Groundwater irrigation and sustainable intensification of agricultural production systems: A study in India

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Introduction and motivation of the study

• Irrigation is the most important water use sector accounting for about 70 per cent of global freshwater withdrawals and 90 per cent of consumptive water uses

• India is the largest user of groundwater for irrigation
  – Continues to increase both in absolute terms and as percentage of total irrigation in India

• Net irrigated area increased to 65.26 million hectares in 2013 from 20.85 m ha in 1950-51

• Share of groundwater irrigation during this period increased from 28 per cent to over 62 per cent
Factors contributing to growth in groundwater irrigation and its outcome

- Multiple factors contributed to growth in groundwater irrigation
  - Demand side
    - Poor public irrigation system and its maintenance
    - Farmer’s preference because of flexibility and timeliness of supply
    - Less vulnerable than surface sources to climate fluctuations
  - Supply side
    - Availability of drilling and pump technologies
    - Subsidized energy for extraction
    - Improvements in rural infrastructure

- Growth in growth of water irrigation has both positive and negative outcomes
  - Positive outcome
    - Promotion of agricultural growth and reduction of poverty through several pathways
  - Negative Outcome
    - Intensive use of groundwater resources results in aquifer depletion and pollution of groundwater resources
      - Out of 6607 assessment units, 1071 (16 %) are over exploited, 217 (3.2 %) critical and 697 (10.5%) are semi critical; 4530 (68.5) are safe.
Groundwater availability and poverty at all India level

• Relationship between groundwater availability, exploitation and poverty is very complex and is spatially diverse.

  – High availability of annual replenishable groundwater-high exploitation-low poverty (eg. Punjab, Haryana, etc)

  – High availability-low exploitation (safe)- high poverty (eg. parts of UP, Uttarkhand, Bihar, etc)

  – Low availability-high exploitation-low poverty (eg. parts of Rajasthan, North western regions, Tamil Nadu, etc)

  – Low availability-low exploitation-high poverty (parts of Maharashtra)

  – Moderate availability-low exploitation-high poverty (eg. parts of central India)

  – Moderate availability - high exploitation-low poverty (parts of Gujarat)

Understand the pathways by which groundwater irrigation contributes to poverty reduction and sustainable agricultural production.
Objective of the study

• Analyze the relationship between spatial variability in the distribution of groundwater availability, accessibility to irrigation, agricultural development and poverty in the Godavari River basin in India.

• To draw policy insights from understanding this relationship for sustainable intensification of agricultural production system as well as management of groundwater resources.
Study Location: The Godavari River Basin

- Lies in the Deccan plateau
- Third largest river in India
- Largest of the peninsular rivers
- Drains about 10 per cent of the total geographical area
- Rises at an elevation of 1,067 m in the Western Ghats near Thriambak Hills in the Nashik district of Maharashtra
  - Maharashtra (48.6%)
  - Andhra Pradesh and Telangana (23.4%)
  - Madhya Pradesh (10.0%)
  - Chattisgarh (10.9%)
  - Orissa (5.7%)
  - Karnataka (1.4%)
- Flows for about 1,465 km in a generally south east direction and falls into the Bay of Bengal
60 per cent agricultural
30 per cent forest

Godavari basin net irrigated area by sources

Source: NRSA

49 per cent crystalline basement
43 per cent volcanic

Source: ACWADAM (2014)

46 per cent depend on well irrigation

Source: CWC (2010)
Data and Methodology

- Uses primary data collected at household level
  - Data have been collected during 2012-13 agricultural year from sample agricultural households (landless not included)

  - From the upper, middle and lower reaches of the Godavari basin, assuming that they represent different scenarios with regard to resource availability. Regions demarcated based on CWC map.

  - Water resources planning carried out basin level; Godavari largest basin in peninsular India; Higher availability of water resources (surplus basin) but also have high levels of poverty in some pockets..

  - Since most data are available at administrative and not river basin boundary levels, we selected Nashik district each from the upper and Karimnagar from the middle and East and West Godavari districts from the lower reaches.

  - Final selection of villages was based on the stage of groundwater development.

