Common Pools and Common Knowledge

Coordination, Assurance, and Shared Strategies

in Community Groundwater Governance

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Abstract: Innovative approaches to creating shared knowledge about groundwater and irrigated agriculture can contribute to more productive and sustainable resource management. This study looks at the role of knowledge commons in institutional design for a recently-begun project on water commons, drawing on analysis of experience from previous projects in Andhra Pradesh and other parts of India.

Groundwater governance can be made more feasible by shifting the focus from controlling withdrawals from wells to informing choices about which crops to grow. Participatory hydrological monitoring of rainfall and well water levels and discussion of community crop-water budgeting estimates, based on pooled information about farmers' plans, can play a key role, not just in improving information but in changing understanding of the resource, values, and options for its management, changes in "environmentality." Satellite remote sensing of rainfall and evapotranspiration can be combined with local knowledge to support decisions for local water management. The role of formal monitoring may be important initially, but sustainability may depend on changing local knowledge and informal practice, without necessarily requiring perpetuation of formal measurement. Coordination and assurance game models show how successful collective action can occur based only on shared strategies coming from the creation of knowledge, without necessarily requiring norms that prescribe what should be done, or rules with enforced sanctions.

This study illustrates how an innovative information-based strategy for creating local common knowledge could lead to successful collective action, where top-down regulation has failed, while also showing lessons about how local regulation might further enhance equity and sustainability. It shows the potential for improving the production of knowledge as a local public good, and situations in which shared strategies based on common knowledge could be sufficient to improve management of a water commons.

Keywords: knowledge commons, groundwater governance, institutional analysis and development, solving social dilemmas, problems of collective action

1 Introduction

The proliferation of tubewells and pumps in India and other countries has brought benefits to millions of farmers, but has also contributed to depletion of aquifers. Attempts at top-down formal regulation of groundwater use, based on well licensing and regulation of water withdrawals, have usually been ineffective (Shah 2009). By contrast, the Andhra Pradesh Farmer Managed Groundwater Systems Project (APFAMGS) applied a voluntary, information-based process through which farmers were able to earn more money while using less water (Pahuja 2009; Das and Burke 2013). Lessons from APFAMGS and other projects can contribute to more effective design of activities such as the Water Commons Project being carried out by the Foundation for Ecological Security (FES) with support from the Hindustan Unilever Foundation (HUF). This study analyzes how sharing information, a form of “cheap talk” without requiring new norms or sanctions, may be sufficient to coordinate collective action and lead to more sustainable natural resources management.

The paper begins by introducing the Water Commons Project, outlining challenges of groundwater governance, and describing key aspects of the APFAMGS Project. It analyzes mechanisms for pooling environmental knowledge that help make better groundwater governance feasible, by shifting attention from controlling withdrawals to informing choices about crops; monitoring rainfall and groundwater levels; and comparing aggregate water demands of planned crops with available water supplies. The paper then looks at options for making groundwater governance more equitable and sustainable, through combining remote sensing information with local knowledge, taking an inclusive approach to making decisions and expanding access to water, and focusing on sustainable changes in how people see and use water as a commons.

2 The Water Commons Project

The Foundation for Ecological Security has worked with communities in many parts of India to improve management of common lands. Community cooperation has helped to protect and restore forest and pasture land. For watershed conservation, simple earthen structures have been constructed to retain runoff, store water, and promote infiltration to recharge aquifers. Communities have been assisted in analyzing their situation using participatory rapid appraisal techniques such as resource mapping, as a basis for local plans.

The Water Commons project seeks to scale up work focused on shared water resources, such as ponds, tanks and groundwater (FES 2013). Activities are supported by the Hindustan Unilever

Foundation, and seek to improve the effectiveness of watershed conservation works funded through the Mahatma Gandhi National Rural Employment Generation Act (MNREGA). The project is scaling up to work with over 700 communities in 7 states, with most locations in Rajasthan, Karnataka, and Andhra Pradesh. The project focuses primarily on the habitation level, settlements of tens to hundreds of households, but also seeks to work across landscapes of multiple communities in sub-basins, panchayats (subdistrict-level), and districts; along with policy discussions at district, state, and national level. It includes capacity building, through agricultural training, exposure visits, education materials, newsletters, and websites, supporting core communities and neighboring areas. It aims for a triple bottom line of social, economic, and environmental benefits, improving local governance institutions, household livelihoods, and sustainable management of water resources, including groundwater.

