Managing groundwater in India

Problems and Policy Options

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GW as a buffer resource for Ag

- GW serves as an important source of water for agriculture, given its abundance in key basins
- The experience of the ongoing drought in California shows how important GW has been to stabilizing water supplies to agriculture
- The same is true for other regions – such as India and China
- But GW faces problems of over-extraction given its common-pool nature

The Importance of Irrigation to India

- A key driver of agricultural productivity on the Indian sub-continent has been irrigation
- Irrigation was a key “green revolution” technology that, combined with improved seed technologies, helped to boost yields for key cereals
- A wide range of agro-ecological conditions across India – but a sizeable share of agriculture relies on irrigation, across all regions

Deepening GW overdraft in India

- Increased demand for limited water resources for both agricultural and non-agricultural uses has led to deepening problems of scarcity
- A number of emerging ‘megacities’ within India continue to demand more water resources from both surface and groundwater sources
- Options for supply enhancement are running out – need measures to manage the demand side
- Groundwater management is particularly challenging (as in many other regions)

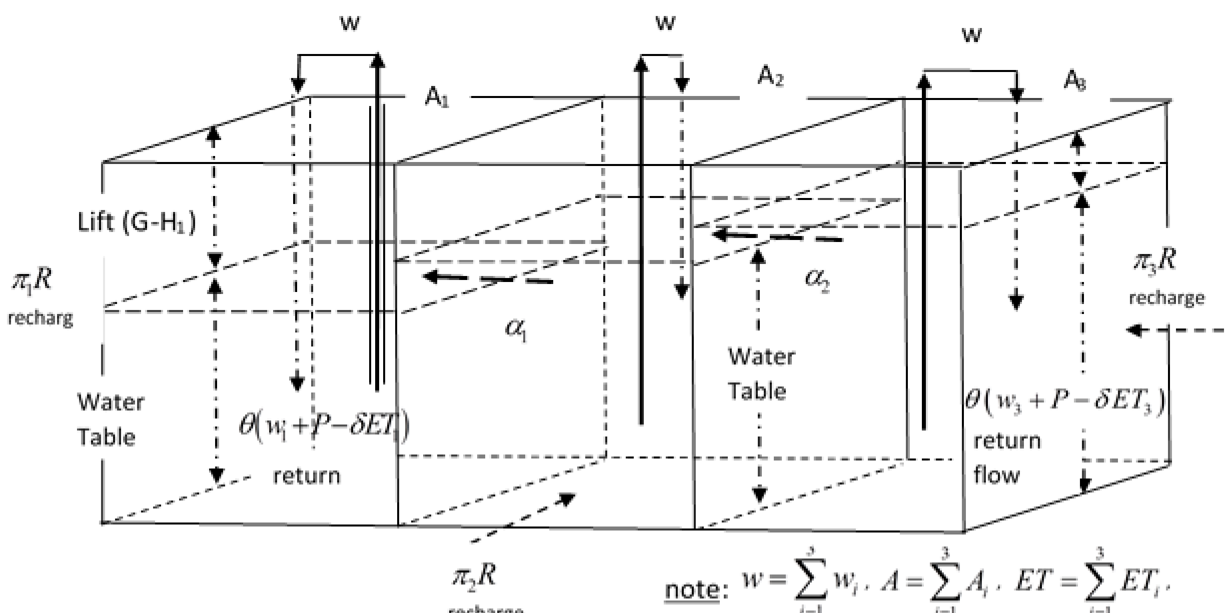
Representing GW management and its linkages to agriculture

Simple representation of an aquifer

A simple 3-cell representation of an aquifer underlying select villages in Maharashtra state.

