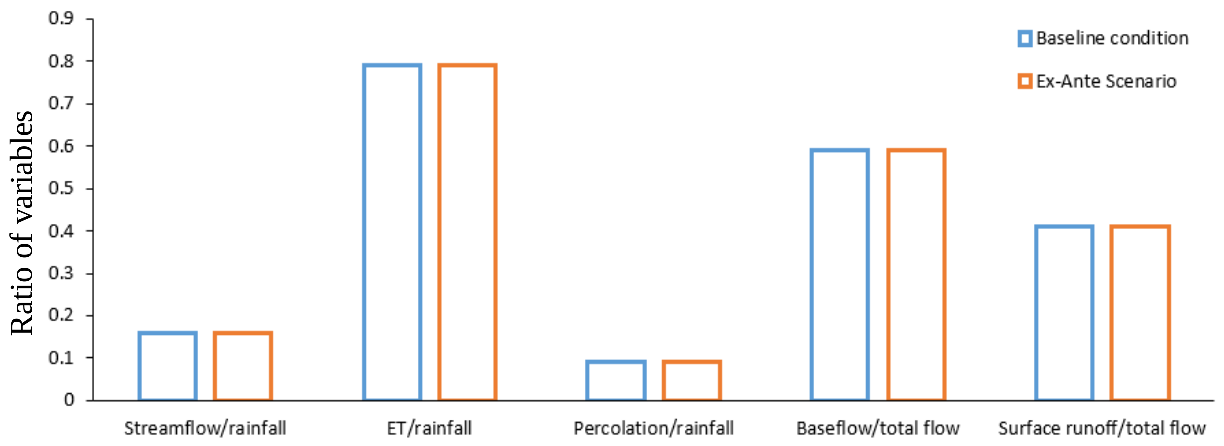
- Amount of water required for dry season irrigation = 958,878 $m^3$

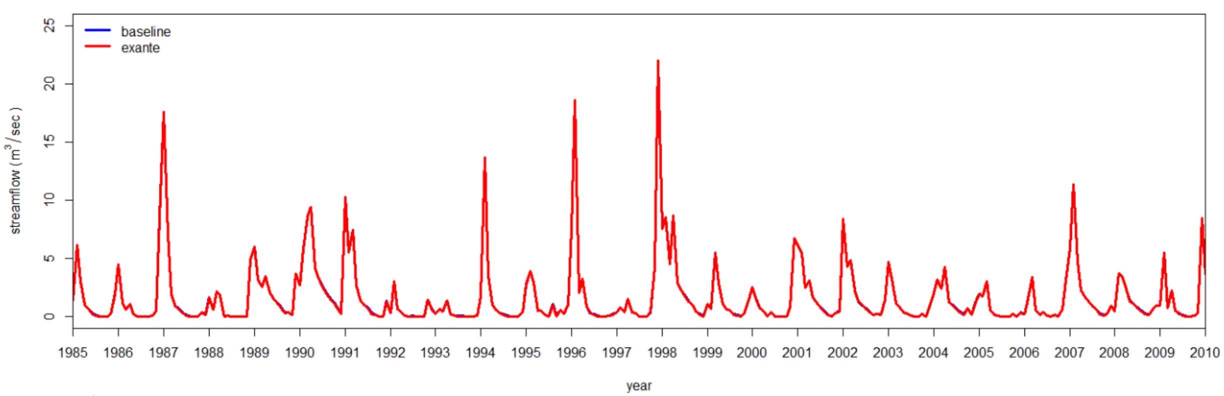
  → ~<1% of the **streamflow leaving the watershed**

- The streamflow diversion can support irrigation for vegetable and fodder production in a sustainable manner in the Kilosa watershed.

FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

# IMPACTS OF SSI AT THE WATERSHED SCALE

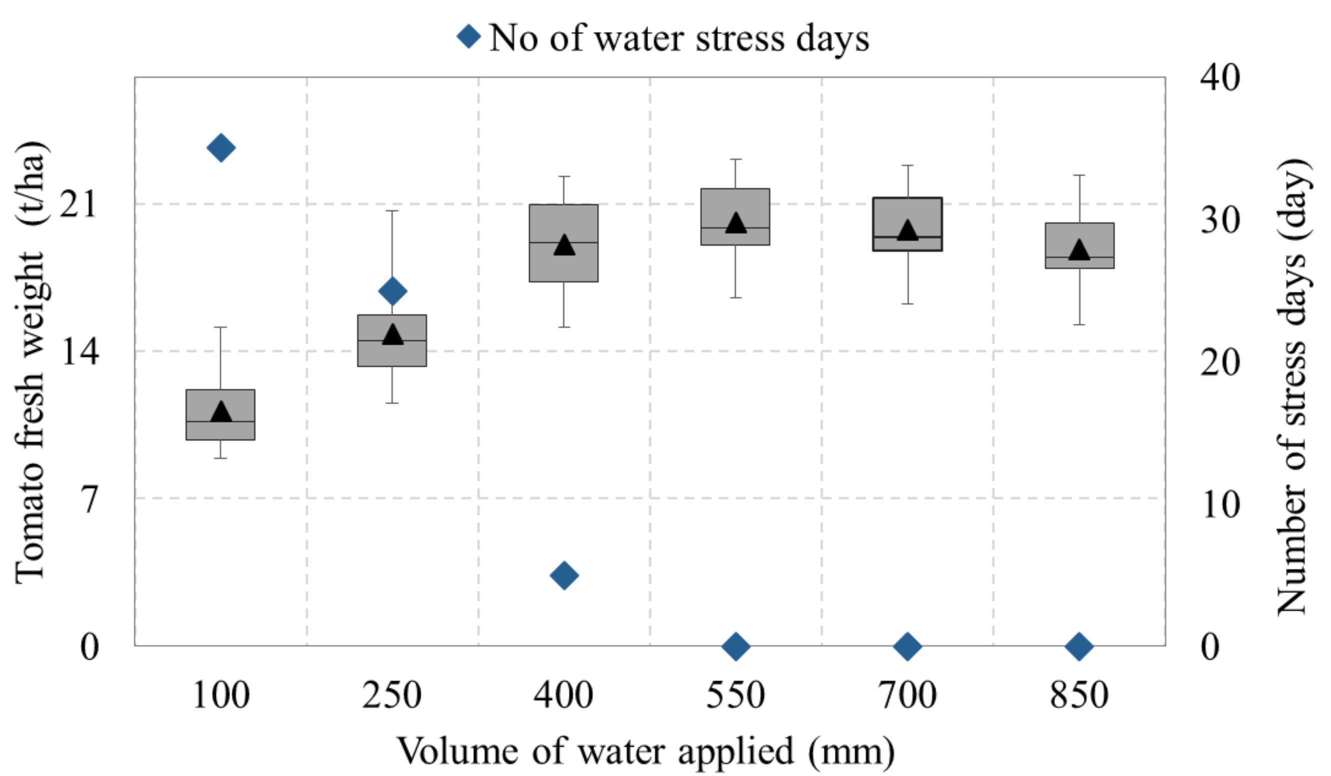



USAID FROM THE AMERICAN PEOPLE · THE BORLAUG INSTITUTE for International Agriculture · TEXAS A&M AGRILIFE RESEARCH · THE TEXAS A&M UNIVERSITY SYSTEM · IFPRI INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE · IWMI International Water Management Institute · ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE · NORTH CAROLINA A&T STATE UNIVERSITY