3 Groundwater as an Invisible Commons

Groundwater is a classic example of a common pool resource where exclusion is difficult and one person's use subtracts from the resource available to others. Groundwater is much harder to observe than surface water, making it harder to manage as a socio-ecological system. Farmers and other water users make decisions about installing wells, how much water to use, and what crops to grow. Users are often dispersed, taking water from a multitude of individual wells, in contrast to surface irrigation systems that divert water at a single point. People can't easily see how groundwater flows or how their water use may affect others. In many areas, widespread use of deep tubewells (boreholes) and mechanized pumps is relatively recent, so that there has been limited time to learn about aquifers and develop customary norms or rules to regulate use of deep groundwater. Formal state regulation of groundwater is often absent or ineffective. People may not even perceive groundwater as a commons, and instead think of it as purely private property, with people entitled to take however much water they want from underneath their land, without considering the impact that might have on other users or how groundwater flows underneath landscapes. Under such conditions, it is possible to have social dilemmas, situations where people could be better off if they cooperated, but private decisions based on narrowly perceived short-term self-interest instead make everyone worse off. This can lead to depleting groundwater; a race to the bottom where those who can pay for the biggest pumps and deepest wells may win, until groundwater reserves are exhausted.

The conventional recommendation for dealing with such a situation, often embodied in formal policies and legislation, is to regulate the installation and use of wells, requiring licenses for wells as a foundation for measuring and controlling water abstraction. However, such an approach is often ineffective, due to a variety of factors including limited government capacity, the multitude of dispersed users, difficulty of understanding aquifer stocks and flows, and objections from those who have already invested in wells and pumps. There are examples, particularly for shallow aquifers, of how simple customary rules, such as requirements for spacing between wells, can be effective under some circumstances (Steenbergen and Shah 2003). Under some conditions, collective action for watershed conservation, to retain more runoff and recharge groundwater has had significant impacts (Shah 2009). Examples of effective formal regulation and management of groundwater are rarer. However, there are examples such as groundwater basins in southern California where, in some but not all cases, users have successfully organized themselves (with legal authority derived from legislation and court decisions) to manage water, including importing additional supplies of surface water, reversing seawater intrusion into aquifers, and actively managing storage and use of groundwater reserves (Blomquist 1992). Given the difficulty and rarity of successful groundwater management, institutional design for groundwater management should try to learn from examples that have achieved some success in collective action to improve groundwater management.

4 Information as an Intervention

The Andhra Pradesh Farmer Managed Groundwater Systems Project (APFAMGS) offers a remarkable example of a voluntary, information based intervention to improve groundwater governance, with win-win outcomes that raised farmer incomes and reduced water use (Pahuja 2009; Das and Burke 2013). A previous project, AP-WELLS, had supported the expansion of irrigation through supporting installation of wells and pumps, as well as agricultural extension, but led to concern about aquifer depletion.

The APFAMGS project carried out a variety of activities, including innovative approaches to training and education. Communities were involved in participatory hydrological monitoring, measuring local rainfall and groundwater levels, and showing the information in public displays, painted on the outside walls of village offices or other buildings. Farmers were surveyed about what crops they planned to grow, and the results used to estimate water demand. This could then be compared to estimated supplies, based on information about rainfall and rates of infiltration, in a crop-water budgeting activity. The project provided farmers with information about alternative crops and cultivation practices, including their impacts on income, water use, and risks.

