Water Commons and Information Commons:

Combining Local Knowledge and Remote Sensing to Support Community Groundwater Governance

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Abstract

Participatory hydrological monitoring has played a crucial role in the development of local groundwater governance in Andhra Pradesh, India and elsewhere. However, this is labor intensive and may be unsustainable, while remote sensing can potentially provide better information, at lower cost. From a practitioner's perspective, this paper explores issues involved in designing a new program to promote the development of water commons, working with a non-government organization with substantial experience and strengths in supporting community-led natural resource management, and in geographic information systems. Focusing on combining local knowledge and remote sensing information to support community water management, the paper examines lessons from previous watershed conservation activities, issues involved in understanding water flows and stocks, and the challenges of helping communities develop common property institutions.

Introduction

In the Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) Project, community monitoring of rainfall and groundwater levels followed by estimation and community discussion of water supply and demand changed farmer decisions about which crops to plant and how much water to use (Livingston 2009; Das and Burke 2013). An information-based intervention influencing voluntary decisions seems to have had a substantial impact in improving farmer incomes and reducing water use. This contrasts with the widespread ineffectiveness of top-down regulatory approaches to groundwater management, in India and elsewhere (Shah 2009). The Indian government now intends to expand the application of participatory hydrological monitoring and crop-water budgeting at a national scale. This makes it important to understand the lessons from APFAMGS and similar activities, and how local water management can be made more effective, efficient, equitable, and sustainable.

Several challenges could affect further implementation of the kind of approach used in APFAMGS. Post-project studies indicate that that monitoring and crop-water budgeting activities have usually not been sustained (Verma et al. 2012) raising questions about long-run impact. APFAMGS focused on water withdrawals, without monitoring changes in water consumption which actually determine net impacts on water balances. While a large amount of information was collected about groundwater levels, there seems to have been little systematic analysis of trends and comparative impacts in different areas. Remote sensing may be able to provide information on rainfall and water consumption more easily and cheaply, to better inform local water management decisions, but only if local people are willing and able to use it.

An emphasis on information and voluntary farmer decisions may not be sufficient at all sites or over the longer term, and so, at least in some cases, there may also be benefits if effective regulations could be established. Access to water may not be equitably distributed, and other approaches besides APFAMGS seem to have done more to expand equitable access to irrigation (Reddy, Reddy, and Mohan 2012). A crucial question for applying participatory hydrological monitoring and crop-water budgeting concerns whether there are better ways to combine local knowledge and remote sensing data to improve community management of aquifers and other water commons.

Research on common property governance has found that monitoring of the condition of resources and their use, by users or by monitors accountable to them, is an important principle for successful management of commons (Ostrom 1990; Cox, Arnold, and Villamayor-Tomas 2010). Surface water in tanks, streams and canals is visible, making it relatively easy to monitor how water is used. However, groundwater is often extracted, repeatedly, from many wells scattered across wide areas, making it much harder to monitor and manage. While there is often long local experience with surface water management, and relevant customary institutions, groundwater extraction with tubewells and pumps is newer, and aquifers less well understood, with fewer examples of effective institutions. APFAMGS is a remarkable and important example of an innovative approach to groundwater governance, in which participatory hydrological monitoring has played a central role in changing how groundwater is managed.

This paper looks at use of local knowledge and remote sensing information in the context of a project, Water Commons: Improving Practice and Policy, to develop community management of surface and groundwater resources in villages in India, including Andhra Pradesh, Karnataka, Maharashtra, Madhaya Pradesh and Rajasthan. The project is being carried out by the Foundation for Ecological Security (FES) a large Indian non-government organization. The first section of the paper examines lessons from previous projects, which indicate that local water monitoring contributed to changes in cropping that helped to reduce water demand, but that changes introduced by the project were usually not sustained, and that there may be opportunities to make changes more inclusive and equitable. The second section describes crop-water budgeting, the process through which communities learned how to better balance water use demand with the availability of renewable water resources. Water is supplied by rainfall, for which data can be gathered through local measurement, interpolation from national meteorological statistics, or from satellite measurements, and the third section explores questions about which sources to use or how to make best use of multiple sources of rainfall data. Water demand depends on crop-evapotranspiration, for which satellites now offer the potential for low cost and relatively high resolution information, as analyzed in the fourth section. The conclusions highlight the importance of shifting from regulation of water withdrawal to coordination of cropping choices in making groundwater governance feasible, the potential for using remote sensing data on rainfall and crop consumption to inform local decisions, and the need to consider how sustainable change may depend not only on temporary interventions emphasizing quantitative measurement but on longer run changes in local understanding and action regarding water use in agriculture.