# WATER USE FUNCTION OF TOMATO

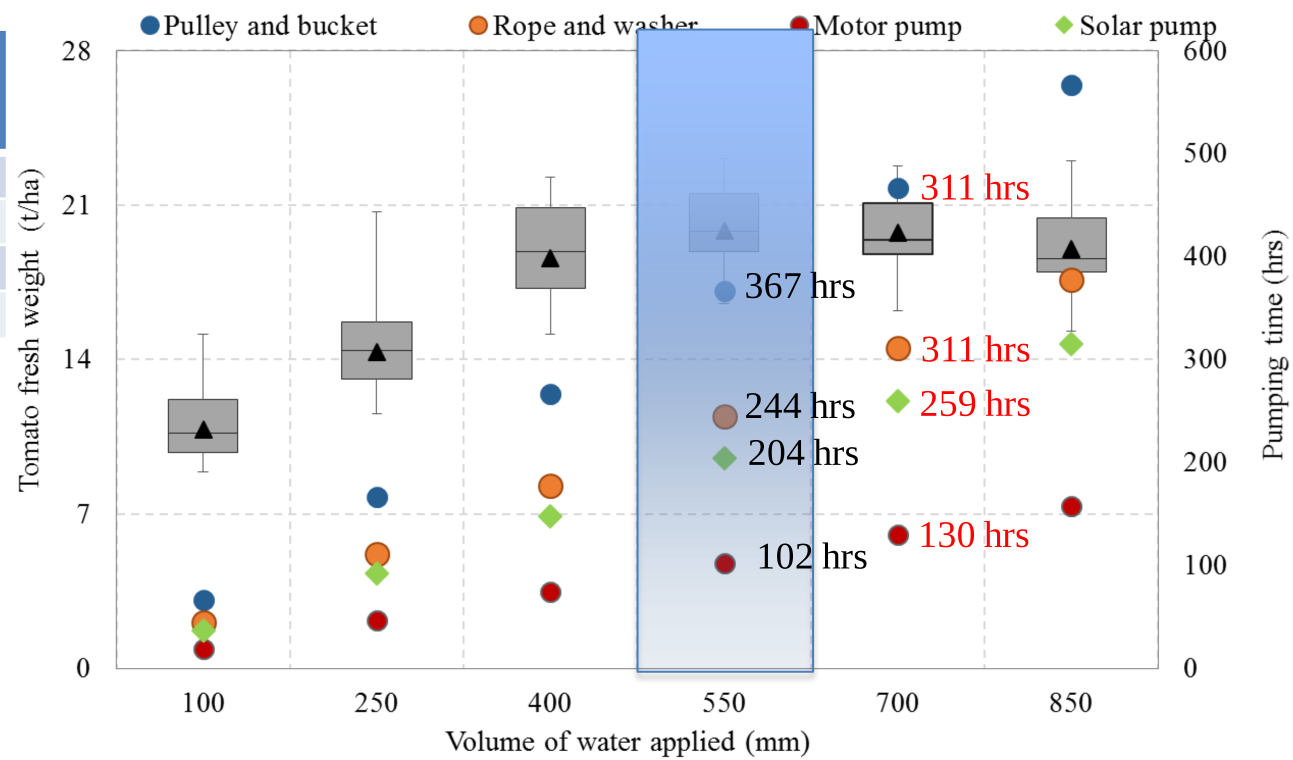
| Season total (mm) | Application rate (mm/2-day) |
|---|---|
| 100 | 1.54 |
| 250 | 3.85 |
| 400 | 6.15 |
| 550 | 8.46 |
| 700 | 10.77 |
| 850 | 13.08 |




- Average tomato yield ranges b/n 10-20 ton/ha depending on the irrigation amount
- Optimal water to maximize tomato yield is 550 mm/year

# WATER USE FUNCTION AND PUMPING TIME OF TOMATO

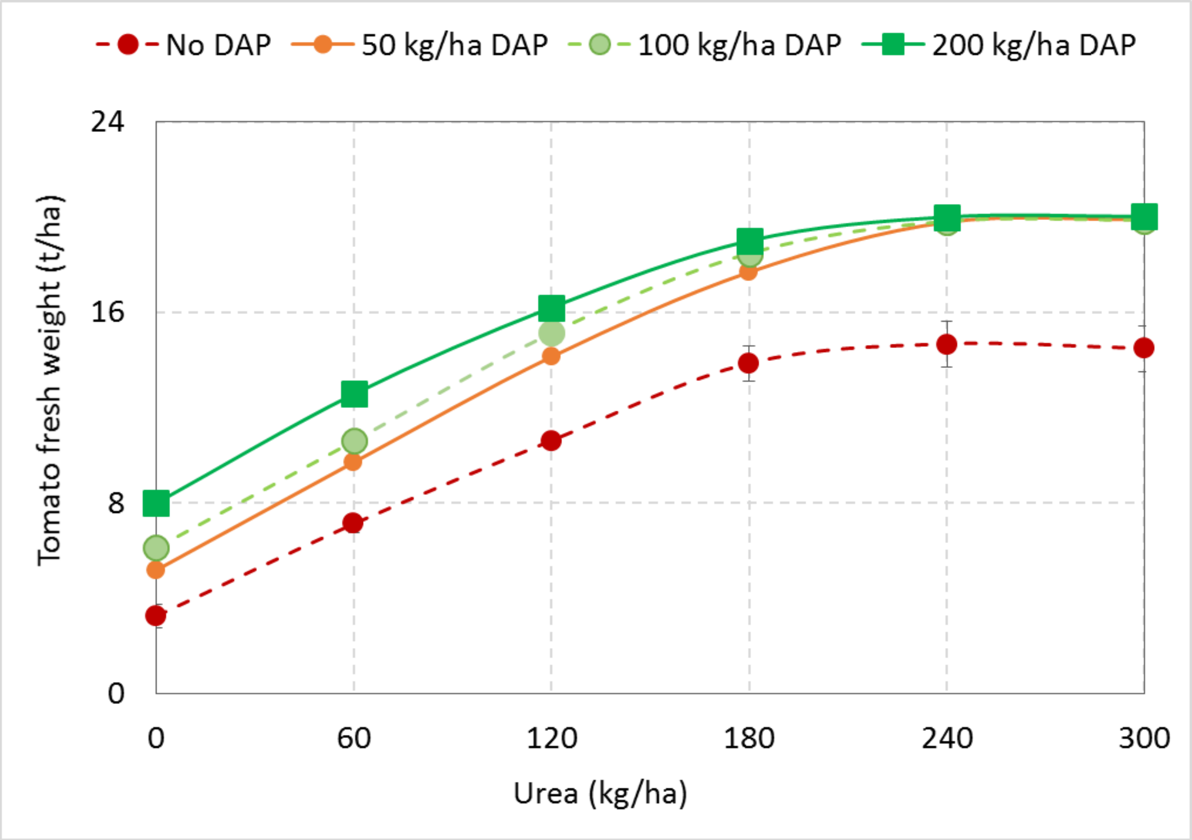
| Technology | Pumping capacity (l/min) |
|---|---|
| Pulley/bucket | 10 |
| Rope and washer pump | 15 |
| Motor pump | 36 |
| Solar pump | 18 |




