Developing Models for Community-Based Ground Water Management in Andhra Pradesh (India)

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Abstract

With the intensive use of groundwater in agricultural economies, management of the resource becomes imperative. This paper aims to synthesize the experiences from several programs that supported community based groundwater management in Andhra Pradesh (India). Arguably, Andhra Pradesh has most experience in systematically supporting local groundwater management – more than any other State in India and more than almost any other part of the world, even though much of the experience is still relatively young. Like other parts in India Andhra Pradesh has experienced a groundwater irrigation boom – with bore well numbers tripling over the past three decades to 3.2 million. This may be contrasted to surface irrigation, which remained stagnant over the same period. The impact of the groundwater boom has been double-edged: on the down side water shortages and reduced soil moisture at the end of the dry season cultivation period and in some areas mobilization of fluoride in drinking water systems, on the up side increased agricultural production, crop diversification and larger access to water for many purposes.

Several programs have tried to restore the balance between supply and demand and use through local management, ranging from participatory monitoring and crop planning on sub-catchment basis; the encouragement of local norms and rules to the connection of individual bore wells in collectively managed systems. The uptake of these systems has been surprisingly positive and empirical evidence is that they were able to reverse the decline in water tables and at the same time create higher agricultural outputs. The challenge still lies in further scaling up local management without loosing the conducive environment that encouraged the transition to collective groundwater management.

Keywords

Andhra Pradesh, irrigation, groundwater, local, management, community, India.

1. Introduction

Over the last three decades groundwater has established itself firmly as a major source of water in large parts of the world. Whereas in the 1980's groundwater was 'discovered' in agriculture in Asia, it stands to do so now in Africa. At present an estimated 70% of the world's population depends for its basic water services on groundwater. In 51% of countries groundwater withdrawal tops 100 m3 per capita annually. Groundwater has created the miracles of accelerated agricultural production in rural economies in India, South Asia, China, North Africa and the Middle East. Even in large surface irrigation systems in South Asia and North Africa 30-50% of the water at farm gate comes from groundwater, creating 'conjunctive realities'. Much of the groundwater development is by private, individual initiative and groundwater is at hand in many parts of the world, even 'where there is no river'.

It is the resource that in several areas still provides the 'breathers', because in many areas all surface water is committed. Particularly if groundwater development is combined with increased recharge and retention of rain water, run-off and flood water there is still scope to expand the use of the resource. At the same time, there are several groundwater disasters – areas with lowered groundwater tables, unbalancing economic and ecological systems, and groundwater quality getting out of hand due to intrusion, up-coning or pollution.

Both the achievement and the problems have triggered attention for managed groundwater development. Yet by and large in spite of the interests at stake, effective groundwater management is the exception rather than the rule. The rule in fact is 'default': nothing happening, sometimes studies, monitoring and the development of laws but often precious little follow up.

In this debate community based groundwater management is now often put forward as a solution with considerable promise. It for instance figures prominently in the policy document on Groundwater Management of the Expert Group of the Planning Commission of India (Planning Commission, 2007). It states: *"Sustainable use of ground water is possible only when users restrict average extraction to long term recharge. Even when recharge is augmented artificially, restraint on use will be required in water scarce regions. In a common property resource, individuals will restrict their use only if there is a credible agreement among all users to limit their use. Cooperative management of ground water by the users is thus necessary. Peer group pressures can generate socially responsible behaviour as has been observed in self-help groups"*.

This paper aims to contribute to the learning mentioned above and documents and discusses the various efforts in promoting community based groundwater management in Andhra Pradesh. Arguably, Andhra Pradesh has most experience in systematically supporting community based groundwater management – more than any other State in India and more than almost any other part of the world, even though much of the experience is still relatively young and at pilot stage. Andhra Pradesh has also initiated several other initiatives to address the intense use of groundwater: large watershed development, subsidized supply of micro-irrigation systems and the promulgation of the Andhra Pradesh Water Land and Trees Act. The State Government has been giving and taking at the same time, because it has also continued to sponsor the use of groundwater: until 2004 agricultural power supply was provided below market rate. As of 2004 the new State Government supplied free power even for free although supply at the same time was rationed to seven hours per day. In general high water consumption crops have been supported more than dry land crops: in the Public Distribution System for instance rice has a guaranteed minimum price.

This article first discusses development of groundwater in Andhra Pradesh. It next documents the policy responses in Andhra Pradesh to the changes in groundwater levels that came with the intense development of groundwater. It especially discusses different efforts in promoting community based groundwater management and the effectiveness of these efforts as they stand now.

2. GROUNDWATER MANAGEMENT IN ANDHRA PRADESH

Like other parts of India, Andhra Pradesh has seen a spectacular increase in groundwater based irrigation. In 1979 the area under groundwater irrigation stood at 1 million hectares. It increased steadily over a thirty years period and in 2008 reached an area of close to 3.2 million ha, equivalent to the area under surface irrigation. There was a shift in Andhra Pradesh in rice production towards the dry Telangana region and there was an increase in horticultural production too in the same area. There are over 1.9 million wells officially registered in Andhra Pradesh.[1]

A plateau of some sorts appears to have been reached. Between 2000-01 and 2005-06, power consumption increased with 18%, whereas the area under groundwater irrigation increased with 7% only (Murali Krishna Rao, 2009). This suggests that pumping had to be done from larger depths and more power was required to lift the same amount of groundwater.

The rapid and steady increase in groundwater irrigation in the last thirty years may be contrasted with the development of surface irrigation. Over the same period the area under surface irrigation in Andhra Pradesh ended where it started in the beginning of the period but with considerable upswings and downturns in spite of considerable investment in infrastructure and institutional change. This goes to suggest that surface irrigation services are volatile and less robust than groundwater irrigation (though overuse may move groundwater in unpredictable territory as well). The same point is also made in Shah (2009).

The geology of Andhra Pradesh is made up of a patchwork of small water basins. Nearly 85% of the entire state is underlain by hard rocks: volcanic and metamorphic rocks, mainly granites, gneisses and khondalites. The groundwater-dependent part of the Andhra Pradesh falls almost entirely in this geological category. As a result, the aquifers have limited storage capacity and limited interconnectivity. Dolerite dykes extending from a few meters to a few kilometres cuts across the state at many places (Murali Krishana Rao, 2009).

The main point to be made on the geology of Andhra Pradesh, however, concerns s not the composition of the aquifers, but the <u>size</u> of the hydrological units in Andhra Pradesh. Aquifer systems in Andhra Pradesh are quite small – making their management relatively uncomplicated. According to the State Level Groundwater Estimation Technical Committee, the State is divided into 40 drainage basins and 81 sub basins of major and minor rivers. These 81 sub-basins are further divided into 1195 groundwater basins of 100 to 300 square kilometres size - based on local drainage circumstances, geomorphology and hydro-geology. Detailed monitoring undertaken in the Andhra Pradesh Farmer Management Groundwater Systems (APFAMGS) project suggests that, from the hydrological perspective it is rational to manage groundwater on the basis of these groundwater sub-basins as all wells in a given sub-basin behave more or less in the same manner.