These are ‘hard rock’ aquifers and hard to model, compared to alluvial aquifers

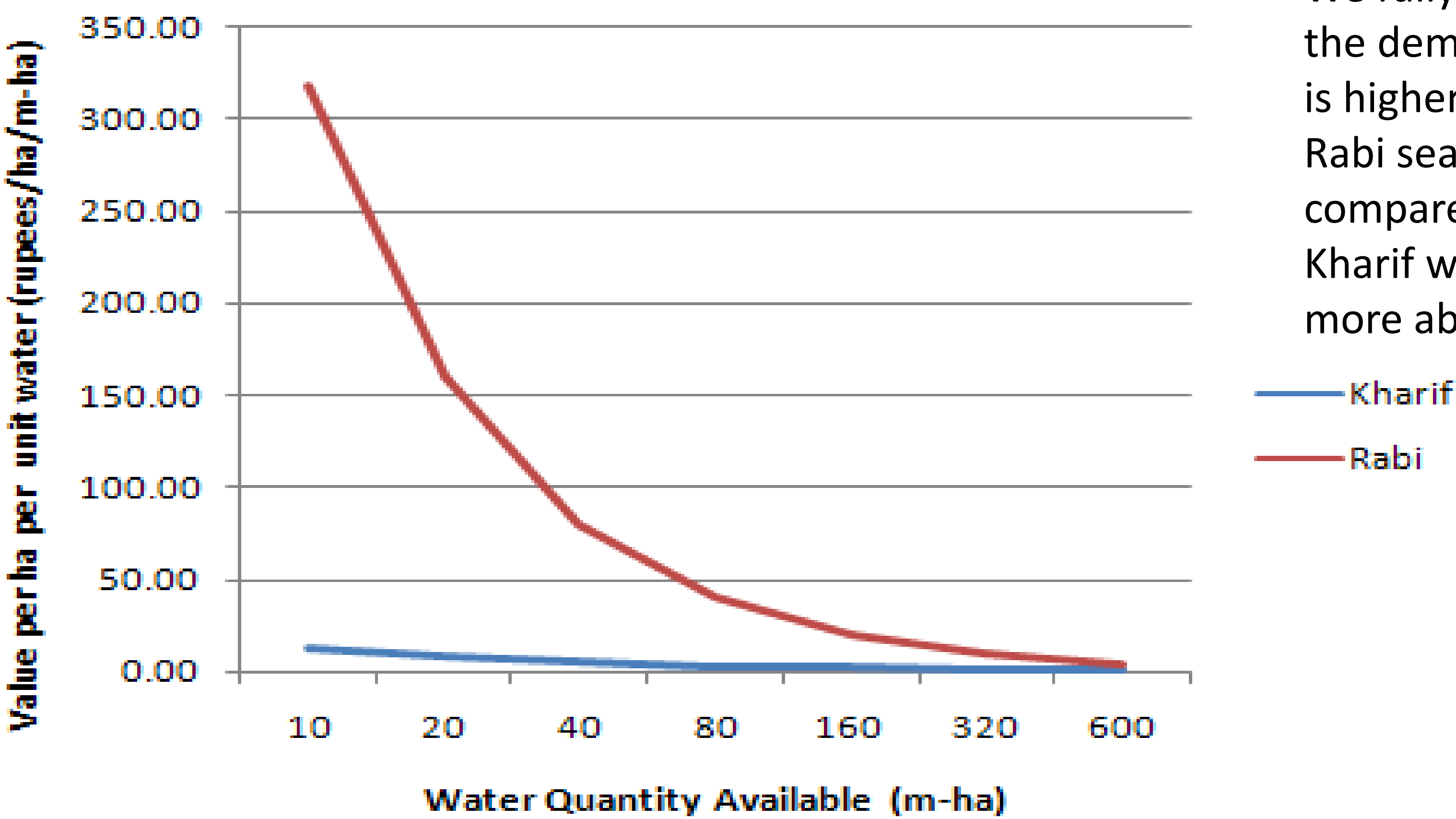
This is linked to an economic model of agricultural water use – to compare the impacts of different management regimes on the groundwater levels



Looking at the demand for water in agriculture

Derived per-hectare demand for Water in the Kharif and Rabi Seasons for Hivre Bazaar

(Rs per unit water per hectare)