The Water Commons Project

The project on Water Commons: Influencing Practice and Policy supports communities in improving the management of shared water resources, to serve a triple bottom line of social, economic, and environmental benefits. It is funded by the Hindustan Unilever Foundation. Community planning uses participatory rural appraisal to analyze local conditions and formulate a perspective plan, including proposals for water conservation works to be funded through the National Rural Employment Generation Act. The National Bank for Agriculture and Rural Development is supporting more intensive watershed restoration in selected areas. Exposure visits, farmer field schools, and technical advice develop local capacity. Governance institutions, based on inclusive universal membership, are developed at the habitation level to protect and restore common lands and water resources. Communities decide how to use livelihood funds for changes such as better seeds, fertilizer, training in off-farm skills, and different farming and irrigation techniques. Community participants are engaged at the micro watershed and landscape scale in wider networks and platforms for improving natural resources management and policies.

The Water Commons project builds on the previous experience of FES supporting communities in reclaiming, protecting, and restoring pasture and forest lands. It relies on the same kind of participatory planning process, with additional attention to water resources and irrigated agriculture. For example sketch mapping of wells and other water resources helps synthesize local knowledge about groundwater and aquifers. Alternative crops and farming practices can be compared in terms of farmer's criteria for choosing crops, such as risk, ease of cultivation, and profitability. PRA activities can also assess ways of adding value to farm products. Where irrigation relies on electric pumps, there may be opportunities for coordination to improve electricity supply for irrigation (Kimmich 2013).

In FES's previous work on common lands, communities have often established rules, such as restricting burning, or temporarily closing areas to grazing until new trees can get established. These activities have primarily relied on local knowledge, however monitoring has looked at changes in biodiversity and biomass. FES' experience has shown that these kind of changes take time, but can be successfully carried out in many cases. There are also examples of communities that have already taken an active role in governing water as a shared resource, for example through ensuring that plans for pond construction include agreement about who will be able to access the water, rules about installation of wells, or restrictions on what kinds of crops may be irrigated. The feasibility of specific changes depends on local geographic and social conditions, but evidence from previous work shows that there is substantial potential for catalyzing local collective action to improve management of land and water commons, leading to better incomes, more equitable and effective governance, and ecological restoration.

Learning from APFAMGS

The Andhra Pradesh Farmer Managed Groundwater Systems Project offers an innovative example of changing water management through local monitoring of rainfall and groundwater levels and community discussion of the implications of different crops and farming practices for water demand (Livingston 2009; Das and Burke 2013). In contrast to conventional assumptions that rules with effective enforcement of sanctions are necessary to manage groundwater, APFAMGS emphasized voluntary decision making by farmers, particularly changing from irrigated rice to other crops that could consume less water and increase earnings. In many locations, the impact of changes in cropping practices was large enough to contribute to increasing groundwater levels, indicating substantial improvements in balancing water budgets at the local level.

Participatory hydrological monitoring of rainfall and water levels in wells collected data that was used to estimate water availability, based on the percentage of water expected to infiltrate into aquifers. Farmers proposed cropping patterns were then used to estimate their demand for water withdrawals. Supply and demand could be compared to see whether water use would be exceeding the renewable supply, and so contributing to further groundwater depletion. APFAMGS experience showed that in response to this information, many farmers shifted their cropping patterns, leading to reduced water use and improvements in water availability.

Groundwater management is usually considered to be difficult, given the large number of dispersed users withdrawing water from an aquifer. Conventional recommendations for requiring permits for well construction, installing meters, and regulating the amount of water withdrawn usually turn out to be difficult or impossible to put into practice.

Thus, the example of community groundwater management based on better information and voluntary coordination is remarkable as an alternative approach.

Analytically, part of the reason for effectiveness may be due to switching attention from the difficult problem of monitoring and controlling water withdrawal, to much more visible choices about what crops to grow on how much area. Focusing on crops makes it much easier for farmers to observe each other, and see whether people are doing what they said they would.

Shared Strategies in Action Situations

In some cases, coordinated strategies may be sufficient to achieve a result that is better for everyone, if cooperation can be assured, without necessarily requiring norms and social pressure or rules and penalties, to bring about change. Conventional assumptions about groundwater governance seem to assume that the underlying situation is a tragedy of the commons, and that rules with penalties are necessary and may be the only possible solution, either externally imposed regulations, or local rules. Prisoner's Dilemma is not the only possible strategic situation for collective action (Taylor and Ward 1982), and instead there are a variety of other situations, which may be modeled with 2x2 games such as Prisoner's Dilemma, Chicken, Simple Coordination, and Stag Hunt. Reflecting on the effectiveness of a voluntary information-based approach suggests that there may be a variety of underlying incentive structures, in some of which successful cooperation can occur without norms or rules with penalties.