Over-irrigation:

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

# FERTILIZER USE EFFICIENCY OF TOMATO




- Optimal fertilizer use is at 240 kg/ha Urea with 50 kg/ha DAP,
- Farmers' practice is far lower and of different proportional rates.

# ECONOMIC AND NUTRITION IMPACTS

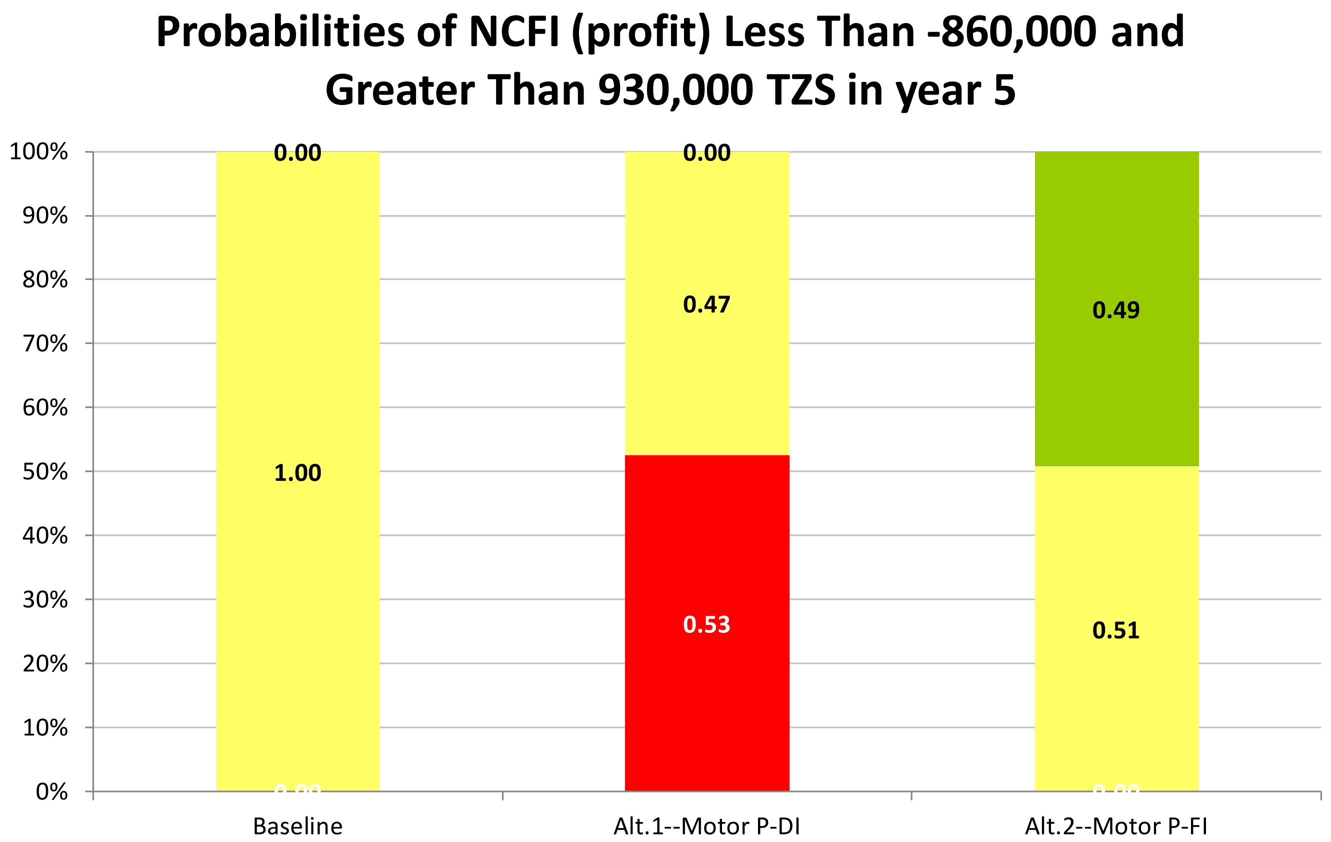
| | Min req. | Baseline | Alt. 1 (MP-DI) | Alt. 2 (MP-FI) |
|---|---|---|---|---|
| <u>Economics</u> | | Averages values in TZS /family in year 5 | | |
| Net present value | | 5,218,217 | 3,858,429 | 16,479,114 |
| Avg. net profit | | 112,537 | -860,005 | 931,536 |
| % change profit: Alt./Baseline | | | **-864%** | **728%** |
| Benefit-Cost Ratio: Alt/Baseline | | | **-0.6** | **1.7** |
| <u>Nutrition</u>: | Min req. | Averages daily nutrients in year 5 | | |
| Energy (calories/AE) | 1750 | 3,780 | 3,785 | 4,129 |
| Proteins (grs/AE) | 41.2 | 77.0 | 77.3 | 94.0 |
| Fat (grs/AE) | 39 | **43.1** | **43.5** | **45.9** |
| Calcium (grs/AE) | 1 | **0.12** | **0.14** | **0.27** |
| Iron (grs/AE) | 0.009 | 0.02 | 0.02 | 0.03 |
| Vitamin A (grs/AE) | 0.0006 | **0.00028** | 0.0009 | 0.003 |

Observation: the fusarium wilt disease caused major drop in yields in drip irrigation scenario which led to low production and income compared to furrow irrigation and baseline in Kilosa

<u>Note:</u>
Baseline: No or minimal irrigation;
Alt.1--MP-DI: Motor pump used with **Drip irrigation** in optimally irrigated systems
Alt.2--MP-FI: Motor pump used with **Furrow irrigation** in optimally irrigated systems

AE = Adult Equivalent
For economic variables: numbers in green show increase while those in red show decrease
For nutrition variables: numbers in red show quantities of nutrients intake < minimum required