  - Listing of farming households done to identify users and non-users
**12 Sub basins of Godabari**

G1: Upper Godavari,  
G2: Pravara,  
G3: Purna,  
G4: Manjira,  
G5: Middle Godavari,  
G6: Maneru,  
G7: Painganga,  
G8: Wardha,  
G9: Wainganga,  
G10: Lower Godavari,  
G11: Indravati,  
G12: Sabari

Source: CWC
## Sample selection

<table>
<thead>
<tr>
<th>Godavari basin reaches</th>
<th>Total households</th>
<th>Gw users</th>
<th>Non users</th>
<th>hhs sample</th>
<th>Gw users</th>
<th>Non users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper reaches</td>
<td>2973</td>
<td>1589</td>
<td>1384</td>
<td>300</td>
<td>179</td>
<td>121</td>
</tr>
<tr>
<td>Middle reaches</td>
<td>3735</td>
<td>1256</td>
<td>2479</td>
<td>300</td>
<td>183</td>
<td>117</td>
</tr>
<tr>
<td>Lower reaches</td>
<td>3356</td>
<td>399</td>
<td>2957</td>
<td>225</td>
<td>132</td>
<td>93</td>
</tr>
<tr>
<td>All</td>
<td>10064</td>
<td>3244</td>
<td>6820</td>
<td>825</td>
<td>494</td>
<td>331</td>
</tr>
</tbody>
</table>
Conceptualizing relationship between groundwater, agriculture and poverty

- Linkage between water, agriculture and poverty is complex and also non-linear.
  - Not all households/people lack adequate water resources
  - Not all households/people living in water scarce areas are poor

- Endowment of water resources alone does not explain the state of poverty within a basin or region

- The question is:
  - to what extent access to groundwater irrigation and its management explains poverty, in relation to other factors and to what extent it can be improved by better management of groundwater?
According to Allison and Ellis (2001) the well being that people derive from water depends on the interaction between the following:

- The water system, that determines availability and reliability
- The agricultural system that converts the water into livelihood support, through food, income and others
- The livelihood system that modifies access according to the social relations, institutions and organizations

In this three variable system poverty is a function of water availability and agricultural incomes derived from the existing agricultural water management system that also enables people to derive other livelihood benefits.

The implications are that poverty can be reduced through improving the agricultural water management system of the region concerned.
Description of key variables and estimation techniques used

• **Irrigation**
  – Groundwater users vs non-users

• **Agricultural development**
  – In terms of crop incomes
  – Collected input output details of all crops cultivated by each households and estimated net returns from each crop and aggregated
  – Used weighted averages

• **Poverty estimation**
  – Poverty of agricultural households only (landless excluded)
  – Taken into account both agricultural and non agricultural income
  – Estimated per capita income and used poverty line defined by the Planning Commission 2011-12
  • Poverty: head count ratio

• **Determinants of poverty**
  – Logit model
Cropping pattern of users characterized by high value crops like grapes, onion, tomato along with wheat and maize.
Soya bean emerges out as a major crop for both users and non-users.

Source: Primary survey
While cotton is the single major crop for non-users, cotton, followed by paddy and maize are cultivated by users.

Source: Primary survey
Cropping Pattern Lower reaches

Cropping pattern more diversified than middle reaches; high value crops like tobacco cultivated by users

Source: Primary survey
### Estimated annual income of the household from various sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Upper</th>
<th>Middle</th>
<th>Lower</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-agri income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agri-income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Non user</th>
<th>User</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>70664</td>
<td>281188</td>
<td>351852</td>
</tr>
<tr>
<td>Middle</td>
<td>51427</td>
<td>158155</td>
<td>210892</td>
</tr>
<tr>
<td>Lower</td>
<td>11679</td>
<td>29969</td>
<td>41648</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>88250</td>
<td>301232</td>
<td>394232</td>
</tr>
</tbody>
</table>

**Note:** The chart shows the estimated annual income of the household from various sources across different income levels and categories. The total income includes both non-agri and agri-income for each category and sub-category.
Per capita monthly income

- Upper:
  - Non-user: 1710
  - User: 4241
  - Total: 5951

- Middle:
  - Non-user: 1690
  - User: 1814
  - Total: 3504

- Lower:
  - Non-user: 2121
  - User: 4125
  - Total: 6246

- Total:
  - Non-user: 1775
  - User: 3433
  - Total: 5208

- Per capita monthly income in rupees

Reaches:

- Upper
- Middle
- Lower
- Total
Poverty line based on Planning Commission estimates
upper reaches = Rs 967; Middle and lower reaches = Rs 860;
user_nonuser  Whether household is a user of groundwater or not (Dummy) 1= User; 0 otherwise

land  Amount of land owned in acres

hh_size  Family size

fuel  Fuel used for cooking by the household (dummy) 1= Firewood; 0, otherwise

age  Age of the head of the households in years

gender  Gender of the head of the households (dummy) 1= Male; 0 otherwise

caste  Caste of the household (dummy) 1= Schedule caste; 0 otherwise

Upper  Whether households belong to upper reaches or not (dummy) 1= upper; 0 otherwise

lower  Whether households belong to lower reaches or not (dummy) 1= lower; 0 otherwise

occupation  Main occupation of the head of the household (dummy) 1= own farm agriculture; 0 otherwise

no_inc_sources  Number of income sources of the household

illiterate  Literacy status of the head of the household (dummy) 1= literate; 0 otherwise