With the current level of groundwater abstraction Andhra Pradesh as a state is in the 'water scarce' territory – defined as more than 40% of its water resources being used. In some districts the proportion is much higher: in Ranga Reddy, Ananathapur, Medak and Nizamabad, the proportion of water resources used is upward of 70%. The water table dropped significantly from 1998 to 2006, with an average decline of 1.90 meter (Murali Krishana Rao, 2009). With the relatively wet monsoons from 2006 onwards, the large scale implementation of watershed and adoption of water saving measures the groundwater level in the state has recovered in the period 2006-2008, yet 2009 with a dry monsoon again saw a drop in water tables. Besides the overall year to year trend the main issue is the intra-annual decline: with lower groundwater tables crop production is

[1] As in several areas there are many unauthorized connections, the figure may even be higher.

in peril in the dry *rabi* season – with water in some sub-basins 'running out' before the end of the crop season.

One factor often associated with the decline in groundwater is the policy of providing electricity at subsidized rates to agricultural users (Kishore et al, 2004). Before 2005 agricultural electricity subsidies reached almost 90% of total costs. After the new government assumed power after the 2004 elections, electricity even started to be supplied free of charge to agricultural consumers. At the same time, however, supply was reduced from an average of fourteen to seven hours a day – usually in two shifts.[2] In terms of cost to the public exchequer the change was thus not large – and probably even positive. The removal of the last 10% of the cost was off-set by a 50% reduction in power availability.

The availability of free electricity from 2004 onwards therefore did not lead to a drastic jolt in agricultural groundwater use. There has been no sudden change but rather a steady increase in groundwater use (Murali Krishana Rao, 2009). The 2005-2009 period was also a period with above average rainfall, reducing the need for new wells. In fact many dried wells started to yield water again in this period – some throughout the year, others for part of the year.

The electricity subsidy resulted in a skewed money transfer: large farmers (owning more than 3 ha) making up 23% of the farm population received 54% of the subsidies. This is because larger holdings have a larger coverage of electric pumps (27% of landholdings equipped with a borewell) and hence they disproportionally benefit from the power subsidies (on average INR 17200 a year). Marginal farmers (owning less than one ha) on the other hand make up 43% of farmers (only 8% of whom own a tube well) but are the collective recipient of only 10% of the free power units (Colombia University, 2008). It should be noted that accurate figures on power consumption are notoriously difficult to obtain, because unauthorized connections are not uncommon. Case studies suggest that they may even make up 30-40% of all connections (CWS, 2009).

The criticism with regards to the free power system is that it is costly and has suppressed the price incentive to develop more efficient irrigation systems and more efficient power supply systems. There is considerable scope for the latter: many pumps (15%) are set far below pumping depth causing unnecessarily lift and hence power savings are possible (according to the APFAMGS data base). Also the widespread use of assembled pump kits[3] rather than branded kits is a cause of high energy consumption. Branded kits are assumed to be twice as energy efficient as assembled kits.

One may however question how much electricity price incentives should be blamed for the overuse of groundwater or for the lack of management. Even when electricity was free, both adoption of efficient irrigation methods and adjustment in pump settings took place - apparently driven by other benefits than saving on the electricity bill. Hence though subsidized or even free electric power is encouraging groundwater pumping and is a huge waste of public resources, it is <u>not</u> preventing better water management – individually or collectively.

In fact, the link between groundwater use efficiency and electricity is far more complex than that of a price-incentive or disincentive. One important link is the timing and reliability of power supply. If electricity comes at night, it may not be used depending on the crop and the crop stage - for fear that uncontrolled irrigation might do more harm than good. However, the introduction of sprinklers – though a water efficiency measure –

[2] With farmers typically banking on 5.5 hours a day.

[3] It is estimated that 55-65% of pump kits in Meheboobnager and Ananthapur are assembled.

has made it easier to irrigate at night as sprinklers that are triggered by the automatic switches do less damage, because they do not create a large uncontrolled field flow. It seems that efficient groundwater irrigation is not so much a function of a higher electricity price. Instead groundwater irrigation efficiency seems to be more related to the convenience with which electricity is supplied: high efficiency irrigation goes hand in hand with convenient power supply (see also box 1). This is also the basic assumption underneath the use of dedicated agricultural feeders as a trigger to manage groundwater based agriculture efficiently – in particular the Jyotigram scheme in Gujarat (Shah, 2009). Under this scheme dedicated feeder lines were installed supplying power at pre-announced schedules. A review of the scheme suggests that it has helped reduced the electricity bill for the state – substituting abundant but erratic supply with pin pointed high quality power. The downside at the moment is that the groundwater markets in Gujarat (that thrived on the cheap access electricity) have shrunk – and hence reducing access of the not-haves.

Box 1: Electricity and groundwater in Andhra Pradesh

In Andhra Pradesh long power lines causes hardship. This has been demonstrated by work undertaken by the Centre of World Solidarity (2009). CWS has studied energy issues in two villages in some detail. In both areas there was a 'tail end issue'. At the end of the local electrical feeder lines tension was extremely low making it difficult to simply run the pumps in these areas. There was in general a large disconnect between the farmers and power distribution company (DISCOM). This manifested itself from both sides: many unauthorized connections, poor quality of wiring in low voltage lines, poor motor connections and non-use of capacitors which are meant to switch off pumps at potentially damaging low voltages. The result was regular burning of the transformers and the motors and also very low voltage at the end of the distribution lines, causing low discharges. In these two villages CWS and its partners initiated discussion on efficient energy and water use, encouraging the installation of capacitors on all pump-sets and with the power providers attempting to regularize unauthorized connections. The efforts led to increase in voltages (20%) at tail-end pump-sets, fewer power interruptions as well less motor burn-outs, lower current consumption and distribution losses.

The impact of dropping groundwater tables comes in different forms. First there is the immediate human tragedy in many areas. Severe distress has been reported, caused by the hardships of a failed crop due to a shortfall of water availability at the end of the cropping season.

A second impact is the adjustment in cropping strategies. Especially in rabi (dry season) the area sown varies depending on the pre-seasonal level of the water table. During years of low water tables farmers reduce the area sown and vice versa in a good year. (Colombia University, 2008). A similar but weaker trend occurred in the wet *kharif* season – but here rainfall takes care of a large part (50% - 60%) of the water requirements.

Thirdly, the gradually declining groundwater tables do result in costs of failed wells, the need to pump from larger depth and the loss of soil moisture. A particular important loss is the loss of the buffer that could compensate for a bad year or delayed rainfall. This is illustrated with the example of E. Palaguttapalli Panchayat in Chittoor District. Until the 1970s all irrigation was based on bullock-driven open wells, of which a total of 76 were in place. The area irrigated was 16 ha and groundwater consumed was 21880 cubic meters per year In the 1980s and 1990s new bore well development took off in a major way and groundwater consumption increased more than 10 fold. The area under irrigation reached 60 ha during these years made possible with the development of 152 new bore wells. Some open wells (46 in total) survived the groundwater onslaught. From 2000 onwards the miracle in E. Palaguttapalli started to falter. All dug wells fell dry, but the tube wells did not escape this fate either. Only 59 continue to be productive, whereas all dug wells have dried up. The area under irrigation is back to where it was in the seventies. Only, the groundwater buffer has been lost in the process: exposure to a dry year is worse than it was before (Kolagani, 2008). Previously a dry year could be tidied over with the groundwater reserve available, but now – with lowered water tables and diminished buffer capacity - the exposure to variability is higher.