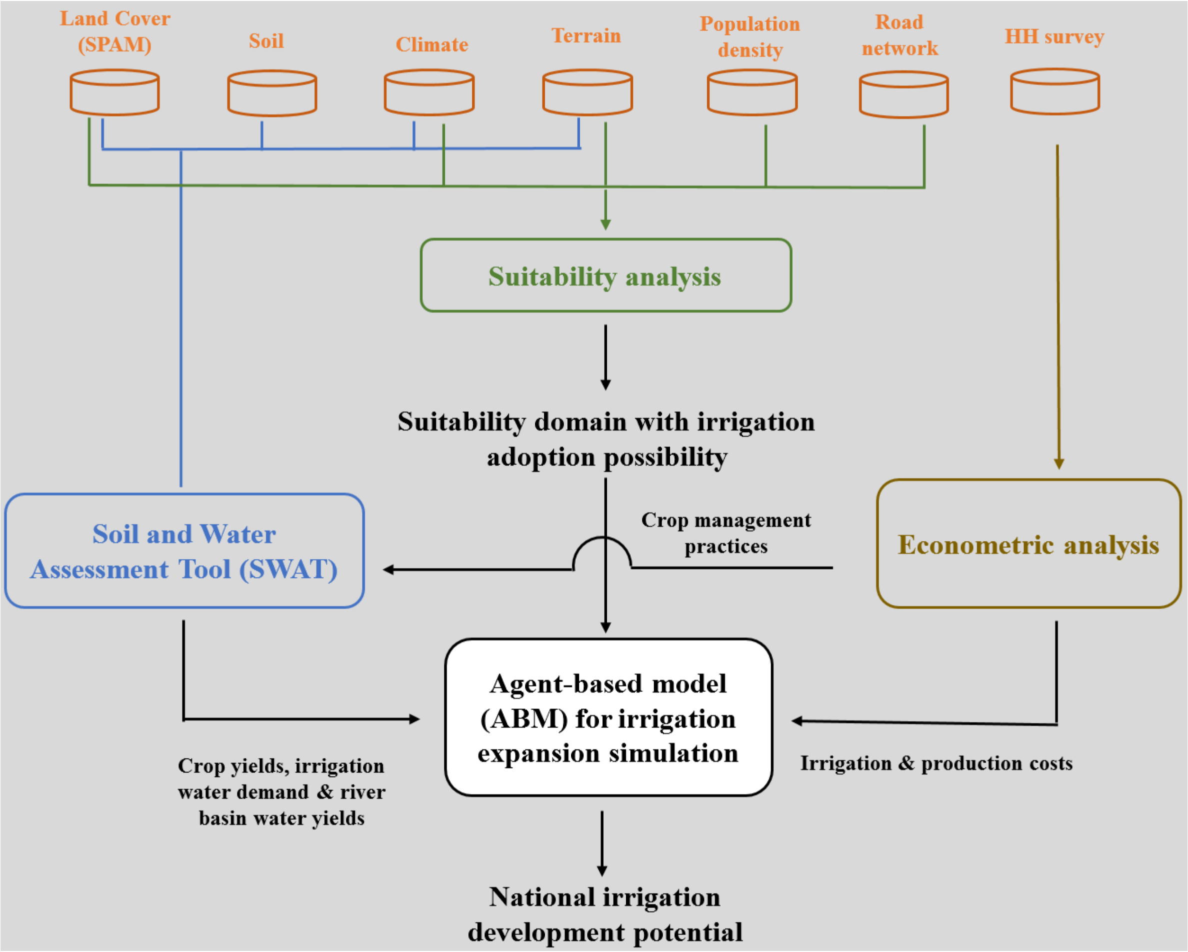
# ECONOMIC AND NUTRITION IMPACTS



# PLANNING AND EVALUATION OF SMALL SCALE IRRIGATION AT NATIONAL SCALE

- **ILSSI field research** showed SSI improves agricultural production, and household income & nutrition without compromising environmental sustainability. 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

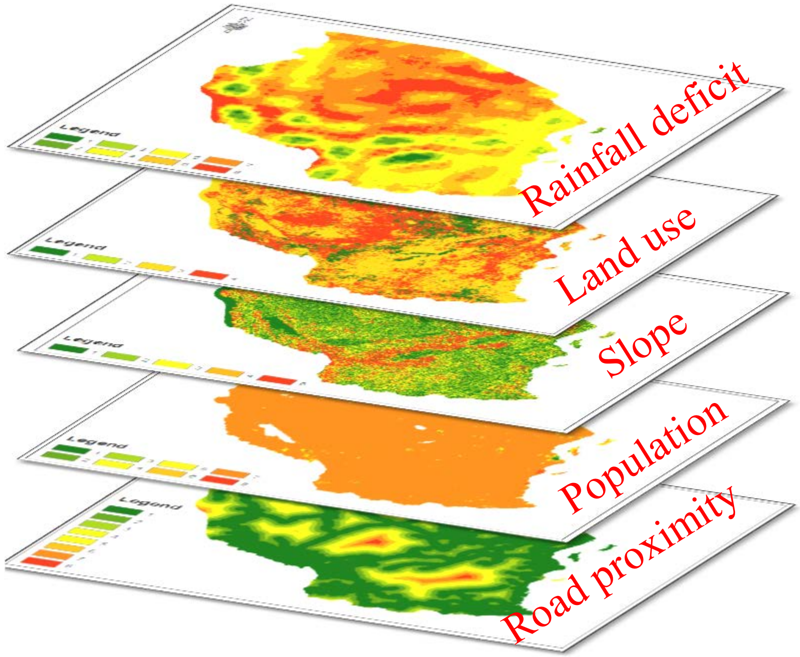
- Spatial Production Allocation Model (SPAM) to disaggregate the land use data into different crop types for SWAT,
- SWAT to estimate spatially explicit water availability, water consumption, crop yields, and environmental impacts, and
- ABM to estimate economic-cost benefit and water balance.