Another distinctive aspect of the project is what it did *not* do. It did not try to promote regulations or restrictions on water use or well installation. This was left up to voluntary decisions by individual farmers. In many cases, farmers did make changes that reduced water use, such as shifting from dry-season (rabi) rice to chili peppers, groundnuts (peanuts), or other crops that need less water. Monitoring during the project indicated that there were shifts in cropping patterns, and the amount of groundwater extracted was substantially reduced, although there is a lack of independent evaluation. Nevertheless, and at least during project implementation, the project seemed to have had substantial impacts, in the views of villagers, those involved in implementing the project, and outside observers (Garduño et al. 2009).

Some accounts argued that this was mainly a matter of ensuring that farmers had enough information to see what would be privately profitable for them (Pahuja 2009). However, in such a situation the long-term sustainability of changes seems highly questionable. If irrigated production becomes more profitable, then farmers would have incentives to expand their use of irrigation. Rather than “saving” water, they could instead use the same amount of water to grow more crops, or even increase their water use. A sustainable change would require a situation where farmers would have reasons to limit their use of irrigation water. In part this could be due to constraints, such as limitations in land, labor, finance, electricity, or other inputs, but again, if irrigated production were more profitable, then over time farmers would have incentives to overcome such constraints in order to expand production, and so increase water use.

This paper suggests that rather than simply being a matter of individual information and incentives the change is also related to the creation of common knowledge and shared strategies that help to limit water use and balance water demand and supply. While individual incentives certainly play a crucial role, this paper suggests the creation of common knowledge may also have played an important role, changing perceptions so that water was seen as a shared commons, increasing awareness that one person's use affects others, focusing attention on cropping patterns that would be sustainable if adopted by most people, and offering assurance that many others were also prepared to moderate their water use, facilitating conditional cooperation. Monitoring rainfall and groundwater levels, and discussing cropping alternatives could allow people to coordinate their strategies in a way that shifted toward a more sustainable pattern of water use.

5 From Controlling Withdrawals to Choosing Crops

Analysis of action situations in commons, as part of socio-ecological systems has highlighted the importance of monitoring as a key element affecting the feasibility of governing commons (Ostrom 1990; Ostrom 2005; Cox, Arnold, and Villamayor-Tomas 2010). Typically, local rules are diverse and crafted to fit particular conditions, including what is more easily feasible to monitor. Analysis of conventions and solutions to coordination games also emphasizes the tendency to focus on aspects of the situation that are easily observable, focal points considered to be prominent or salient (Schelling 1960; Lewis 1969; Sugden 1986).

APFAMGS focused on understanding water demand and supply, alternative crops, and cultivation practices, and ways of increasing farmer incomes (and reducing risks) that could also affect water use. In terms of resource management, focusing on alternative crops rather than directly controlling water use switches attention from something that is hard to monitor and manage, water withdrawal by lots of farmers at many times and places, to decisions about what to grow, including what kind of irrigation to use. The choice of crops is much easier to observe, and a more credible commitment to make. An important reason for the impact of APFAMGS seems to come from focusing on the parts of water balances that are more feasible to affect, rather than the more difficult task of controlling water abstraction at a detailed level of individual wells. There is thus a shift in the kind of knowledge that is used for resource management, towards information that is easier to observe, share, and coordinate.

6 Participatory Hydrological Monitoring to Create Common Knowledge

Engaging communities in monitoring rainfall and groundwater levels is not just a simple matter of making measurements or obtaining data, but also a way of facilitating changes in perceptions, redirecting attention and changing the concepts people use in understanding, discussing, and making decisions. Using the concept developed by Arun Agrawal in his analysis of community forestry, this can be seen as a change in environmentality (Agrawal 2005), transformations in how people think about and act on their world.