Fourthly, in some areas overuse also affects water quality - in particular in fluoride levels. In several parts of the state fluoride levels are above the 1.5 mg/litre with the latest data from the Groundwater Department suggesting that 12% of samples were affected by high fluoride levels and 33% by nitrate (Murali Krishana Rao, 2009). In Andhra Pradesh fluoride problems are made worse as water tables decrease – with more fluoride mobilized from deeper levels with fluorite, apatite rocks. Fluorosis is more widespread in areas categorized as 'overused'. The fluorosis that is the result causes the mottling of teeth or – at higher exposure – severe affection of the joints and even renal failure. What is equally tragic is the stigma that comes with endemic fluorosis and other effects of water contamination.[4]

The final point to be made however is that the effect of overuse of groundwater in Andhra Pradesh is not necessarily irreversible. In many areas it is an annual gamble with water availability with the risk of water running out from one's well before the season is over. At least in a large number of areas groundwater is replenished in the monsoon season. Investments in watershed management have further increased the recharge of the small fragmented aquifer systems (Bakka Reddy and Ravindra, 2004), but the impact has differed from locality to locality – depending on the thickness of the local aquifer and the availability of recharge zones. The small relatively shallow aquifer systems make it possible in theory to restore order, even in relatively short time frames. This contrasts with the notion of the 'race to the bottom' in which groundwater depletion is often depicted – suggesting a relentless pursuit of dwindling groundwater resources that would take ages to restore. At least in Andhra Pradesh the situation is different and in many respects less grim.

3. PROMOTING COMMUNITY BASED GROUNDWATER MANAGEMENT

Closing the deficit

Several initiatives have been undertaken to regulate groundwater development in Andhra Pradesh – in many cases by actively engaging groundwater users. The sheer task of regulating the enormous number of groundwater users 'from the top' only is generally considered unrealistic – see for instance the quote from the Planning Commission in section 1. This is underscored by the difficulty and limited success in implementing the

[4] An example is Pullavolle Village in Nellore, where fluorosis has become very widespread and where people find it now hard to marry persons from outside the village.

Andhra Pradesh Water Land and Trees Act – promulgated in 2002 and amended in 2004. Under the Act, well owners are required to register wells and pay a small registration fee. Landowners wanting to develop a new well need to have a license for their electricity connection and a permit from the designated authority, who will assess whether the well is located in an overexploited area and, if a permit is granted, will decide on the distance that must be observed to neighbouring wells.[5] The drilling rig operator has to obtain a feasibility certificate from the Groundwater Department and cannot charge the landowner for a failed well. The designated officer from the Groundwater Department can also announce a ban on pumping in a given area for a period of six to twelve months. In addition, there are rules on sand mining operations and on recharge structures. One shortcoming of the Act is that it does not address the use of existing wells and the situation of overuse that they may contribute too. The larger problem however is that the Act has been cumbersome to implement and that there is still confusion as to who is responsible for what part of the enforcement provisions.

The Government of Andhra Pradesh has initiated several programs to restore the balance in groundwater availability. Over the last ten years it has undertaken several large watershed development programmes, installing a large range of water harvesting and ground water recharge measures: infiltration trenches, contour bunds, gully plugs, percolation tanks and infiltration wells. There has been much debate on the impact of the watershed on groundwater levels. There are, however, not many detailed impact studies. Case studies for a number of watersheds, i.e. Kunkanur (Kunrool), Mailaram (Ranga Reddy), Chityal (Mahaboobnagar) and Edulapally (Medak), have shown that the impact of the watershed improvements has been very much a function of local geological formations – i.e. adequate siting - with not every watershed program being able to deliver the goods. In three out of four watershed water tables however rose significantly and dry dug wells filled up again. This impact however rapidly disappeared. The rise in water tables was followed by the development of new bore wells again causing the disequilibrium that existed prior to the water harvesting measures to reinstate itself. It was realized that promoting water harvesting without simultaneously introducing local demand management would not resolve the problem of groundwater running out before the end of the irrigation season (Bakka Reddy and Ravindra, 2004).

Another important response by government to the intensive use of groundwater was the promotion of micro-irrigation through the Andhra Pradesh Micro-Irrigation Project. Under this so-called APMIP project eligible farmers were provided with subsidized drip and sprinkler systems from recognized manufacturers. The cost of the systems is of the order of US$1500/ha—with 50-70% of this cost typically subsidized by the government. The price for this package included after sales and extension services by the manufacturers.[6] Initially, the demand for the drip irrigation systems was particularly large among medium-size and large farmers as they had land to which they could expand irrigation coverage. The drip systems were particularly popular because they allow water to be conveyed over large distances (which is important because it is difficult to develop wells) and because they save labour costs in weed control and field channel maintenance. A rough estimate is that savings resulting from installation of drip irrigation amount to US$250/ha (APFAMGS Data Base) – with variations depending on soil type and slope). Increasingly, however, drip and sprinkler systems are appreciated because they lead to increased crop production. Using sprinklers in peanut cultivation is said to double yields for instance: this is because the incidence of fungi and pests is reduced. Similarly, in the

[5] A minimum distance of 250 meters to a drinking water well needs to be there and in areas designated as overexploited distance rules may be put in place.

[6] These have been hard-pressed to deliver on this, among other reasons because of a shortage of trained manpower in these fields.

cultivation of sweet orange yield increases of 30% have been obtained and the fruits are said to be harder and thus less susceptible top post-harvest damage and of better taste.[7]

There is a very important lesson here: the use of micro-irrigation (and other field water management techniques – see next) allows for significant gains in farm production and productivity and a concomitant reduction in water consumption. In other words – put in the right context – micro-irrigation and other water management techniques allow a combination of sustainable resource management and economic growth. Sometimes these two objectives are projected as opposites: gains on one front (growth) are said to have to happen at the expense of the other (sustainable resource use). Improved field irrigation methods make it possible to achieve higher production and lower water consumption at the same time. The experience in Andhra Pradesh suggests the opposite of the Malthusian zero-sum.

A different mechanism is at work hence – that of pressure on the resource triggering better and balanced use and overexploitation being reversed. As a standalone intervention, however, the introduction of efficient field irrigation systems may not result in overall reduced water demand or a restoration of the balance between recharge and discharge. Nor are watershed programs on their own sufficient to reverse the tide. They are however very important components to get to a stage of sustainable resource use which, as will be discussed below, will have to be put in the context of local community-based groundwater management and regulations.