Ostrom and Crawford (Crawford and Ostrom 1995) distinguish between rules, that have "or else consequences" such as penalties, norms that say what should be done, and shared strategies which are just a matter of people making the same choices. Analysis of the possible underlying action situations helps show why, in some circumstances, information may be sufficient for successful collective action, without necessarily requiring norms or rules.[1]

As seems to be suggested by the World Bank (Livingston 2009) study of APFAMGS, the situation might simply be one of lack of information. Once farmers understand there are

1 It should be noted that the terms norms and rules are often used much more loosely than in Ostrom and Crawford's definitions.

alternatives that are more profitable, and may have lower risks, their individual incentives may be sufficient to lead to an outcome that is better for everyone. This would be an "invisible hand" situation, where collective action might be unnecessary, or only be relevant in facilitating the flow of information.

The situation could also be one where coordination alone is sufficient, as long as there is assurance that others will cooperate. Thus, if everyone, or at least most people, refrain from investing in a tubewell, they may all benefit from pumping from a relatively high water table. If some install deeper tubewells and pumps, others may be forced to do the same or lose access to water, even though all then end up with similar, but more difficult, access to water. Thus there could be two equilibrium situations, one with open wells and a high water table, and another with tubewells and a lower water table. Everyone would be better off in the first situation, but only if they can be assured that others will also cooperate, avoiding the risk of losing access to water. Coordination in choosing strategies may be sufficient for collective action in such a situation, so that collective action to share information, as in community discussions about crop-water budgeting, is sufficient to get the best outcome for everyone. In such a case sharing information about plans could be sufficient, but norms about what is proper behavior may help to stabilize cooperation, building confidence that others will also cooperate. Various mechanisms (Nowak and Highfield 2011) can facilitate successful cooperation, including limiting cooperation to a group where others are more likely to cooperate, and making more conspicuous signals about willingness to cooperate.

Alternatively, the situation might be one where each individual could be better off by not cooperating, for example by installing a private pump, but this would lead to a situation where everyone is worse off, a Tragedy of the Commons (Hardin 1968). For a simple two person case this can be modeled as a Prisoner's Dilemma. If the Prisoner's Dilemma situation involves repeated interaction, then it may still be better to cooperate (Axelrod 1984) based on the benefits from future cooperation, and potential retaliation against those who do not cooperate. Communities may be able to establish rules that penalize those who choose not to cooperate, shifting the relative payoffs for cooperation and defection so that cooperation is more attractive.

The analysis of possible action situations can be further extended, for example to situations with unequal payoffs, as in Chicken or Leader (Battle, also known as Battle of the Sexes), and asymmetric situations where different people face different payoff structures. The point for the analysis here is that the situation is not necessarily a Prisoner's Dilemma. Furthermore, even Prisoner's Dilemmas have solutions, especially for repeated interaction, and where people can communicate and even make agreements. The situation may be one where assurance that others will cooperate, coordination on a particular alternative, or just better information is sufficient for cooperation that makes everyone better off. Thus there can be stable solutions for collective action situations where agreement on shared strategies is sufficient, without necessarily requiring norms underlain by social sanctions, or rules with enforced penalties, even though these may be useful and necessary in some cases.

Sustaining Changes

Post-project assessment at selected APFAMGS sites indicates that many of the formal activities sponsored by the project were not sustained (Verma et al. 2012). Thus, in 2008 88% of communities collected groundwater data, but by 2012 only 31% continued to do so. In 2008, 92% held crop-water budgeting meetings, but only 33% did in 2012. The study suggests that changes were more likely to be continued where there was a continuing linkage with an outside organization or activities, such as credit or milk collection. A recent visit to the project area in later 2013 suggests that only two of the hydrological unit networks set up to link activities in different villages were still functioning.

Failure to continue activities after the project makes sustainability questionable. However, it appears that, at least in some cases, changes in farmer's consideration of water in cropping decisions may have continued, even if the formal apparatus of quantitative measurement and estimation of water supply and demand did not. This is suggested in the IWMI study, and by the author's visits to some field sites. Farmers say that they still think about water needs, and discuss this, particularly with those with neighboring fields or those sharing the same well.

The risk that formal activities are not sustained makes it important to think about the actual objectives in changing water use, rather than assuming that this can only occur through the perpetuation of particular formal procedures. A working hypothesis could be that water measurement, estimation of water availability and demand, and community discussions may play an essential role in bringing about change, but subsequently awareness and different patterns of decision making and community coordination may be sustained through more informal, vernacular understandings and practices. Thus, it may be important to define success, and indicators of project impact in terms of changes in knowledge and behavior, and in terms of more balanced water use, rather than only in terms of whether particular project-promoted activities are continued or not.

