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

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Photo: Desalegne Tadege/IWMI
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
ILSSI RESEARCH SITES IN ETHIOPIA

EX-POST CASE STUDY:

ROBIT SITE
~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.
RESOURCE ASSESSMENT AT WATERSHED SCALE: ROBIT CASE, ETHIOPIA

- Average annual rainfall = 1,400 mm
  - groundwater recharge = 280 mm
    (~4,000,000 m³ over the watershed)
  - surface runoff = 520 mm
    (~7,000,000 m³ over the watershed)

- Amount of water required for dry season irrigation for tomato = 1,500,000 m³
  - ~40% of the groundwater recharge

- At the watershed scale, groundwater recharge can support irrigation for vegetables (in suitable areas) in a sustainable manner.
estimating the water resource potential to determine irrigation potential at watershed scale.
IMPACTS OF SSI AT THE WATERSHED SCALE

The diagram shows the ratio of various variables over time. It compares baseline conditions with ex-ante scenarios. The variables include:
- Stressflow/rainfall
- ET/rainfall
- Percolation/rainfall
- Deep recharge/rainfall
- Baseflow/total flow
- Surface runoff/total flow

The graph indicates trends and changes in these variables from 1995 to 2013, with a focus on streamflow (m³/sec) over the years.
WATER USE FUNCTION OF TOMATO

Average tomato yield ranges between 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.
### Over-irrigation:
- Costs more time and money
- A threat to irrigation expansion

<table>
<thead>
<tr>
<th>Technology</th>
<th>Pumping capacity (l/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rope with pulley &amp; bucket</td>
<td>10</td>
</tr>
<tr>
<td>Rope &amp; washer pump</td>
<td>15</td>
</tr>
<tr>
<td>Solar pump</td>
<td>16</td>
</tr>
<tr>
<td>Motor pump</td>
<td>36</td>
</tr>
</tbody>
</table>

![Graph showing water use function and pumping time of tomato](image)

- **Rope with pulley and bucket**: 10 mm, 267 hrs, 178 t/ha, 167 mm
- **Rope and washer pump**: 15 mm, 367 hrs, 244 t/ha, 229 mm
- **Motor pump**: 16 mm, 102 hrs, 74 t/ha, 74 mm
- **Solar pump**: 36 mm
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.
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
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 potential investment areas? and
- What are the environmental and socio-economic impacts?

Upscaling instrumental to address these and other questions.
UPSCALING ANALYSIS FRAMEWORK

- Land Cover (SPAM)
- Soil
- Climate
- Terrain
- Population density
- Road network
- HH survey

Suitability analysis

Suitability domain with irrigation adoption possibility

Soil and Water Assessment Tool (SWAT)

Crop management practices

Agent-based model (ABM) for irrigation expansion simulation

Crop yields, irrigation water demand & river basin water yields

Irrigation & production costs

National irrigation development potential

Econometric analysis
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
A significant amount of surface runoff and groundwater recharge available across the country to expand SSI.
A large part of the country, productive for producing vegetables and fodder during the dry season.
High adoption probability for SSI at Lake Tana and Ethiopian Great Rift Valley areas
- SSI development may pose widespread water scarcity
ESTIMATED SMALL-SCALE IRRIGATION ADOPTION POTENTIAL IN ETHIOPIA

<table>
<thead>
<tr>
<th></th>
<th>Vegetables &amp; pulses (ha)</th>
<th>Fodder (ha)</th>
<th>Total (ha)</th>
<th>Profits (Million USD/yr)</th>
<th>Number of beneficiaries (Thousand People)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addis Ababa</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Affar</td>
<td>51</td>
<td>14</td>
<td>66</td>
<td>0.1</td>
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<td>Amhara</td>
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<td>141,047</td>
<td>455,440</td>
<td>1,066</td>
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<td>Benishangul-Gumuz</td>
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<td>16,120</td>
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<td>2.3</td>
<td>3</td>
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<tr>
<td>Harari</td>
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<td>46</td>
<td>0.2</td>
<td>0.3</td>
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<td>SNNP</td>
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<td>670</td>
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<td>Tigray</td>
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<td>6,596</td>
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<tr>
<td>Oromiya</td>
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<td>433,619</td>
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<tr>
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<td>219</td>
<td>245</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>675,642</strong></td>
<td><strong>361,021</strong></td>
<td><strong>1,036,663</strong></td>
<td><strong>2,593</strong></td>
<td><strong>5,874</strong></td>
</tr>
</tbody>
</table>

- ~1 million ha of land, **economically and biophysically** suitable for SSI development in Ethiopia,
- A net income of ~2.6 billion USD/year from the SSI adoption,
- Amhara, Oromia and SNNPR having the highest SSI adoption potential.
DEVELOPMENT OF DASHBOARD TO HARNES 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
CAPACITY DEVELOPMENT FROM IDSS

- Regular workshops (5-day) – 327M + 41F = 368
- Extended training for experts from project countries (90-day)
- Graduate professional training in U.S. institutions (2-3 years)
- Institutionalization of IDSS (long term commitment)
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.
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 could benefit generating more than 250 million USD/year 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
THANK YOU
Drip irrigation improves crop water productivity, and reduces water loss.
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.
PLANNING AND EVALUATION OF SMALL SCALE IRRIGATION AT NATIONAL SCALE

Farms to Nations using models
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.
A large part of the country, productive for producing vegetables and fodder during the dry season.
A large part of the country, productive for producing vegetables and fodder during the dry season.
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** are interested to use IDSS for planning and evaluation of government initiatives, e.g.
  - Ethiopian Agricultural Transformation Agency (ATA),
  - Abay (Blue Nile) Basin Authority – Ethiopia,

- **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