In some villages in Andhra Pradesh such local regulation has come about spontaneously. An example is Maramreddypalli in Nellore. In this village bore wells are only allowed for drinking water. Irrigation requirements need to be met from dug wells. This triggered several water saving measures: the use of lined channels and shade trees for instance as well the implementation rainwater recharge activities. In other villages in Andhra Pradesh – for instance in Anathapur, dry season paddy has been spontaneously banned and outside contractors have been prevented from mining sand. The latter measure ensure that groundwater recharge from local rivers is not disturbed (Water Conservation Mission 2003). These spontaneous cases are however few and far between: the question is how they can be promoted.

The demand for addressing local groundwater management is substantial. This became clear from short village training on groundwater management that was organized under the Water Conservation Mission in 2003-4.[8] The training consisted of two local workshops, aimed at getting groundwater management on the agenda of 970 administrative units local government units (*Gram Panchayats*), classified as suffering from groundwater overuse. In each of these units a short micro-planning process was organized. 25–35 persons were invited to a training workshop on groundwater management from a cluster of six to eight villages with the large number of persons from the hosting village. The trainees were mostly members of the Natural Resources Committees of the Gram Panchayat. In the training, a series of participatory rural appraisal techniques were used (transect, village mapping, time-line and water budget[9]) to jointly analyze the

[7] The water conserving practices in use for different crops are– groundnut (sprinkler, mulching, drip, check basin), rice (SRI, PVC pipes, mulching), chillies (alternate furrows, mulching, PVC pipes), sweet orange (PVC pipes, mulching, drip, double ring), sunflower (PVC pipes), banana and papaya (both drip).

[8] The Water Conservation Mission was set-up by the then Chief-Minister within the Rural Development Department to support and guide the watershed programs, implemented on a large scale in this period, under the Neeru Meeru program. In addition it was meant to support water policy development, among others through the preparation of a Water Vision.

[9] This was a simplified water balance – using largely generic figures on recharge and discharge.

development of the groundwater status and the causes for declining water tables. A total of 27800 persons were trained in this way. The training was undertaken by district-based non-government organizations, which were already involved in the implementation of watershed.

As part of the training, 970 micro water resource management plans were prepared. In general, these consisted of a package of local regulatory measures and usually quite modest investments. A breakdown of the contents of the micro plans indicated that specific activities were identified for action in four realms (the numbers in parentheses indicate the percentage of the plans that included that specific provision:

- Local regulation of groundwater use (98%)

- Desiltation and clearance of tanks and feeder canals (90%)

- Small water harvesting and groundwater recharge measures (88%)

- Repairs of local drinking water facilities (75%).

The local regulations consisted of plans to change to less water consuming cropping patterns (92%); restricting the area under rice cultivation in the dry season (88%) and restriction on the development of new wells (82%)—either in absolute terms or in terms of well depth or zoning. In a small number of cases —located near small rivers— restrictions were proposed on indiscriminate sand mining by outsiders as sand mining affects the capacity of these local streams to buffer monsoon flows and recharge local aquifers (van Steenbergen 2006).

The willingness for regulating local groundwater use hence is there as seen from the response to this training and more in general, from the adjustment in the area sowed following a monsoon with limited rainfall. The challenge is how to systematically promote community based groundwater management. The remainder of this section discusses the experience of four projects that have worked on local groundwater management in Andhra Pradesh: the pilot on social regulation by the Centre for World Solidarity (CWS); the groundwater component of the Andhra Pradesh Drought Adaptation Initiative (APDAI), the APWELL project and the Andhra Pradesh Farmer Managed Groundwater Systems Project (APFAMGS).

Promoting local groundwater management

Local groundwater management in agriculture can take many different shapes. There is a spectrum of local governance arrangements – from using informal norms to allocating groundwater to different users (van Steenbergen 2006). In the different activities promoting local groundwater management in Andhra Pradesh there are three levels:

- Coordinating crop plans – adjusting crop plans to water availability

- Promoting social regulation – collective agreement on groundwater use and new well development and sharing access to groundwater – moving from individual to collective systems

The first project that aimed to promote local ground water management was the Andhra Pradesh Well Development Project (APWELL). APWELL started off as a classic groundwater development project aiming at installing group tube wells for marginal farmers. In the latter part of the project community-based groundwater management was introduced as well – following increasing concern on the overuse of groundwater in the project districts. Participatory hydrological monitoring was introduced whereby male and female farmers were trained to take groundwater level readings and collect meteorological data. In several project sites experience developed with regulating local use of groundwater and promoting alternative cropping patterns. A prime example, MC Thanda, is described in box 2.

Box 2: Social regulation in MC Thanda

In MC Thana up to 1994 the main source of income was labour migration – bringing the normal hardships with it. Rain fed cultivation was the main form of agriculture at the time. There were four individually owned bore wells only in 1994. All this changed when MC Thanda became part of the APWELL project. Under this project twelve bore wells were installed, that were given in ownership to groups of four farmers each. Group members contributed both to the drilling of wells and the cost of the transformer and electricity line. Soon after the bore wells in MC Thana became operational there were concerns that groundwater was going to be overused. Farmers were therefore trained to measure groundwater levels – under the participatory hydrological monitoring package. Following these experiences collectively a number of social regulations were put in place that was meant to balance groundwater use and supply:

- No paddy and sugarcane to be irrigated from the boreholes
- No one allowed to sell his/her land
- No one allowed to sell water from a bore well
- No individual bore well to be permitted – unless with the permission of the committee
- No new bore well to be developed
- No bore well deeper than 200 feet allowed

These rules have been robust and have been maintained locally – not needing support from outside. Part of the confidence of the local committee comes from the perceived community ownership of the transformers. As farmers contributed to the cost of the transformer under the APWELL project, they feel entitled to regulate who is connected and who is not. This is one success factor. Another one is the relative uniformity of the community and also the equality in status: all 90 families have access to land directly (84) or through land lease (6).

Coordinating crop plans

The successor project of APWELL was the Andhra Pradesh Farmer Management Groundwater Systems Project (APFAMGS). APFAMGS operated from 2003 to 2009.[10] It made promoting community based groundwater management its very central concern. APFAMGS was probably the first project globally with such a scale and exclusive focus on groundwater management. In APFAMGS there was no investment in infrastructure. The emphasis instead was on increasing the collective understanding of the groundwater resource by and through farmers. This thrust was captured in the project's sub-title: *'demystifying hydrological science'*. Farmer measurement of basic hydrological parameters was to be the basis for coordinated crop planning by groundwater-dependent farmers.[11]

APFAMGS was active in 62 hydrological units (sub basins); spread over seven districts in Andhra Pradesh. The average population size of a hydrological unit is 9684 households. Though there is a range the average number of groundwater users in a hydrological unit is 406 households. In each of the hydrological units a number of activities are undertaken:

- Promoting participatory hydrological monitoring
- Crop water budgeting for the entire hydrological unit
- Farmer water schools – to improve understanding of groundwater and introduce water saving techniques and change cropping patterns.

In each 'habitation' (village unit) in the hydrological units farmer volunteers are trained in measuring water tables. These farmer volunteers then become the nucleus of the Groundwater Monitoring Committee (GMC) for the particular habitation. There has been much emphasis on not making this a male prerogative, but rather the opposite. Considerable attention in fact was given to training women farmers.