# AGENT-BASED MODEL (ABM) OUTPUT

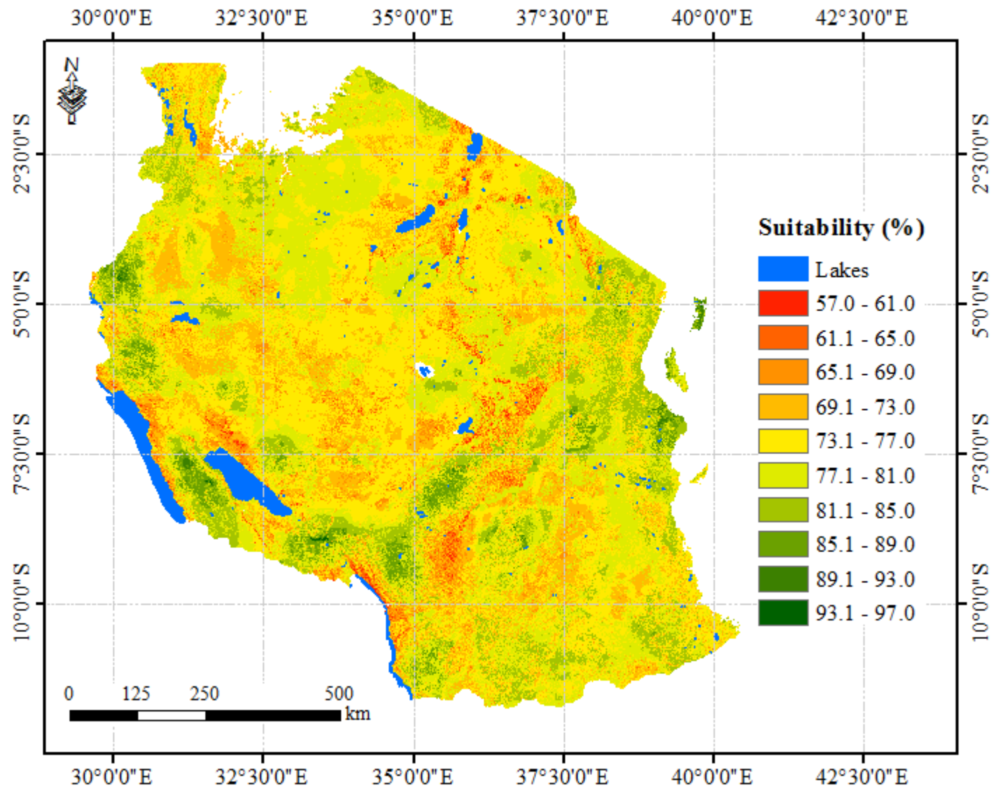
- Adoption probability and area of SSI in each geographic domain across the country,
- Environmental risk of water scarcity due to the adoption,
- Economic benefit for irrigators from the adoption, and
- Number of beneficiary population.

FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

# SUITABLE IRRIGABLE LAND




Overlay analysis

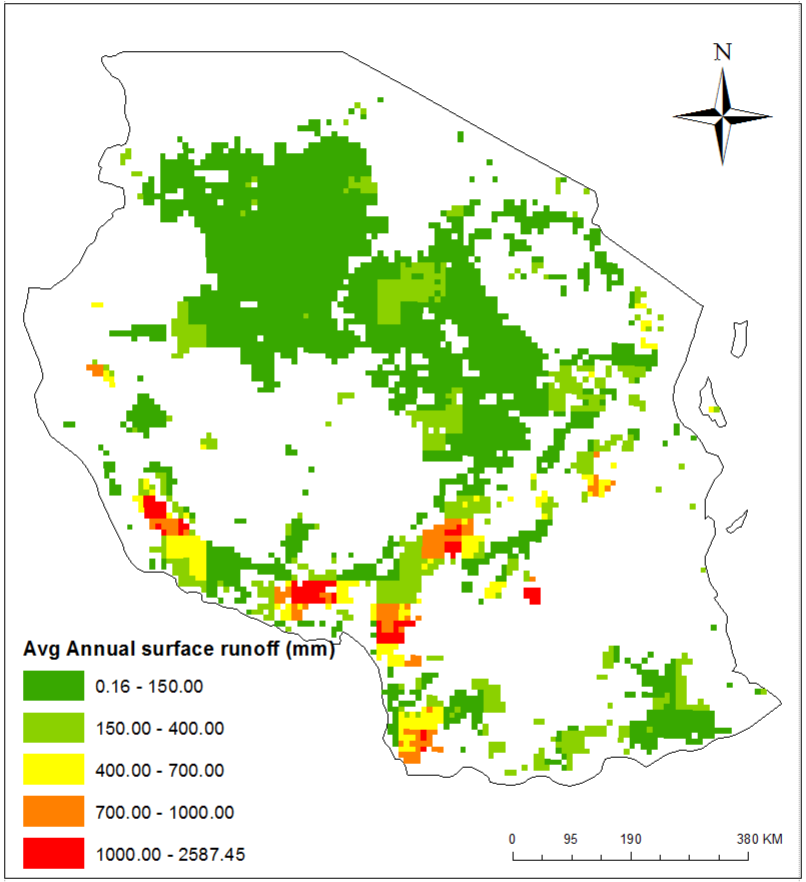


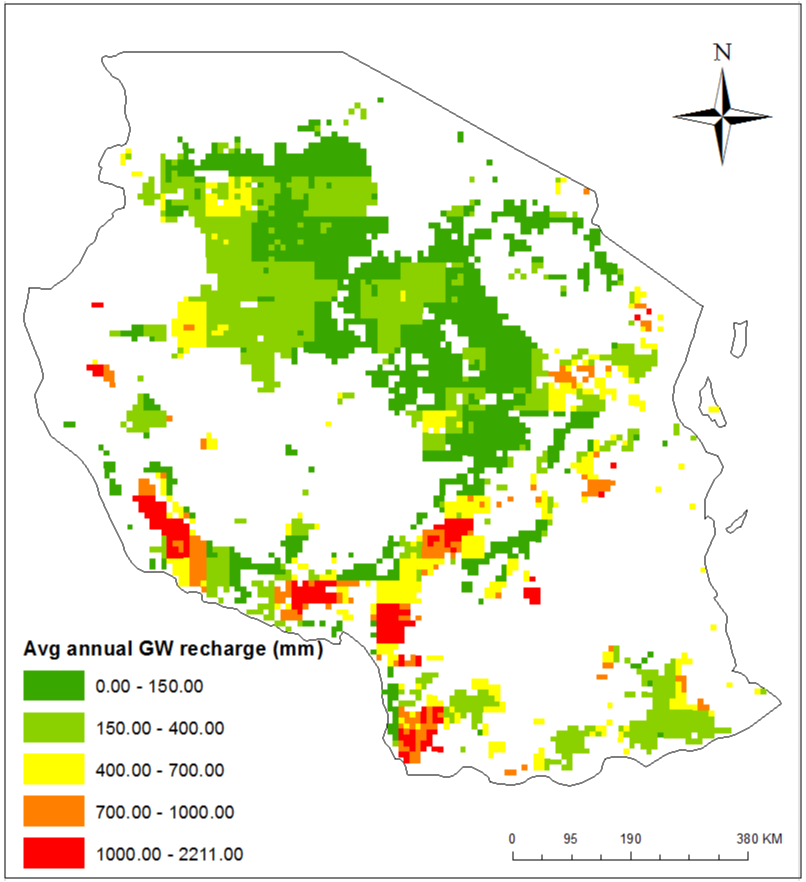

322,000 $km^2$ land is suitable at 85% level of suitability

USAID FROM THE AMERICAN PEOPLE | THE BORLAUG INSTITUTE | TEXAS A&M AGRILIFE RESEARCH | THE TEXAS A&M UNIVERSITY SYSTEM | IFPRI INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE | IWMI International Water Management Institute | ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE | NORTH CAROLINA A&T STATE UNIVERSITY

FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

# WATER RESOURCES POTENTIAL

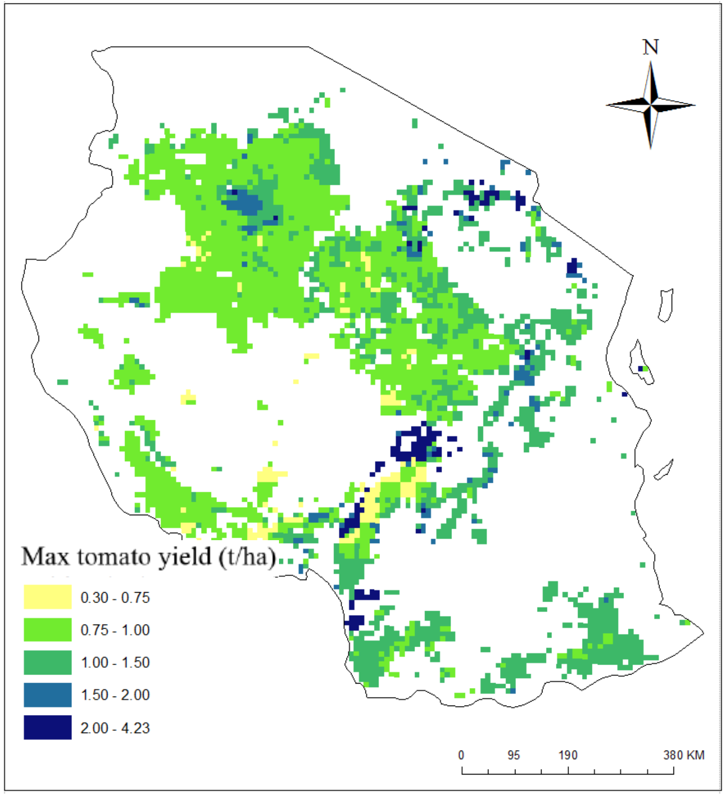


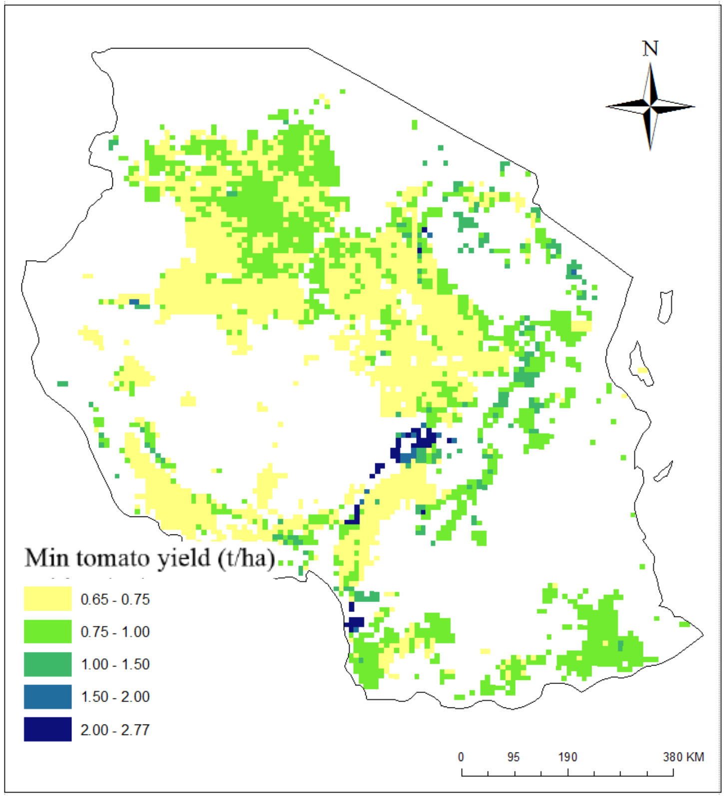




- A large amount of water resources exists in the southeastern and central part of the country.

USAID FROM THE AMERICAN PEOPLE · THE BORLAUG INSTITUTE for International Agriculture · TEXAS A&M AGRILIFE RESEARCH · THE TEXAS A&M UNIVERSITY SYSTEM · IFPRI INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE sustainable solutions for ending hunger and poverty Supported by the CGIAR · IWMI International Water Management Institute · ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE · NORTH CAROLINA A&T STATE UNIVERSITY