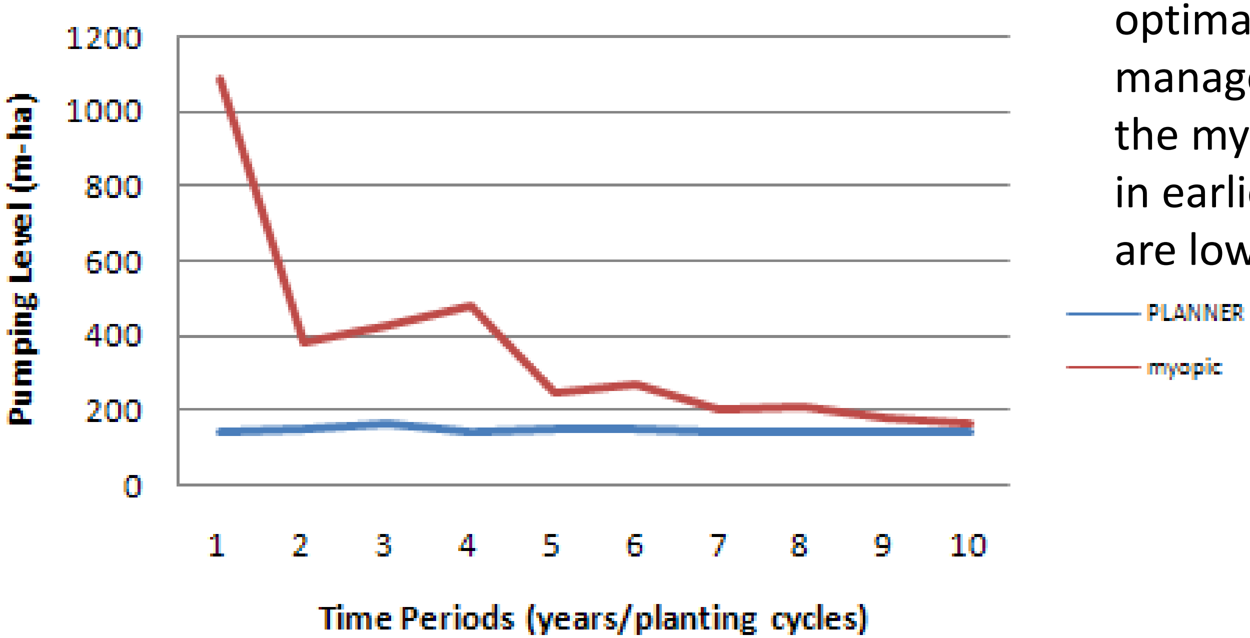


We fully expect that the demand for water is higher in the drier Rabi season, compared to the Kharif when rainfall is more abundant

Comparison of GW pumping

GW pumping levels under dynamically-optimal management of a social planner and a myopic extraction regime

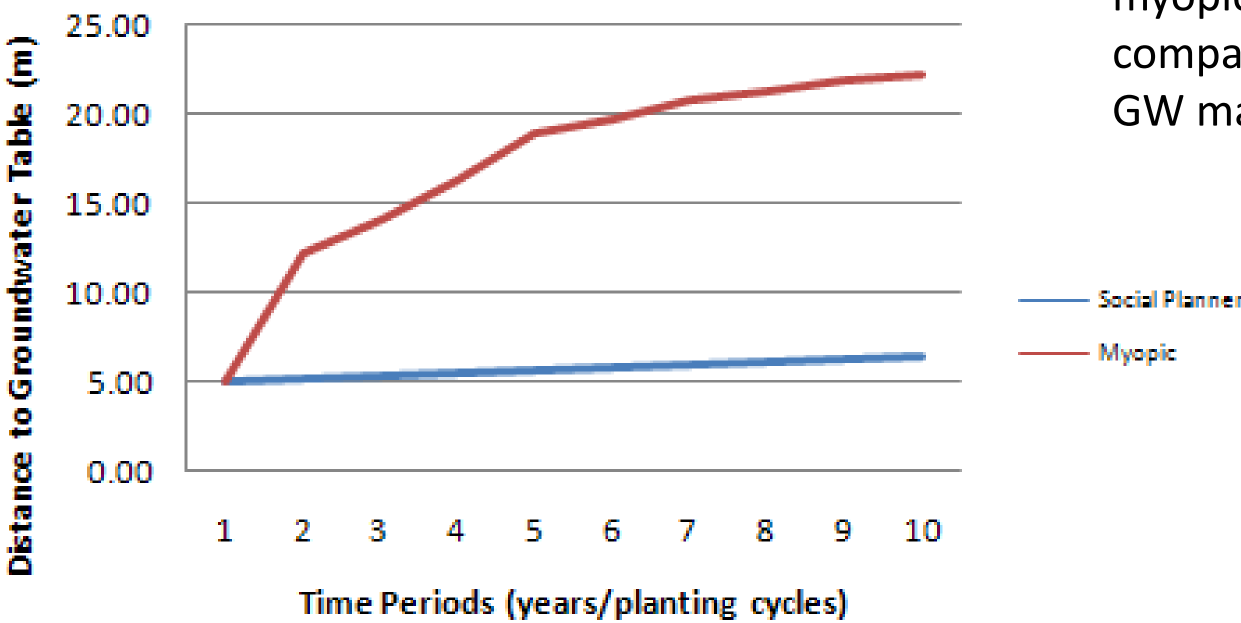
(Hivre Bazaar village)



The groundwater pumping is consistently lower under an optimal, forward-looking management regime, whereas the myopic agent extracts more in earlier periods (which costs are low)