Going a step further, the GMCs in a hydrological unit became the basis for the Hydrological Unit Network (HUN), set up on the basis of sub-basins. The HUNs have been legally registered under the Societies Act, which has meant that they - apart from undertaking groundwater related activities - are legally allowed to operate accounts and handle funds. Farmer Water Schools (see next section) for instance were directly run by the HUNs.

In each habitation piezometers[12] were installed on selected tube wells. Groundwater readings from the piezometers were taken by the farmer volunteers. In addition, there is a basic weather station for a cluster of three to four villages too. This is again managed by farmers. All the data are displayed on a board in the concerned village and the board is posted on a wall in a prominent place. The local monitoring is feeding into an annual Crop Water Budgeting exercise, undertaken prior to the dry rabi season. In the planning exercise the expected water demand for the rabi season is compared against the estimated recharge. The water demand is based on the combined cropping plans of all farmers of all habitations in the hydrological unit. This information is collected by the

[10] APFAMGS first phase funding came to an end in 8/2009 but is expected to resume in 2010. In the meantime the HUNs keep a low intensity operation (including crop water budgeting and hydrological monitoring) running.

[11] In contrast to the other initiatives discussed in this paper APFAMGS only works with groundwater users.

[12] A piezometer is a relatively simple instrument that measures the depth of groundwater.

Groundwater Monitoring Committees. Based on the crop water requirement the total water demand for the (dry) rabi season is calculated for the sub-basin. This is then compared with the available recharge.[13] Available recharge is based on the average rainfall for the rabi season and the recharge factors per soil type as established by the Groundwater Estimation Committee. This estimated recharge is added to the balance of the recharge available from the preceding (wet) kharif season. The balance from the kharif season is based on actual rainfall, recharge factors and the cropping pattern in the kharif season.

At the Crop Water Budgeting meeting a number of water saving measures are showcased such as the use of farmyard manure, vermi-compost and green manure, the SRI methods for rice cultivation and alternate furrow method for cotton, drip systems as well as the use of less water demanding crops. The Groundwater Management Committees then discuss the water balance. The point to make is that the adjustments that farmers might make to their original plans are voluntary and individual. There is no mechanism to coerce adjustments or for that matter impose a crop plan. The crop water budgeting exercise makes it possible, however, for farmers to make a more informed decision on their cropping pattern and adjust plans to expected water availability. The is in line with a general pattern of adjustments in sown areas and cropping patterns undertaken following a monsoon with low rainfall (Colombia University 2008).

An addition and important component of the APFAMGS project is that in each HUN a Farmer Water School was set up. The training provided by these schools consists of sixteen sessions starting in July each year. The program for the season is, by and large determined at the beginning of each cycle by the farmers attending the course.[14] Use is made of a variety of non formal education methods in order to get the groundwater message visualized and understood. A typical season could include the following sessions: Introducing the Farmer Water Schools; Knowing the Hydrological Unit; Participatory Hydrological Monitoring; Groundwater Recharge; Estimation of Groundwater Recharge; Estimation of Discharge and Groundwater Balance; Crop Water Budgeting Workshop; Review of Farmers Decisions; Crop Adaptation Results; Alternate Irrigation Practices; Increase Soil Moisture Retention; Analysis of Participatory Hydrological Analysis; and ending with a Farmer Water School Field Day. On request other topics are included too. Since the inception of the APFAMGS project in 2008 over 15000 farmer volunteers completed the water school training and the schools were eventually largely run by the HUN committees who handle both the budget and their organization (FAO, 2008).

The impact of the APFAMGS activities has been analyzed from the detailed data base that the project maintained – containing for a large number of hydrological units information on the original crop plans for each rabi season (prior to the crop budgeting meeting), the adopted cropping plan, the use of water conservation methods, the water tables and the number of running wells.

The impact of a creating a joint understanding on the groundwater situation can be assessed from comparing the original crop plans for the rabi season with the crop pattern that in the end was actually adopted in the season. As described above, based on the measurement of groundwater tables and the rainfall in the kharif season an estimate was made of the volume of water available for the rabi crop was made. This was compared with the irrigation requirements in the original crop plan – resulting in a negative or a positive balance. This balance was discussed in the Crop Planning Meeting.

[13] The method used does not fully take into account subsurface stream inflows and is cautious on estimating the effect of water efficiency measures. This means that it errs on the conservative side.

[14] This is done by a ballot exercise whereby each farmer indicates his special preference.

In the years 2005-2006. 2006-2007, 2007-2008, respectively 25, 47 and 49 HUNs provided data for original crop plan and achieved cultivation. For this analysis the data of 22 HUNs have been used for which there were data for all three consecutive years. In 16% (2006-2007) to 37% (2005-2006) of the HUNs the water balance on the basis of the original cropping plan was positive, but in 63% to 84% of the HUNs the predicted water balance was negative – even in spite of the relatively good monsoon rains in these years. There were essentially three responses possible for each of the two situations. In case of a positive balance farmers could either (1) adopt crop plans that would even use more water but stay within the limits of sustainable yields (the adopting response), (2) use more water but overshoot the target (the overreaction response) or (3) adopt a cropping patterns that even used less water in spite of the predicted positive balance (the irrelevant response). The response for HUNs with a predicted negative balance is the main interest as APFAMGS was set up particularly to rebalance overuse situations. The categories of responses are essentially similar and also fall in three categories. The adopting response (1) concerns the HUNs where water consumption was reduced in the adopted cropping patterns as compared to the original crop plan. The strong reaction/ overreaction response (2) concerns the HUNs where a predicted negative balance in the end transformed in an actual positive balance. This overreaction ranks as a positive achievement as well as it ends overuse. The irrelevant response concerns the HUNs where in the end the negative balance from the adopted cropping patterns was worse even from the predicted balance of the original crop plans.

Table 1: Responses to crop water budgeting in 22 HUNs of APFAMGS

	Predicted Positive Water Balances			**Predicted Negative Water Balances**		
	Adopting response (%)	*Overreaction response (%)*	*Irrelevant response (%)*	*Adopting response (%)*	*Strong reaction response (%)*	*Irrelevant response (%)*
2005/2006	*3 (37.5)*	*0*	*5 (62.5)*	*6 (42.9)*	*1 (7.1)*	*7 (50)*
2006/2007	*0*	*0*	*1 (100)*	*13 (61.9)*	*2 (9.5)*	*6 (28.6)*
2007/2008	*0*	*0*	*6 (100)*	*8 (50)*	*2 (12.5)*	*6 (37.5)*

Table 1 traces the different responses to the crop planning exercises for the three subsequent years. The main results are:

- In HUNs with a predicted positive water balance on balance there has not been a systematic follow up to the crop planning meetings: in some HUNs farmers went for a cropping pattern with even larger water requirements (which was possible), but in a larger number of cases the crop water requirements in the adopted cropping patterns where lower than in the original plan – in spite of a positive balance. The same is true for all three years, though responsiveness to the Crop Planning Meetings increased slightly over the three years;

- In HUNs with a predicted negative water balance on the other hand responsiveness was higher. Responsiveness also increased in the second year and went down slightly the next year. In the first year only in less than half of the HUNs cropping patterns were adjusted to the predicted overuse. In the second and third year this was 71 and 63%.