Enhancing Equity

Experience from some similar but smaller scale projects suggests there may be opportunities to increase inclusiveness and equity in decision making and sharing of benefits. (Reddy, Reddy, and Mohan 2012). Some NGOs promoted a "water for all" approach that included having owners of wells share water with others. If well owners can avoid competitive deepening of wells, they can save money, achieving mutually beneficial cooperation. Over time, at least in one site visited in the field, this seems to have evolved into arrangements for payment for water, in cash or through crop shares. Well-sharing need not rely solely on altruism, but may also offer tangible benefits for well owners, while also expanding access to irrigation.

Some communities have forbidden tubewells (boreholes). In some geological situations, this may allow farmers to continue to rely on open wells and keep the water table higher, rather than being trapped in a situation where everyone is forced to switch to tubewells. There is the opportunity for mutually beneficial cooperation, if enough others cooperate. In other cases, community rules, such as about distance between wells, can help to limit groundwater extraction. Such relatively simple rules may be much easier to establish and maintain than more complicated arrangements for licensing wells or defining formal water rights (Steenbergen and Shah 2003).

Lessons

Analysis of experience from APFAMGS indicates several important points, which can contribute to a strategy for the Water Commons Project and thinking about how to use remote sensing information and local knowledge:

- An information-based approach may lead to substantial changes in water use, based on voluntary decisions and without requiring rules and enforcement
- Managing decisions about crop choices may be much more feasible than controlling pumping
- Shared strategies may be sufficient for successful collective action in some situations, without necessarily requiring norms saying what should be done, or rules and enforcement of penalties.
- Sustainability may come through changes in awareness and action, without necessarily requiring perpetuation of quantitative measurement and other formal project-sponsored activities
- There may be opportunities to go beyond the APFAMGS model in promoting equitable access to irrigation water, and in using rules in some cases

Measuring Rainfall

Rainfall data is available from national meteorological statistics. This grid data can be interpolated to estimate rainfall at a particular location, although this may be less accurate than local measurements. In theory, it would be easy and cheap to simply supply rainfall data based on national statistics to communities. However, the experience of APFAMGS indicated that local measurement was more effective, apparently because it was believed to be more credible and meaningful (Livingston 2009). On the other hand, local measurement is time consuming, and it appears it was often not sustained. For communities starting up activities it takes time to build up a record of measurement. Therefore, providing historical data could offer a useful baseline. However, climate change means that past patterns of rainfall are less reliable as a guide to the future (non-stationarity) so there is a need to go beyond just showing long term tendencies in the past, such as average, minimum or maximum rainfall.

Satellite estimates of rainfall, in particular the Tropical Rainfall Measurement Mission (TRIMMS) can now provide relatively accurate estimates of local rainfall. Archived grid data can be used to provide information for previous years, as well as annual and monthly averages and other statistics. Cellphones now make it possible to share information easily and cheaply through text messages (SMS). Thus, in theory, individual farmers or community representatives could be easily provided with regular information on rainfall measurements, and summary information that could be used to estimate water availability for crop-water budgeting.

The question for the Water Commons Project is what source, or combination of sources of information to use for rainfall data. The experience of APFAMGS suggests that simply providing external data is probably not sufficient. Local measurement appears to be necessary, at least for a period of time, even though its sustainability is questionable. However, this could be supplemented with information about previous rainfall based on grid or satellite data.

It should be relatively easy to routinely provide rainfall information from remote sensing, delivered by SMS. As smartphones and cellular data service, such as 3G, become increasingly available this could also be done over the web. Providing remote sensing data on rainfall might also allow concentration of limited resources on measuring groundwater, for which remote sensing is less useful. A compromise approach, as a working hypothesis for the Water Commons Project, would be to use all three sources of rainfall data:

- Measure local rainfall, at least for the first few years of activities in a habitation
- Provide communities with annual rainfall data based on nearby grid locations, for example monthly averages during the 20th century
- Provide more recent satellite-based data, for example monthly rainfall total over the past ten years.

While the basic data may be numbers in tables, charts can show this information in an accessible, more easily understood way: on paper, on webpages, or painted on the sides of buildings. Over time, the use of rainfall data can be reviewed and adjusted. One possibility is that communities may be willing to rely on satellite data, reducing the need for local measurement. Or, as discussed later, over time they may feel that quantitative data is less necessary, and they prefer to rely on their own observations. In such cases, remote sensing data may still be useful for monitoring conditions in project areas, and has the advantage of not depending on whether local measurement continues or not.