Participatory hydrological monitoring is part of a process of helping people to pay more attention to water and how it flows, and see it as a commons, a shared resource. Farmers consider information from local measurements more credible and meaningful than data from the national meteorological grid, especially where measuring stations may be located some distance from the community and subject to different conditions. Routine government monitoring of groundwater covers a much smaller number of sites, and the locations of monitoring wells are not publicly disclosed. Aquifer conditions may be variable, so monitoring sites somewhere else in the district may not be representative of conditions in the community. Farmers have a sense of water levels in local wells, from their experience with installing and deepening wells, and observing how wells respond to pumping. Use of measuring equipment in wells can allow more precise measurement, and facilitate systematic record keeping. Pumping tests on wells, and analysis of relevant geological information can also contribute to better estimates of how aquifers are depleted and recharged. With some reasonable simplifying assumptions, rough estimates can be made of how much rainfall infiltrates and contributes to aquifer recharge, and therefore how estimated demand compares with renewable supplies, to assess whether planned use is generally in balance or well above or below a sustainable level of use, as discussed below.

Posting of information in a public place, such as painting data tables and charts on the wall of a village office, contributes to awareness. This not only provides specific data but also encourages a change in what people pay attention to and how they think about it. Participatory hydrological monitoring can also be seen as part of a larger set of processes that may influence how people observe and understand their environment, what kind of knowledge they have and use. This may also occur with activities such as making maps of local resources or preparing seasonal calendars showing crop schedules and other important activities. When these are done through public activities, rather than private interviews, they contribute to showing or even creating common knowledge, things that are not only known by everyone (or by most competent adults) but also common knowledge in the more technical sense of things that you know that others know, and they know that you know, and so on. Such knowledge is not secret, private, or individual, but instead is common, at least within a particular local public. This shared knowledge can then form the basis for conventions, understandings about how to coordinate cooperation (Lewis 1969; Aumann 1976; Sugden 1986). Participatory hydrological monitoring is a part of creating common knowledge, and a knowledge commons where information on rainfall and groundwater levels is publicly displayed, as a way to inform local discussion and decisions.

Crop-water budgeting brings together information about farmers' plans to generate an aggregate estimate of water demand, based on assumptions about water use for each crop. This can then be compared with estimated supply, based on information about rainfall and estimates of infiltration rates and groundwater flows that may add or subtract water from the underlying aquifer. This shows whether farmers are planning on using more or less than the water supply received from rainfall. As mentioned, other activities help farmers to better understand the options available for crops, and what they could mean for income, risks, water use, and other considerations. Overall, this process seems to have been sufficient to lead to substantial changes in farmers decisions about what crops to grow, and in how much water they used.

7 Rules, Norms, and Shared Strategies

Public discussion creates a forum for learning about what others plan to do. It thus facilitates coordination. As stated above, a distinctive part of APFAMGS is that it relied on a voluntary, information-based approach. It did not try to establish rules about water use, or even norms about what should be done. Instead, the attempt was more a matter of recommendations about what would be prudent and advisable, given water availability and other local conditions. Project activities facilitated awareness and a form of deliberation, but without trying to insist on consensus or regulation. This contrasts with most approaches to groundwater governance, which assume regulations are necessary.

Ostrom and Crawford (1995; Ostrom 2005) analyze collective action by distinguishing between rules, norms, and coordinated strategies. This offers a way of seeing how coordinated strategies might be sufficient for groundwater governance, without always or necessarily requiring rules or norms. This is part of their institutional grammar, that also examines strategies, norms, and rules in terms of the relevant attributes of people and things involved, aims and activities, and conditions under which may they apply.

- Rules include both statements about what should be done, and “or else” clauses, stating sanctions that apply if rules are violated.
- Norms include statements about what should be done, (*deontics)* but without explicit sanctions.
- Shared strategies are statements of intention to pursue a particular course of action, which may be considered prudent or recommended, but without a normative value or sanctions.
- In practice these can be seen as more of a continuum, rather than sharply distinguished categories.
    - Statements about strategy may embody ideas about what would be prudent and advisable, and represent a consensus about what is best to do, even if they do not contain explicit disapproval of other courses of action.
    - Violating norms may have consequences, especially in small communities and networks where reputation is important and people interact repeatedly on many different matters, leading others to withhold cooperation or other benefits, perhaps on unrelated activities. So informal sanctions may mean that norms function like rules, even if not written down in formal regulations with explicit sanctions.