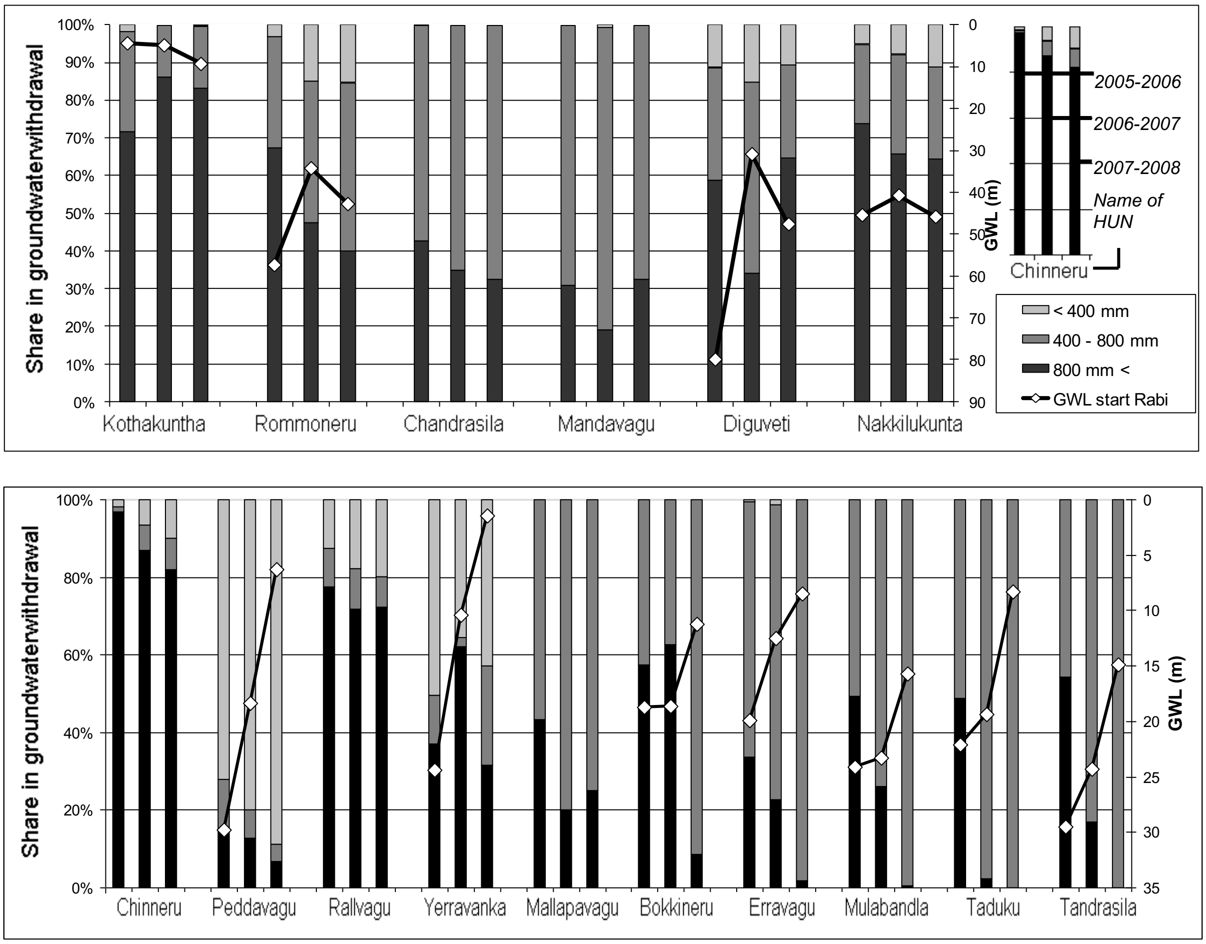

Figure 1: Trends in cropping patterns over 2005-2008 with hydrological units having positive (a - above) and negative (b - lower) water balances in the first year.

There appeared to be a learning effect with the crop planning methodology catching on in the second year only. In fact the responsiveness if not looked at from the angle of a single year (i.e. the adjustment immediately following the crop planning meeting) but looked at over a series of years is far higher. This is demonstrated by figure 1. All the HUNs that started with a negative water balance did better over the years and reduced the proportion of high water demand crops. In all these HUNs paddy cultivation in particular reduced very significantly over the three year period – in half of the cases almost making an exit from the rabi (dry season) cropping patterns, even from high starting points. This resulted in rising water tables, as can be seen from the dot lines in figure 1b, suggesting that the intensive awareness program was very successful in the overstressed areas particularly. In contrast HUNs where there was still a 'slack' and where the prediction was that water consumption would not exceed available supply did not adjust their cropping pattern (figure 1a). Water tables in this category of HUNs fluctuated and were not in a corrective mode as in the overstressed HUNs.

In addition to the adjustment in cropping patterns, there has also been a significant increase in the use of improved field irrigation, moisture conservation and micro-irrigation methods in the APFAMGS areas – going up from 14.7 % of the area in 2005/2006 to 33.7% of the area in 2007/2008. The increase concerns methods that involve subsidized investment – in particular drip and sprinkler systems, provided under APMIP (see above) as well as methods that concerned management measures adopted by farmers, such as check basins or the use of vermicompost. The two changes – the move to medium delta crops and the increased use of SWC and micro irrigation reinforce one another, because most of the efficient irrigation methods are particular suitable for middle delta crops.

As part of the World Bank Review of APFAMGS by the University of Delhi the changes in farm profitability as related to shifts in cropping pattern were estimated. The Net Value of Output (NVO) from cultivation of different crops was estimated using the data collected from sampled farmers. The NVO was estimated as the difference between gross value of crop output (GVO) per ha and the paid out cost (Malik, 2008). The shifts in farm profitability have been assessed by comparing the farm profitability of the project farmers 'before' and 'after' the project. This comparison has been supplemented by a comparison of the shifts in farm profitability of project versus non project locations in the same area. To partly offset the effect of changes in prices of inputs and outputs in the pre and post project periods, all the inputs and outputs both in the base (2005) and current period (2008) have been evaluated at the level of 2008 prices.

The results show that the NVO in all the HUNs in the project areas is higher in the current period than that in the base period though the order of changes does vary across different HUNs (table 2). In the non project areas on the other hand, the NVO per acre in the current period is lower than that in the base year in two of the three HUNs. Further the NVO per acre in the corresponding HUNs in the project and non project areas in both the current and base years as also the changes in them over the period is much higher in the project areas as compared to non project areas. There are several factors at play here and project impact being one of them, yet the comparison between project and non-project areas makes a convincing case that crop water budgeting – and the changes in cropping pattern and field irrigation methods that it triggered – had an overall positive impact on famers' economy as well as the water balance.

Table 2: Change in NVO per acre of groundwater irrigated area between current and base period – Field Crops, Project and Non Project Areas.