# POTENTIAL FOR VEGETABLE PRODUCTION

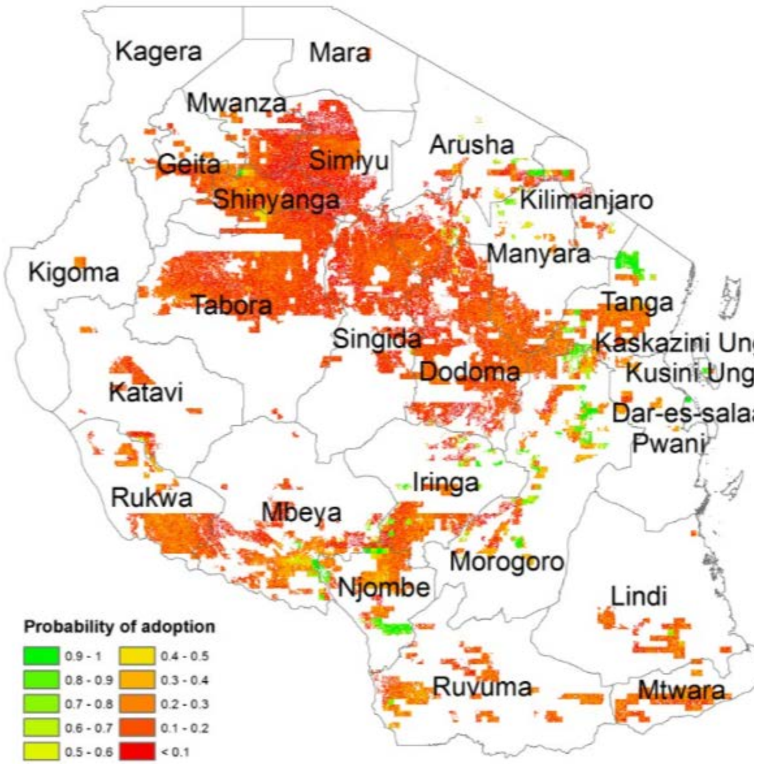


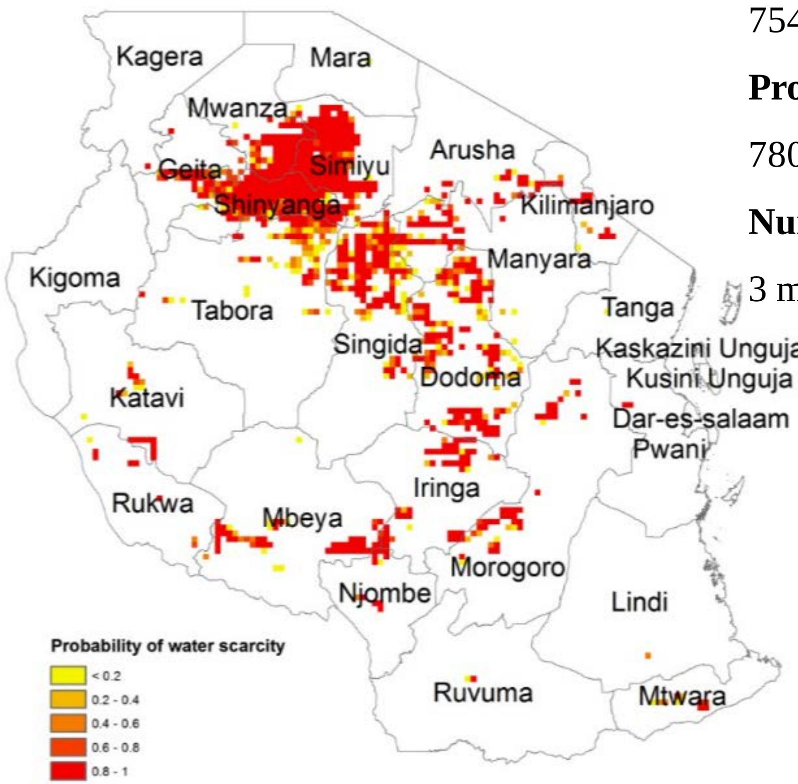




- High potential for SSI is located in the central part of the country.

FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

# PROBABILITY OF IRRIGATION ADOPTION AND WATER SCARCITY




**Potential area**

754,454 ha

**Profits**

780 million USD/yr

**Number of beneficiaries**

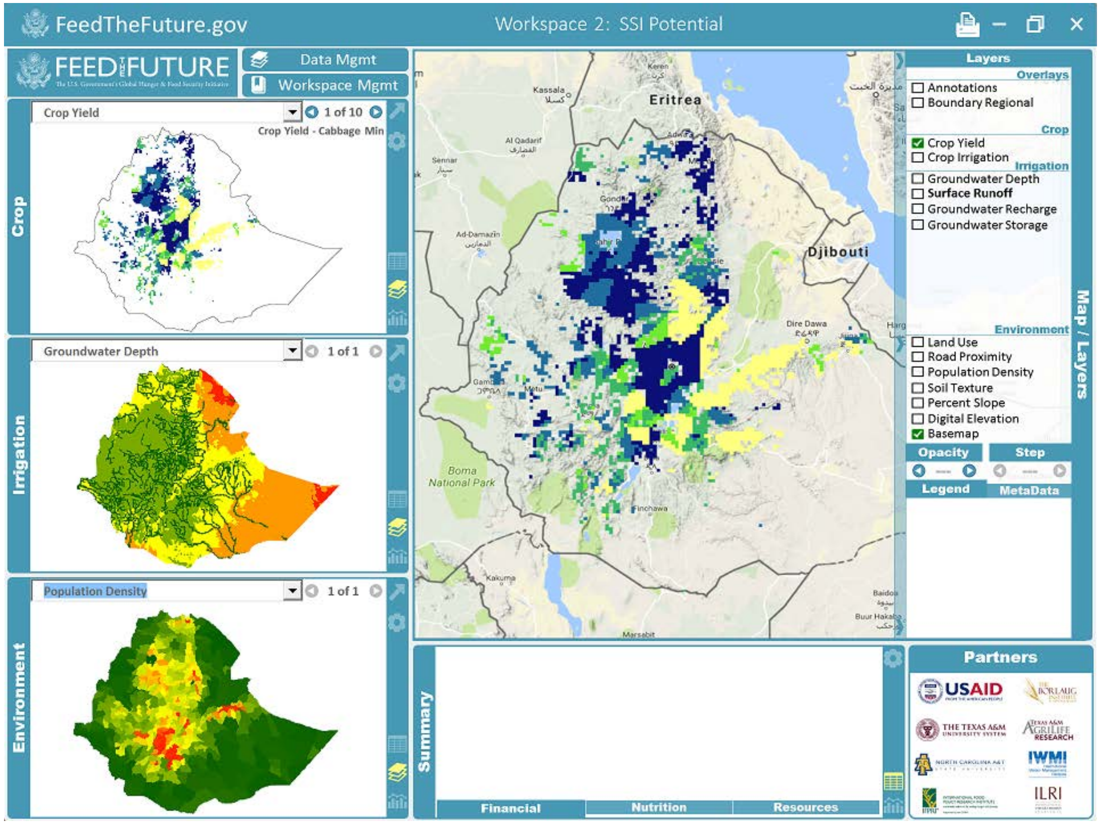
3 million people

- a high adoption probability strip stretching from the border of Arusha/ Kilimanjaro region to Mbeya region.

USAID FROM THE AMERICAN PEOPLE · THE BORLAUG INSTITUTE for International Agriculture · TEXAS A&M AGRILIFE RESEARCH · THE TEXAS A&M UNIVERSITY SYSTEM · IFPRI INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE · IWMI International Water Management Institute · ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE · NORTH CAROLINA A&T STATE UNIVERSITY

# 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
- Targeted end-users include:
  - Farmers and farmer organizations
  - Agents/practitioners that provide education and outreach



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

# CAPACITY DEVELOPMENT FROM IDSS

- Regular workshops (5 days) – 120M + 42F
- Extended training for personnel from project countries (60-90 days)
- Graduate professional training in U.S. institutions (2-3 years)
- Continued support to stakeholders, graduate students, and CG systems (long term commitment)
- Institutionalization of IDSS (long term commitment)


USAID FROM THE AMERICAN PEOPLE · THE BORLAUG INSTITUTE for International Agriculture · TEXAS A&M AGRILIFE RESEARCH · THE TEXAS A&M UNIVERSITY SYSTEM · IFPRI INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

# 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
  - Interest to support UDES's Regional MSc program at Department of Water Resources Engineering

- The workshops were important venue to exchange data and receive feedbacks on SSI practices in the project countries.

USAID FROM THE AMERICAN PEOPLE · THE BORLAUG INSTITUTE for International Agriculture · TEXAS A&M AGRILIFE RESEARCH · THE TEXAS A&M UNIVERSITY SYSTEM · IFPRI INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE · IWMI International Water Management Institute · ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE · NORTH CAROLINA A&T STATE UNIVERSITY

