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

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Photo: Nana Kofi Acquah
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 GHANA

EX-POST CASE STUDY:

ZANLERIGU SITE
RESOURCE ASSESSMENT AT WATERSHED SCALE

- Average annual rainfall = 970 mm (8.15 million m³)
  - Groundwater recharge
    - ~1.1 million m³ over the watershed area of 840 ha
  - Surface runoff
    - ~0.65 million m³ over the watershed

- Amount of water required for dry season irrigation for tomato = 1.4 million m³
  - ~125% of the groundwater recharge

- Groundwater recharge alone may not support irrigation for vegetables and fodder production in a sustainable manner.
IMPACTS OF SSI AT THE WATERSHED SCALE

Ratio of variables

Streamflow/rainfall  | ET/rainfall  | Percolation/rainfall | Deep recharge/rainfall | Baseflow/total flow | Surface runoff/total flow

Baseline condition | Ex-Post Scenario

Graph showing changes in various ratios over time.
WATER USE FUNCTION OF TOMATO

No of water stress days

Volume of water applied (mm)

Tomato fresh weight (t/ha)

Number of stress days (day)
FERTILIZER USE EFFICIENCY OF TOMATO

![Graph showing fertilizer use efficiency of tomato]

- **No DAP**
- **50 kg/ha DAP**
- **100 kg/ha DAP**
- **200 kg/ha DAP**

Y-axis: Tomato fresh weight (t/ha)

X-axis: Urea (kg/ha)
## ECONOMIC AND NUTRITIONAL RESULTS

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Alt. 1--WaterCan</th>
<th>Alt. 2--Diesel-P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net present value</td>
<td>17,859</td>
<td>38,107</td>
<td>46,674</td>
</tr>
<tr>
<td>Avg. net profit</td>
<td>824</td>
<td>5,559</td>
<td>5,841</td>
</tr>
<tr>
<td>% change profit: Alt to Baseline</td>
<td>574%</td>
<td>608%</td>
<td></td>
</tr>
<tr>
<td>Benefit-Cost Ratio: Alt/Baseline</td>
<td>2.8</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td><strong>Nutrition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy (calories/AE)</td>
<td>1,750</td>
<td>1967</td>
<td>2239</td>
</tr>
<tr>
<td>Proteins (grs/AE)</td>
<td>41</td>
<td>50.6</td>
<td>73.2</td>
</tr>
<tr>
<td>Fat (grs/AE)</td>
<td>39</td>
<td>24.5</td>
<td>26.0</td>
</tr>
<tr>
<td>Calcium (grs/AE)</td>
<td>1</td>
<td>0.4</td>
<td>2</td>
</tr>
<tr>
<td>Iron (grs/AE)</td>
<td>0.009</td>
<td>0.015</td>
<td>0.037</td>
</tr>
<tr>
<td>Vitamin A (grs/AE)</td>
<td>0.0006</td>
<td><strong>0.00007</strong></td>
<td><strong>0.00017</strong></td>
</tr>
</tbody>
</table>

### Note:
- Baseline: No or minimal irrigation;
- Alt.1--WaterCan: Watering Can used in optimally irrigated systems
- Alt.2--Diesel-P: Diesel pump used 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

### Observation:
- Lack of a variety of food consumed may be the cause of nutritional deficit. However, we see a tremendous increase in Ca intake due to amaranth consumption.
Probabilities of Net Cash Farm Income (Profit) Less Than 800 and Greater Than 5,000 GH₵ in year 5

- Baseline: 0.00%
- Alt. 1--WaterCan: 0.47%
- Alt. 2--Diesel-P: 0.53%

- Baseline: 0.53%
- Alt. 1--WaterCan: 0.43%
- Alt. 2--Diesel-P: 0.32%

- Baseline: 0.00%
- Alt. 1--WaterCan: 0.01%
- Alt. 2--Diesel-P: 0.15%
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

- 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

Econometric analysis

National irrigation development potential
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.
DATA PREPARED

450,000 km² land is suitable at 85% level of suitability

Overlay analysis
A significant amount of surface runoff and groundwater recharge available at the northeastern and central part of the country to expand SSI.
The northeastern and central part of Ghana is productive for producing vegetables and fodder during the dry season.
High adoption probability for SSI at the western part of Ghana, and SSI development may pose widespread water scarcity in Ghana.
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
CAPACITY DEVELOPMENT FROM IDSS

- Regular workshops (5 days) – 100M + 30F = 130
- 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)
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
  - Labor – a major limitation on using low cost technology
  - Solar pumps – economical and workable
- Minimal to modest environmental impacts due to adoption of SSI
- Substantial potential for scaling SSI nationally, e.g. more than 690 thousands people benefited generating more than 285 million USD/year to farmers
- Key personnel trained with IDSS application, and efforts are in the making to institutionalize IDSS to educate more scientists and professionals to scale up SSI
- A dashboard developed for planning and evaluation of SSI
THANK YOU VERY MUCH
WATER USE FUNCTION AND PUMPING TIME OF TOMATO

Excessive irrigation:
- Limits irrigation expansion;
- Costs more time and money;
CDF of Net Cash Farm Income (Profit): Year 5

- Baseline
- Alt. 1--WaterCan
- Alt. 2--Diesel-P
PLANNING AND EVALUATION OF SMALL SCALE IRRIGATION AT NATIONAL SCALE

Farms to Nations using models
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.
IRRIGATION FOR DRY SEASON CROPPING (E.G. TOMATO)

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

Irrigation related to max yield (t/ha)
- 18.00 - 100.00
- 100.00 - 200.00
- 200.00 - 300.00
- 300.00 - 400.00
- 400.00 - 621.56

Irrigation related to min yield (t/ha)
- 23.77 - 100.00
- 100.00 - 200.00
- 200.00 - 300.00
- 300.00 - 400.00
- 400.00 - 635.00
### ESTIMATED SMALL-SCALE IRRIGATION ADOPTION POTENTIAL IN GHANA

<table>
<thead>
<tr>
<th>Region</th>
<th>Expected adoption area (thousand hectares)</th>
<th>Expected profits received by irrigators (million USD/yr)</th>
<th>Expected beneficiary population (thousand people)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashanti</td>
<td>5</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Brong Ahafo</td>
<td>16</td>
<td>14</td>
<td>52</td>
</tr>
<tr>
<td>Central</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Eastern</td>
<td>16</td>
<td>24</td>
<td>54</td>
</tr>
<tr>
<td>Greater Accra</td>
<td>3</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Northern</td>
<td>115</td>
<td>133</td>
<td>377</td>
</tr>
<tr>
<td>Upper East</td>
<td>20</td>
<td>39</td>
<td>65</td>
</tr>
<tr>
<td>Upper West</td>
<td>27</td>
<td>48</td>
<td>89</td>
</tr>
<tr>
<td>Volta</td>
<td>7</td>
<td>13</td>
<td>23</td>
</tr>
<tr>
<td>Western</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>211</td>
<td>285</td>
<td>690</td>
</tr>
</tbody>
</table>

- ~211 thousands ha of land, **economically and biophysically** suitable for SSI development in Ghana,
- A net income of ~285 million **USD/year** from the SSI adoption, benefiting 690 thousands people
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,

- 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