	NVO Per Acre		
HUN/ Type of Area	Current	Base	% Change
Project Areas-Field Crops			
Chandrasagar	16838	8987	87.35
Mallapavagu	9884	5835	69.39
Nakkilavagu	13339	6301	111.72
Narsireddypalli	11208	8378	33.78
Erravagu PRT	7042	5317	32.43
Peetheravagu	7583	7124	6.44
Vajralavanku	18051	9420	91.62

Non Project Areas-Field Crops			
Chandrasagar	4348	6415	-32.22
Mallapavagu	3491	2605	34.01
Peetheravagu	2500	5173	-51.67

Source: Malik (2008)

Sharing access

Whereas the central concern in APFAMGS was a better understanding of the groundwater situation (demystifying groundwater hydrology) combined with coordinated crop planning in order to trigger responses at individual level, the Community Based Groundwater Management (CBGWM) pilots of CWS and APDAI have operated on the other end of the spectrum. Instead of individual responses following intensive awareness as in APFAMGS, they focused on the 'collectivization' of groundwater systems: interconnecting the different borewells and coming to joint operation of the wells. This is a more difficult route, as it required transforming individual ownership into shared access to the common groundwater resource. The argument for the collectivization approach is that this approach makes it easier to come to[15] social regulations on groundwater use – because it takes both bore well owners and current non bore well owners on board. Earlier, non-bore well owners only had access to groundwater by renting boreholes for a number of hours at a time, an option that usually meant being the last in the queue.

CWS has promoted shared access to groundwater and social regulation in four villages. The activities undertaken consisted of creating awareness on water issues, participatory resource mapping and participatory hydrological monitoring. These preparatory activities were followed by the evolution of a system for social regulation of water use, consisting of sharing of bore wells, giving non-bore well owner's access to water, shifting to less water intense crops and development of a shared information system. The project worked with local institutions: SHGs, Village Organizations and NRM Sub-Committees of the Gram Panchayats. 181 wells were shared by 305 farmers in 4 project villages. In two out of four villages all wells came under a common water management regime. Equity issues were addressed by developing off-take points in *dalit* colonies. The cost of facilitation per village is INR 10,000. (USD 125).

In the CWS pilots, overall water consumption from the boreholes came down although it still exceeded the recharge. In addition, a number of measures have been undertaken to save water (in particular the promotion of SRI) and promoting recharge, i.e. converting abandoned dug wells into recharge wells.

Table 3: Results of pilots of Centre for World Solidarity

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[15] For some typical local restriction one needs to have the agreement of all – including those without a borewell by now: for instance bans on new wells. Other social regulation do not need this – in particular restriction on the cropping patterns, such as encouraged by APFAMGS,

No (total) of wells	64	60	34	22
No of shared wells	64	39	34	5
No of farmers sharing wells	135	107	56	15

Source: CWS (2009)

Likewise, under the Andhra Pradesh Drought Adaptation Initiative (APDAI) a number of 'collective' pilots were implemented – promoting shared access to groundwater. An important innovation tested by APDAI is to connect several individual bore wells through a pipeline network and enable also non-bore well owners to have access to the shared system. Combined with sprinklers, the shared pipeline system allows a larger area to be irrigated with a smaller amount of water used – this being very much the dividend of introducing micro-irrigation methods. Sprinklers are also popular as they make it possible to reach land that is otherwise out of command and also because their use for instance reduces the incidence of fungi (see above). The second important innovation in APDAI was to encourage a shift from dry rabi season full irrigation to complementary irrigation in the rainy kharif season. Irrigation in the kharif can be life-saving and highly productive as it compensates for delayed rains or lack of rain in critical crop stages.[16] Further as part of the APDAI groundwater pilots, rules were agreed upon that stipulates a moratorium on new wells, discourages paddy cultivation and regulates use of the connected bore wells.

The incentive for individual farmers to join the collective system is the risk reduction, the convenience and possibility to irrigate rain-fed land with the pipelines system that otherwise is impossible to serve. Being part of a collective system – with several borewells connected - reduces the exposure to individual borewell breakdown or failure. Moreover, by having one operator for the combined systems considerable time and costs are saved.

The first groundwater pilot (Chellapur in Mahaboobnagar) became operational in 2008 and served as a demonstration for other areas. The shared system in Chellapur connects five previously independent wells and consists of 1200 meters of pipeline with off-takes/ sprinkler connections[17] and air-vents. The system is relatively small in scale and the shareholders are related through family ties, which made it comparatively easy to set it in motion. Following Chellapur the concept of the groundwater pilots was discussed in fifteen villages where APDAI is active. In eight of the villages the concept was not feasible and there was no interest. The main reasons were:

- Technical: the rain-fed area was too distant from the area where boreholes were developed – making it difficult to develop the pipeline system or the yield of the existing boreholes was too low and barely sufficed – especially under the current regime of rationed power supply - for limited cultivation in the surrounding fields (often oranges with drip irrigation).

[16] An example is the supplementary irrigation during the flowering stage of red gram that makes a major difference to the yields of this crop.

[17] Sprinklers are part of the new system and these were obtained through the Andhra Pradesh Micro-Irrigation Project at 70% subsidy of the total cost of INR 22000 (hence farmers paid in total INR 4500 – USD 56). Each sprinkler set consists of 5 pieces of pipe of 6 meters and a sprinkler head.

- Social: reluctance – sometimes of a single farmer - to formally accept the ten year ban on new boreholes, share his well or contribute to the costs of investment in the pipeline systems (especially as there was cash shortage after the failed kharif crop)

Groundwater pilots were developed in three more villages. These new are considerably larger than Chellapur, with more participants and larger land areas involved. The ratio of well owners versus total number of farmers involved are respectively 2/16 (Nagireddapally), Gundlapally (2/36) and 32/72 (Gorantlavaripally). The development of the pilots has required negotiations facilitated by WASSAN. The most sensitive issue was, of course, to convince borewell owners of the benefit they gain in spite of sharing "their groundwater" with others and to arrive at management arrangements for the newly shared system that includes social regulation on groundwater use. Facilitation was undertaken through individual visits, meetings with non-borewell owners, meetings with borewell owners, joint meetings and exposure visits.

Box 3:Collectivization pilot in Gorantlavaripally

The largest collectivization pilot under APDAI is Gorantlavaripally village in Anantapur. Here 72 farmers participate. Until twenty years ago the area was primarily rain-fed with some reliance on dugwells. Rain-fed sorghum, millet (*ragi*) and mulberry were the main crops at that time. Over time, borewells were developed and paddy cultivation gained prominence. Due to intensive use, groundwater tables declined and some borewells failed. Relief followed the construction of three check dams. One check dam placed on the recharge zone proved to be particularly effective and the groundwater table recovered.

At present there are 32 borewells in existence in Gorantlavaripally, although most of these are seasonal as the water table in the area is still in decline. Six independent pipeline systems are planned for Gorantlavaripally, each connecting a group of borewells to a rain fed area. By December 2009, one of the six systems was operational and one in an advanced stage of construction, whereas designs had been finalized for the three remaining systems. The operational system, commissioned at the end of November, was already in use to irrigate rabi groundnuts, and plans are afoot to grow tomatoes and horticultural crops (sapodilla, mango) based on drip irrigation. Though, in principle, the system is meant to be collectively operated in kharif only, it is used this rabi season to make up for this year's failed kharif season. As an additional feature, the Gorantlavaripally scheme will include small concrete reservoirs linked to low cost drip irrigation systems able to irrigate 0.5 acre of land for vegetable cultivation.