The concept of shared strategies shows that one way collective action may occur is simply through pooling information, without necessarily requiring norms about what people should do, or rules with penalties for violations.

8 Solving Social Dilemmas with Shared Strategies

The potential to organize collective action can be analyzed in terms of simple two-person two-move (2x2) games, particularly coordination games and other social dilemmas (Rapoport, Guyer, and Gordon 1976; Robinson and Goforth 2005; Kimmich 2013; Bruns Forthcoming). In the case of a shared resource, such as groundwater, farmers are affected by what others choose to do. Two-person game theory models may be able to capture essential elements of the situation, even though in reality there may be more people involved.

Figure 1 illustrates some possible payoff structures for symmetric 2x2 games, including Concord where interests are harmoniously aligned, and individual interests lead to the best outcome with no need for coordination, social dilemmas where individual incentives may conflict with the outcome that would be better for both (Pareto-optimal) and other situations where coordination may make be worthwhile. While research has tended to concentrate on Prisoner's Dilemma, in practice other situations may be more likely to occur, and somewhat easier to resolve ((Taylor and Ward 1982; Simpson 2010; Simpson, John 2001; Rusch 2013), including Stag Hunts, where there is a problem of coordinating between alternative equilibria, one of which would be better for both (Skyrms 2004).

Some of the options can be represented through different scenarios, looking at different possibilities, depending on the relative payoffs from both growing chili or other crop needing less water, both growing rice or other water-intensive crop, or one growing rice and one growing chili. These are purely for illustration, though information from the field indicates that in many cases growing chili and other crops that consume less water can earn higher profits and have less risk than rice. This paper emphasizes a theoretical analysis of various possibilities. Although the empirical situation could be assessed in more detail, such an assessment is beyond the scope of this paper. The more general point is that cooperation may be preferable, in single-shot Stag Hunt games or in repeated games with a Prisoner's Dilemma or Chicken payoff structure (or it's multi-poayer equivalent).

Concord. The simplest case is if it is in each farmer's interest to choose a less water-intensive crop, such as chili peppers, regardless of what others do. Shifting to a crop that uses less water may be a dominant strategy, better regardless of what the other person does. Thus, the problem can largely be seen as one of ignorance. The main intervention would be improving awareness of the benefits of shifting and the risks of not shifting, including the risks of not having enough water for rice. The individual incentives will lead to an outcome which is best for both, since the shift helps reduce depletion and maintain higher water levels than would otherwise have been the case. In this case, farmers could make their decisions independently, without needing to worry about what others are doing. Neverthess, better information could improve the changes that farmers can actually choose the course of action that would be individually and collectively better.

Chicken. Suppose there isn't enough water for both farmers to grow rice, but enough so that both could have a good crop of chili, or one farmer get a good crop of rice while the other has a modest crop of chili. This would be a Chicken situation. While there could be a cooperative outcome where both get a good crop of chili, each would be tempted to defect and grow rice instead. However, this would lead to failure for both. Public discussion of cropping plans, and the visibility of which crop was chosen could be a commitment mechanism, that might help make cooperation more feasible.

Prisoner's Dilemma. Suppose there is enough water for both to grow some rice but both growing chili would be better. If growing rice in flooded fields also damages the chili crop, for example through waterlogging soils, then if one grows rice that person might get a best outcome, while the other gets the worst. In such a case rice might seem to be the best choice, regardless which crop the other chooses. This would be a Prisoner's Dilemma situation. Each would be tempted to defect from the cooperative outcome of both growing chili. Again, the cooperative solution might be stabilized by public discussion and the visibility of crop choices. This would be easier to monitor and so more credible than a commitment to limit the amount of water extracted for irrigation.

Stag Hunt. If chili or other dryfoot crops would be the most profitable option, but would be damaged by rice, then the safest strategy might be to grow rice, even if chili would be better for both. This would be a Stag Hunt situation, an assurance game (Sen 1967) where it is better to make the same choice as the other person, although one option is best for both the other option is less risky. There might be additional synergies that make growing chili work better when done by both, for example through having better information, or easier marketing. This would make chili better, if the other also cooperates, but otherwise it could be safer to stay with the familiar crop of rice.