high value food crop  Whether households cultivate high value food crops or not (dummy) 1= yes; 0 otherwise

non-agri income  Whether households are having non agricultural sources of income or not (dummy) 1= yes; 0 otherwise

drinking water source  Major sources of drinking water of households 1= Tap water; 0 otherwise

groundwater externality
### Determinants of poverty

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std.Err</th>
<th>Marginal Effect</th>
<th>Std. Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>user_nonuser</td>
<td>-0.07923</td>
<td>(0.22322)</td>
<td>-0.0115771</td>
<td>(0.0328)</td>
</tr>
<tr>
<td>land</td>
<td>-0.04769**</td>
<td>(0.02313)</td>
<td>-0.0069268**</td>
<td>(0.00336)</td>
</tr>
<tr>
<td>hh_size</td>
<td>0.22301***</td>
<td>(0.049308)</td>
<td>0.0323947***</td>
<td>(0.00718)</td>
</tr>
<tr>
<td>fuel</td>
<td>0.701751***</td>
<td>(0.233452)</td>
<td>0.1045513***</td>
<td>(0.03531)</td>
</tr>
<tr>
<td>age</td>
<td>0.007137</td>
<td>(0.008148)</td>
<td>0.0010367</td>
<td>(0.0118)</td>
</tr>
<tr>
<td>gender</td>
<td>0.456542</td>
<td>(0.4631)</td>
<td>0.0010367</td>
<td>(0.05108)</td>
</tr>
<tr>
<td>caste</td>
<td>0.347745</td>
<td>(0.226695)</td>
<td>0.0582383</td>
<td>(0.03477)</td>
</tr>
<tr>
<td>Upper</td>
<td>0.130641</td>
<td>(0.28886)</td>
<td>0.0519453</td>
<td>(0.04295)</td>
</tr>
<tr>
<td>lower</td>
<td>-1.84395***</td>
<td>(0.322138)</td>
<td>0.191979***</td>
<td>(0.02668)</td>
</tr>
<tr>
<td>occupation</td>
<td>0.9627***</td>
<td>(0.28115)</td>
<td>0.208126***</td>
<td>(0.02669)</td>
</tr>
<tr>
<td>no_inc_sources</td>
<td>0.198164</td>
<td>(0.214365)</td>
<td>0.114105</td>
<td>(0.2989)</td>
</tr>
<tr>
<td>illiterate</td>
<td>-0.57451</td>
<td>(0.231088)</td>
<td>0.282324</td>
<td>(0.03314)</td>
</tr>
<tr>
<td>high value food crop</td>
<td>-1.13629***</td>
<td>(0.355618)</td>
<td>-0.0082917***</td>
<td>(0.110303)</td>
</tr>
<tr>
<td>non-agri income</td>
<td>-0.90377***</td>
<td>(0.244024)</td>
<td>-0.1230326***</td>
<td>(0.0578182)</td>
</tr>
<tr>
<td>drinking water source</td>
<td>0.597221***</td>
<td>(0.199421)</td>
<td>-0.137701***</td>
<td>(0.0363636)</td>
</tr>
<tr>
<td>groundwater</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>externality</td>
<td>0.538167***</td>
<td>(0.20494)</td>
<td>0.914661***</td>
<td>(.492121)</td>
</tr>
<tr>
<td>Constant</td>
<td>-3.77049***</td>
<td>(0.738179)</td>
<td>0.0785059***</td>
<td></td>
</tr>
</tbody>
</table>

Number of obs = 825  
LR chi2(16) = 155.38  
Prob > chi2 = 0.0000  
Pseudo R2 = 0.1740

*** Significant at 1 *** 5 and * at 10 per cent significance level
Conclusions

- The pathways through which access to groundwater impact on poverty are complex and diverse

- Access to groundwater gives households to adopt diverse cropping pattern including high value crops where water availability is better but income and poverty levels of users and non-users are very high

- In middle reaches where water availability has reached to scarcity levels, farmers cultivate very few crops and are almost equivalent to wage labourers but just above poverty because of having supplementary income generating opportunities and income and poverty of users and non-users is not very different

- Mere access to groundwater does not seem to be a significant determinant of poverty

- Contrary to the expectation, age, caste and gender of the household head also does not seem to predispose households to be more vulnerable to poverty than others

- Household size, major occupation of the head of the household, source of drinking water and fuel used and groundwater externality problems faced by the households make them more vulnerable to poverty

- Dummies for the river basin reaches shows that availability of ground water resources along with how equitable the distribution of land resources are significant in determining poverty of the region

- The analysis signals that while access to groundwater is important, the way in which water resources are used and governed seem to have a more significant bearing on poverty and one has to delve more into the governance aspects of the resource.
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Thank you