Estimating Water Consumption

Balancing water budgets depends on understanding demand as well as supply. Water is consumed by beneficial evapotranspiration (ET) from irrigated crops, and by non-beneficial ET, for example by weeds in canals or tanks. Return flows may go back to the aquifer or flow downstream, becoming available for reuse unless they go to the sea, saline aquifers, or become too polluted to use.

While farmers can observe how much irrigation water they apply, it is harder to know how much is actually being consumed, and how much return flow is available for reuse, by those sharing the aquifer or located downstream. Conversely, some technologies, such as lining canals, delivering water through pipes, and installing drip irrigation, appear to save water. However, they do so by reducing “losses” that would have returned to aquifers and streams, and so actually take water away from other users. For individual farmers, the technologies may help to save on energy costs, time, and labor, and provide more precise and reliable irrigation, leading to higher production and profits. Nevertheless, to the extent that technological changes reduce water deficits and water stress in crops, contributing to increased production, technological changes may actually increase, not reduce, crop evapotranspiration.

Conventionally, ET was hard to measure directly, and has usually been estimated based on crop coefficients relative to a standard crop such as grass or alfalfa. ET is affected by several factors including temperature and windspeed. Satellite measurements now make it possible to estimate ET directly, based on the cooler temperature of areas where evaporation is occurring. Older satellite measurements, by MODIS, had a resolution of about 250 meters, which could be suitable for monitoring changes on a community scale. The newest Landsat 8 satellite now provides measurements at about a 30 meter resolution, relevant for individual fields or groups of adjoining fields, such as those that may be clustered around a well. The original Surface Energy Balance (SEBAL) algorithm (Bastiaanssen et al. 2009) has been applied by private companies, WaterWatch and eLeaf, to measure ET, using proprietary software. A more recent software package, METRIC, requires less calibration, and is easier to program, and the algorithms for calculation are available in published sources (Allen et al. 2007). As it happens, FES already has significant experience with using satellite data, including MODIS for monitoring land use. Therefore, it may be feasible and suitable to apply the METRIC approach to measure ET in project locations.

As discussed earlier, a key part of the change enabling better groundwater management may occur by shifting from the tough problem of directly monitoring and controlling groundwater extraction to the more manageable question of what crops are grown on how much land. Remote sensing measurement of ET offers the opportunity to better inform individual and community decisions about water consumption, particularly for selecting dry season crops and understanding their impact on water balances. This is particularly important in cases where most return flows become available for reuse, so the crucial question is not how much water is withdrawn, but how much water is consumed by ET. Remote sensing information can play a key role in understanding the actual impact of changes. The challenge, and opportunity, is thus to provide information on ET in ways that are easily understood and used in decision making by communities. Information can be shown on maps, and through charts showing trends in water consumption for a defined geographic area.

For project monitoring, as with rainfall data, use of remote sensing data on ET has the additional advantage of not being dependent on whether local monitoring of well levels is continued or not. Water levels in wells are a very useful indicator for changes in groundwater storage and water availability. However, use of groundwater levels as an indicator is also complicated by the impact of annual variations in rainfall, the time it takes for rainfall to infiltrate and reach the saturated aquifer, lateral flows of groundwater and other factors. ET measurement has the potential to be more immediate and meaningful.

Conclusions

Information from external monitoring of rainfall and water availability is insufficient to inform and improve local groundwater management. Remote sensing cannot provide good information on groundwater levels. Local monitoring can create awareness and credibility that contribute to changing crop choices. However, participatory hydrological monitoring activities themselves appears not to be sustainable. Nevertheless, farmers may continue to make decisions and coordinate collective action in water use, even without quantitative monitoring. Local monitoring can observe water withdrawals, but not consumption, while remote sensing can provide information on consumption for monitoring changes in water demand. Remote sensing information on rainfall and ET could be provided at relatively low cost.

What seems appropriate to support community management of water commons is a hybrid approach, that starts out with local rainfall monitoring, combined with providing data on long-term rainfall based on national grid statistics and more recent local rainfall based on TRIMMS satellite data. Remote sensing data on ET can help inform local understanding and decisions, and provide a cross-check (triangulation) to use of groundwater levels as an indicator of changes in water availability. To the extent that farmers make changes in their local knowledge and practices, particularly awareness of water availability and crop water demand, then remote sensing may not be necessary over the longer term, especially if groundwater levels provide a reasonable indicator of trends in water availability, although remote sensing may still be useful for external project monitoring.

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