Repeated games. The paragraphs above describe choices for a single season, but similar considerations could affect repeated choices. Farmers may face a choice between depleting the aquifer quickly, or using it more slowly or even keeping usage within the limits of annual renewable supplies. It may make sense to choose a less water-intensive crop if that will allow more production in future seasons, but only if the others cooperate. Thus the choice could be one of grabbing as much water as quickly as possible, or using less (stinting). This might depend on having some way of discouraging defection, for example by withholding cooperation the season after others do not cooperate, as in a tit-for-tat strategy (Axelrod 1984), or applying other sanctions to those who do not cooperate. Over a series of repeated interactions, the best outcome would be if both cooperate, while the worst would be to always cooperate while the other always defects. Attempting to minimize risk by avoiding the worst outcome would lead to both getting second-worst. If there is enough trust, both can cooperate and get the best possible outcomes.

In the situations above, norms or rules that restricted growing water-intensive crops could also help change the payoff structure, so that cooperation became preferable. These could convert Stag Hunt, Chicken, or Prisoner's Dilemma into a Concord situation, where growing a less water-intensive crop was the better option. However, the examples above illustrate that norms or rules (with sanctions) are not always necessary in order to achieve cooperation. Rules and norms could still work to encourage cooperation, but coordinated strategies alone could also be sufficient in some cases, particularly in a Stag Hunt game, or a repeated game of Prisoner's Dilemma or Chicken where cooperation is also an equilibrium with a higher cumulative payoff.

Figure 1. Six 2x2 Games

Harmony	Cooperate	Defect
Cooperate	4,4	2,3
Defect	3,2	1,1

Chicken	Cooperate	Defect
Cooperate	3,3	2,4
Defect	4,2	1,1

Prisoner's Dilemma	Cooperate	Defect
Cooperate	3,3	1,4
Defect	4,1	2,2

Stag Hunt	Cooperate	Defect
Cooperate	4,4	1,3
Defect	3,1	2,2

Avatamsaka (Double Hunt)	Left	Right
Up	4,4	1,4
Down	4,1	1,1

Double Coordination	Left	Right
Up	4,4	1,1
Down	1,1	4,4

The information available is not sufficient to be sure what the actual payoffs are, and these may vary between farmers and localities. The payoff matrices here only illustrate ranked ordinal payoffs. Nevertheless, the models illustrate both challenges to cooperation in different social dilemmas, and how public discussion and agreement on coordinated strategies, made visible by choice of crop, might help lead to successful collective action. The general conclusion is that communication facilitates coordination. If there are temptations to defect, to raise individual payoffs or avoid risk, as in Prisoner's Dilemma, Chicken, and Stag Hunts, then making actions a matter of public discussion and visible choices could facilitate collective action, by improving information and common knowledge that creates assurance that others will also cooperate.

9 Enhancing Sustainability, Equity, and Efficiency

Satellite monitoring. After APFAMGS was completed, post-project visits to sites expected to be good examples of successful implementation suggested that by 2012 only about 30% of communities continued to carry out participatory hydrological monitoring, public display of water data, or formal meetings for crop-water budgeting, raising questions about the sustainability of project interventions (Verma et al. 2012). Collecting rainfall data requires detailed daily measurements, and seems hard to sustain. Satellites can now provide accurate estimates of rainfall over somewhat broader areas, about 25 kilometers by 25 kilometers. This could even be cheaply delivered by SMS messages. Participatory monitoring may play an important initial role in bringing about changes in attention and understanding, but there may be more efficient ways to provide information in the long run (Bruns 2014). Thus, one option to be explored in the Water Commons Project is to use remote sensing data, and try to learn if this may contribute to a more sustainable and efficient approach.