# 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

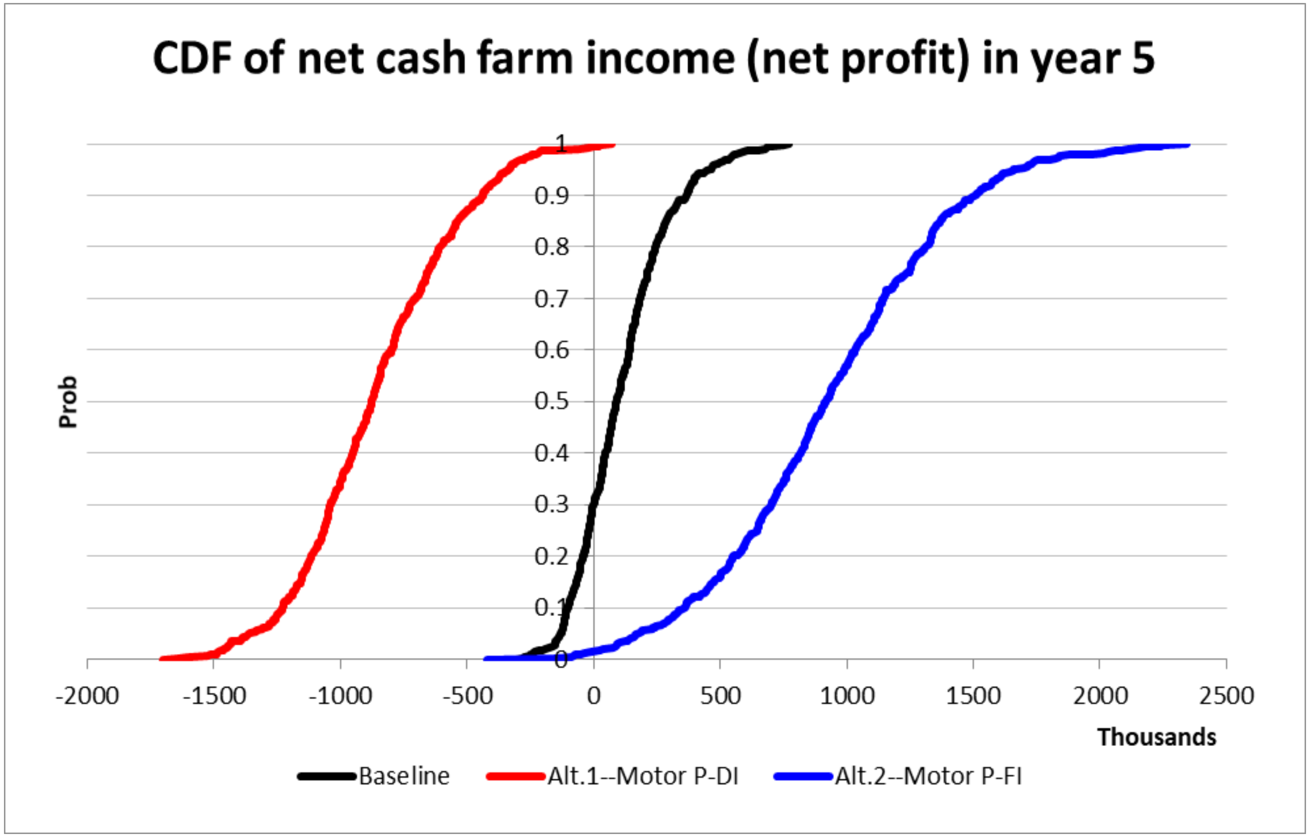
# OVERALL OUTCOMES

- 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 **3 million people** could be benefited and more than **780 million USD/year** generated using SSI in Tanzania
- Key personnel trained with IDSS application, and IDSS institutionalized to educate the next generation scientists and professionals to scale up SSI

FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

# ECONOMIC AND NUTRITION IMPACTS




Note:
Fusarium wild disease led to losses in tomatoes yields that caused the loss in profit for Alt. 1 scenario involving drip irrigation

FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

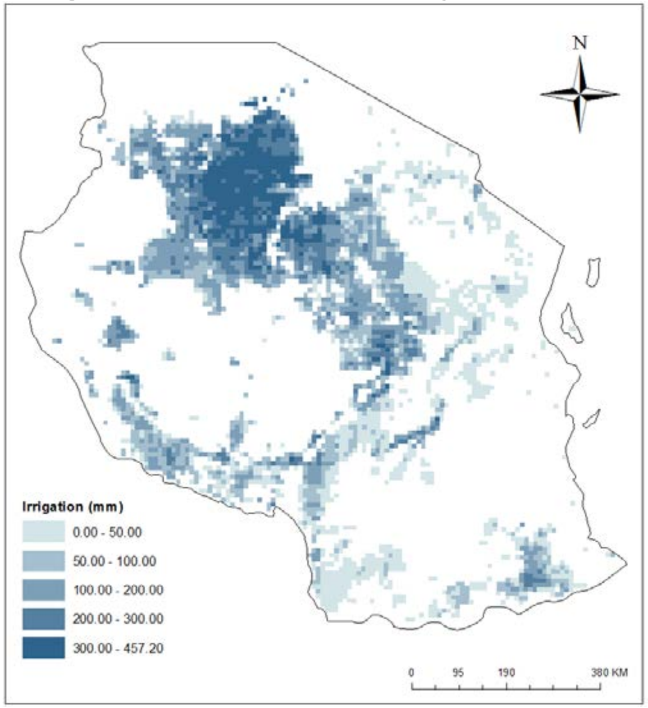
# PLANNING AND EVALUATION OF SMALL SCALE IRRIGATION AT NATIONAL SCALE

Farms to Nations using models

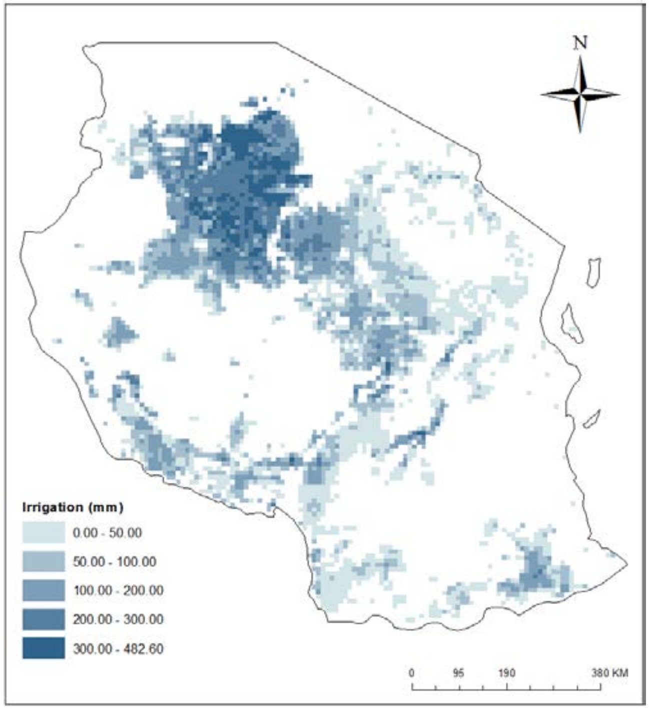

USAID FROM THE AMERICAN PEOPLE | THE BORLAUG INSTITUTE for International Agriculture | TEXAS A&M AGRILIFE RESEARCH | THE TEXAS A&M UNIVERSITY SYSTEM | IFPRI INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE sustainable solutions for ending hunger and poverty Supported by the CGIAR | IWMI International Water Management Institute | ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE | NORTH CAROLINA A&T STATE UNIVERSITY

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

Irrigation related to Max yield (mm)




Irrigation related to Min yield (mm)




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