Comparison of lift (depth-to-GW)

Distance to groundwater table under dynamically-optimal management of a social planner and a myopic extraction regime
(Hivre Bazaar village)



The groundwater pumping lift increases rapidly under a myopic extraction regime compared to a forward-looking GW manager

Addressing the policy problem

Various management approaches

- Numerous legislative bills have been passed
- Local management approaches – such as community-based groundwater management (CBGWM) have been tried, with varied success
- They rely upon villagers cooperating & coordinating their planting choices to match their local hydrology & recharge
- Some argue that local management is not enough – need more basin-level interventions

Some problematic policy distortions

- Many have pointed to the electricity subsidies to agriculture as being a cause of the problem – b/c of the perverse incentives it provides to operators of electric groundwater pumps
- Reforming electricity pricing and the imposition of taxes on volumetric withdrawals have been suggested – but remain difficult to implement
- Observability and measurability are always problematic when it comes to regulating individual users (who are numerous & small)

Addressing energy use and consumptive water use in ag

- We propose that tackling the demand side from both the energy and consumptive use perspective might be effective in addressing GW problems
- In short – we would charge the full electricity cost to farmers (to incentivize reduction in GW pumping), while also offering a rebate to farmers on the basis of what they cultivate (rewarding ‘water-saving’ crops)

Looking at land & energy

The agricultural production problem of the farmer can be written as

$$\max_{\mathbf{x}_i^j, a_j} \sum_j \left[p_j a_j \left[\bar{y}_j \prod_i \left(x_i^j \right)^{\alpha_{ij}} \right] - \phi_j \left(a_j \right)^{\gamma} - \sum_{i \neq water} c_i x_i^j - C(e) \varpi_j a_j + R_j \cdot a_j \right]$$

$$subject\ to \qquad \sum_j a_j \leq \bar{\mathrm{A}} \qquad (land)$$

Where the cost of electricity that is required to pump water (with given energy cost *e*) is multiplied with the consumptive use of water per hectare and the area of the crop.

The first-order condition (wrt land usage) is:

$$p_j y_j(\mathbf{x}) - \gamma \phi_j \left(a_j \right)^{\gamma - 1} - C(e) \varpi_j + R_j - \lambda = 0$$

where $y_j(\mathbf{x}) = \bar{y}_j \prod_i \left(x_i^j \right)^{\alpha_{ij}}$ is the crop productivity function (wrt inputs)

and λ is the shadow value on land.

If we re-arrange this expression, we obtain $a_j = \left[\dfrac{p_j y_j(\mathbf{x}) - C(e) \varpi_j + R_j - \lambda}{\gamma \phi_j} \right]^{\frac{1}{\gamma - 1}}$

Challenges facing such a policy

- The primary challenge is in overcoming the political difficulties entailed in charging the full cost of electricity to farmers
- The other key challenge is in creating a workable and credible system for evaluating and issuing rebates that the farmers believe
- Often constituents are skeptical that any savings from avoided subsidies will actually be used in the way they’re intended by the govt

Is there a role for markets?

- Some have tried to look at the role of markets for water in improving allocative efficiency across users – these markets exist and are active in many parts of south Asia
- The ease of implementing market-based mechanisms diminish when dealing with very small holdings (b/c of information asymmetries)
- The welfare implications, are of concern to some, when larger/richer landowners exercise monopoly power on smaller/poorer neighbors
- Given the inequalities of land ownership and access to resources that is inherent to much of south Asia – issues of efficiency vs. equity arise

How to scale up the successes?

- Some select communities have managed to implement very successful CBGWM schemes (Hivre Bazaar, Ralegan Siddhi)
- But they depend on the presence of charismatic leaders who can influence crop choice and groundwater pumping – not easy to replicate
- Need to look more closely at suitable instruments that can incentivize individuals appropriately– and replicate it at a larger scale that can make a difference at basin-level
- Mechanisms need to be incentive-compatible at the village-level, credible and enforceable (needs local buy-in)

Conclusions

- Managing the expansion of irrigated area (and the consumptive use of water in ag) seems necessary to stabilize GW levels
- Getting the farmers to internalize the costs of pumping (through reforming electricity pricing) is also a key element
- Incentivizing farmers in both their crop choice and pumping behavior seems the most effective way
- In the absence of transaction-cost-reducing institutions like user associations, the village (*panchayat*) leader might still have an important role to play in helping to incentivize the behavior of farmers and increasing the success policies aimed at stabilizing GW resources

Thank you!