Similarly, satellite-based monitoring of evapotranspiration can provide information on trends in water consumption, for areas of about 250 meters by 250 meters for historical data (MODIS) and 30x30 meters for the newest Landsat 8 satellite launched in 2013. Trend data on ET helps indicate what may be happening in terms of net aquifer depletion or recharge, even if detailed well measurements are not continued.

Changes in environmentality. Interestingly, it appears that in at least some cases, farmers have continued to carry out coordinated strategies to grow crops using less water, even though formal monitoring and crop-water budgeting were not continued (Verma et al. 2012). They may have become more aware of water availability and demand, and more concerned about conserving water, changes in perception, knowledge, and values. As mentioned earlier, this can be seen as a change in what Arun Agrawal (2005) has called environmentality. Agrawal studied changes in how people thought, talked, and acted collectively concerning forests, taking on ideas from scientific forest management, making it a subject of common attention and action, considered in light of values for protecting forests. Similarly, ideas and actions about water may change, including understanding water as a commons, a shared, limited resource. Such changes may occur even if formal management activities such as those developed under the project do not persist. During a field visit, one farmer explained that he and his neighbors still consult informally among those sharing wells or with nearby wells, discussing their plans for crops, rainfall, and water availability. There was no attempt to prevent those wanting to grow a more water intensive crop from doing so, but a concern to help them be aware to the risks they were running, especially if crops failed and loans could not be repaid, and to be clear about what people felt was a recommended (but not required) strategy.

Well-sharing. While APFAMGS deliberately avoided promoting rules regulating wells and water use, some other projects and communities have undertaken additional initiatives to influence how wells are used (M. S. Reddy, Reddy, and Mohan 2012; V. R. Reddy, Reddy, and Rout 2014). One example is encouraging farmers to share well water with neighbors. Sharing wells can reduce investment costs while expanding access. While this could be motivated by altruism, it can also have pragmatic incentives, if other farmers pay for water, directly or with a share of their crop. Furthermore, if the well owner does not share, they risk having their neighbor install a competing, perhaps deeper well, so enlighted self-interest, looking ahead over a slightly longer term, offers another incentive for sharing water from a well.

Prohibiting boreholes. In other cases, communities have made a collective decision to rely on open wells, and prohibit installation of tubewells. Everyone may be better off if they can maintain water at a higher level, and avoid excessive investment and a pumping race to the bottom. If this ensures that water remains accessible from open wells, then there is no gain from the expense of installing a borewell and pump, making open wells the better option. However, if others install borewells and pumps and reduce the groundwater so that open wells dry up, then there may be little choice but to do the same. Thus there are two equilibria, with or without borewells, another stag hunt situation. As long as everyone, or a sufficiently large majority, cooperates, then it is better to also cooperate, maintaining higher levels and keeping higher reserves available for the future.

Inclusion. The community organization process used by FES emphasizes universal membership, trying to involve all members of the community in making decisions and enjoying benefits from shared resources, with a concern for social justice and helping the poorest. This contrasts with projects that only focus on a smaller group, for example water user groups composed of irrigators that do not include others using the water resource for domestic water supply or livestock. Putting management within a larger community context may encourage better consideration of how people are affected by others' water use (externalities). It may also promote more pro-active efforts to expand access, targeted at those with greater needs, rather than just going to those located closest to the water resource or best able to take advantage of new opportunities. Development of local governance capacity can make it easier to establish rules where necessary, to protect and improve water resources and coordinate behavior that can make everyone better off, counteracting temptations to pursue private actions that would harm others.

Restoring aquifers. APFAMGS emphasized a voluntary information-based approach to changing crops and water water use. Information during project implementation suggests that in most cases communities substantially reduced water use, slowing the rate of groundwater depletion. Farmer measurements of well levels from 2005-2011 gave an indication of trends (Das and Burke 2013):

- 35 hydrological units (HUs), 55%, had an upward trend
- 18 HUs, 29%, were stable, with a change of less than one meter up or down
- 10 HUs, 16% showed declining water levels

Thus, 86% were being recharged sufficiently to be stable or rising over the period 2005-2011, a period of "generous" monsoons. The report does not provide information on pre-APFAMGS trends in the area, and only describes trends for 2005-2011, without any quantitative data on actual groundwater levels. Estimates of crop-water balances, based on areas under different crops, indicate that withdrawals reduced at 43 HUs, 68%, while increasing in the remaining 20 HUs, 32%. Most HUs were categorized as overexploited, 50, 79%, where withdrawal exceeds recharge, 3 were critical (90-100%), three semi-critical (70-90%), and 7, 11% as safe, where withdrawal is less than 70% of recharge. While it appears that withdrawals were often reduced, it is not clear whether this would be enough to shift many areas to a lower category.

In contrast to many attempts to improve groundwater management which have had little or no impact, particularly in terms of reducing water demand, APFAMGS appears to be a remarkable success. However, the lack of information on previous trends makes it hard to be sure of the extent to which the intervention slowed, stabilized or reversed previous declines.

A challenge for the Water Commons Project is to promote restoration, a shift to sustainable, balanced groundwater use within the limits of renewable recharge. Raising water tables would bring benefits by reducing pumping costs and preventing well failure, as well as increasing reserves (Pahuja 2009). Restoration could include using groundwater as a buffer (Steenbergen, Tuinhof, and others 2010), storing more water in good years and taking out water during dry years. This would represent an adaptive, resilient approach to groundwater management.

Adaptive rules. Another challenge to sustainability is if farmers would have incentives to expand production of chili or other less water-intensive crops. This could accelerate depletion. Adaptive rules that limit water use, for example by only allowing water-intensive crops in wet years, could help keep water demand and supply in balance.

Subsidizing groundwater recharge. In some areas groundwater recharge activities do seem to have been relatively successful in increasing storage and enabling increased cropping, including voluntary groundwater recharge movements promoted by religious leaders and philanthropists (Shah 2009). Usually this seems to have been done without direct intervention concerning water demand, and instead farmers adjust their cropping to improved water availability. Recharge includes not only individual efforts by farmers to improve recharge, but also collective action by groups of farmers and larger communities. Where collective action for watershed recharge relies on voluntary contributions, farmers might have an incentive to free ride, if they could enjoy the benefits without sharing in the costs. This would be another example of a Tragedy of the Commons, the multi-person equivalent to a Prisoner's Dilemma. Within relatively small close-knit communities, where reputation and repeated cooperation on many different matters are important, it may be relatively easy to avoid free-rider problems. In the case where farmers are paid by MNREGA to work on water harvesting structures, there would be no incentive to free-ride. Farmers would be better off working, and the best situation would be where everyone else works, if that enabled greater groundwater recharge. The payment for work would shift the payoffs, either if the other person worked, or did not, transforming Prisoner's Dilemma into Concord.

10 Conclusions: Pooled Knowledge as a Local Public Good

APFAMGS and other projects offer important lessons for designing ways to improve governance of groundwater commons, by improving common knowledge. Participatory hydrological monitoring can change what people pay attention to and how they think about water availability, while farmer field schools and other activities improve their understanding of cropping options and their impacts. Aggregating information about farmers' cropping plans provides an estimate of demand, which can be compared with supplies. In some cases, simply sharing information may be sufficient to enable coordinated strategies that keep water demand within the limits of available supplies. In other cases, communities may take action to restrict demand, for example through rules about well spacing or restricting types of crops. Such measures may be more effective if they rely on easily observed actions, such as choice of crops, rather than detailed technical measurements of flows. While participatory hydrological monitoring may play an important role initially, changes may be sustained through changes in people's ideas and values, their environmentality in practical, informal observations and decisions, and these may be effective even if more formal management activities are not perpetuated post-project. Remote sensing may be able to supplement local knowledge with low-cost provision of information about rainfall and water consumption (ET) trends. While purely information-based interventions may be surprisingly effective, inclusive planning and implementation that develop local governance capacity may be able to go even further in promoting increased equity and sustainability.

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