The results started showing up. One farmer with two critical irrigations and application of tank silt could get a yield increment 8.08 quintals per ha of groundnut over the average of 8.99 quintals per ha yield of all farmers; a yield advantage of about 89 per cent. This initial experience in high water productivity of protective irrigation in monsoon crop has raised interest of the farmers.

A committee, with two group leaders, is managing the system. The main upcoming challenge is to develop the irrigation schedule as the system is now collective. The real test will come in the event of a severe drought, when water resources might not be sufficient to cover everybody's total needs. The development of the shared system is a considerable achievement as it goes against the 'grain' of individual habits that have been forming since groundwater extraction took off in a serious way some 20 years ago. In the coming period, one can therefore foresee considerable learning by doing on issues such as coordination of irrigation schedules, the position of the borewell owners in the group as compared to non-borewell owners and the regulation of total water consumption as, in principle, the pipeline makes it possible to irrigate a larger area in the two seasons. In order to satisfactorily and equitably resolve these kinds of issues, it is likely that a water/crop or even, water/farm budget will have to be developed over time.

The performance of the first pilot - Chellapur – that has been in operation since 2008 - was assessed under the monitoring activities in APDAI. Here five farmers own five bore wells, two of which were already shared prior to the pilot; hence there was already a pattern of common use. The shared system appears to protected cultivation even in the drought period and has improved introduced groundwater management at least among the shareholders of the system. The highlights of the first full year are:

- Out of the total area of 54 acres, the area cultivated during kharif has come from 37 acres in the base year to 35 acre this year: given the drought this is not a large decline.

- The area under cultivation has increased in rabi from 5 to 12 acres. The farmers have a diversified cropping pattern with the availability of water in kharif. They have also taken up fodder and vegetable crops.

- Groundnut crop recorded a substantial gain in yields and returns – because of the good response of groundwater to irrigation by sprinklers. In case of chilly and green gram incomes fell, however, due to a pest attack and an increase in labour cost. The net income of paddy has fallen sharply during the same period owning to increase in input cost, particularly cost of labour.

- In spite of the increase in rabi cultivation, water consumption did not increase. Water was pumped for 500 hours in the last year against 600 hours in the year before– meaning a 16% reduction

- No new bore well was sunk in the area in the last two years. During the same period, the number of bore wells in surrounding area has gone up.

Though experience is still evolving and the scalability of collectivization is still to be tested, the concept is promising for a number of reasons:

- It makes it possible to give protective groundwater irrigation to part of the dry land crops during the dry season that secures crops and livelihoods of many.

- It extends the reach of the irrigation system because of the distribution network and the possibility to create more pressure. Moreover, sprinklers are connected and cover a larger area – including higher and undulating land.

- It is serving those whose do not have a borehole of their own

- The technical solution is matched by social norms that regulate responsibilities of all concerned and as all farmers in a village (or nearly all) are stakeholders, it should facilitate the observance of these rules.

- In a way, the system is bringing the private access to groundwater into a system of common pool, which otherwise is not possible.

Arriving at regulatory and water sharing norms is crucial for the collectivization experience; enforcement of these norms over time is always an issue. The Government of Andhra Pradesh is now actively considering an enabling legislation for such community management systems to spread. Allowing the Gram Panchayats to form their own norms of groundwater use and management, providing a mechanism to legalise these community norms and providing a backup enforcement mechanism, in case the community is not able to resolve the conflicts are the main contours of the proposed legislation. Such a legal framework, it is envisaged can provide a larger basis for public investments into groundwater collectivization.

4. CONCLUSIONS

The cases from Andhra Pradesh show the promise of community based groundwater management and that it is possible to combine reduced discharge with increasing agricultural production and productivity. This is an important conclusion in the context of adaptation to climate change. It has been shown that, in the context of Andhra Pradesh it is possible to adjust farming systems to better cope with irregular drier and wetter cycles that are a consequence of climate change, while still making progress in terms of overall agricultural productivity. The objective should be to encourage and facilitate optimized and balanced use of groundwater – not to simply discourage it.

The key lies in changing cropping patterns and in using efficient field irrigation methods – from compost to sprinkler systems, to better adapted cropping patterns and indeed in a combination of these and other techniques to retain soil moisture for example. The impact of new field irrigation methods should not only be evaluated in terms of crop per drop, but equally in terms of other effects such as better quality fruits, less incidence of pests, ease of management and ability to reach areas at higher slopes. It is reasonable to expect that efficient field irrigation methods will grow in popularity and with the help of the collective processes set in motion in areas such as joint water crop budgeting and shared irrigation systems, it should be possible to reach an equilibrium state in the water table in a large number of the hydrological units of the state. It is after all in the best self-interest of farmers to avoid failed dry season crops and even failed monsoon crops as is increasingly the case as a result of increased climate variability and change.

Social norms and rules will reinforce the innovations that are under introduction, particularly those that are easier to monitor, such as no dry season paddy and no new bore wells. If bore wells are shared, such rules will be easier to discuss and agree upon as non-tube well owners will have a direct stake in the success of the innovations. In MC Thanda the joint ownership of the transformer was another factor that facilitated reaching such collective decisions. It should be noted however, that shared systems are useful and instrumental in the context of community based groundwater management, but they are not a sine qua non. Crop water planning which depends more on informed individual adjustments also goes a long way to avert overexploitation of groundwater in many of the hydrological units. It should also be noted that with regard to all the pilots studied, the costs of facilitation seemed reasonable.

The challenge lies in up scaling from quality controlled pilot approaches to a 'run-of-the-mill' government. There are several opportunities to upscale, in particular through the watershed programs in the state, which is already the case with the APTANKS project. In APTANKS the point of departure is the zone of influence of the tanks and this approach thus includes both surface and groundwater users. In theory, the project also opens the option for discussing recharge strategies. The ultimate test will be in the large scale implementation. A promising short approach consisting of three modules given by ten facilitators is in place – introducing the main concepts of participatory hydrological monitoring, crop water budgeting and groundwater management. The ambition level in APTANKS is high however – with 1200 tank areas selected for the promotion of community based groundwater management. Careful guidance is required – to integrate the approaches in the management context of a government project and to achieve the scale that is envisaged. There is a grave risk is that administrative obstacles – such as late releases of training and mobilization funds – undermines such important efforts at scaling up. The first indications were that such administrative hurdles were a genuine issue.

Another issue is the overall policy context. At present there are many factors in the public subsidy and support system that are in favour of high water demand crops and are loaded against sustainable dry land agriculture, for example:

- The Public Distribution System provides a minimum price for paddy and a public distribution channel – putting a premium on paddy cultivation, whereas there is nothing similar for dry land crops

- Fertilizer subsidies concern chemical fertilizers. There is no similar support related to composting methods that have the added affect of improving soil structure and retaining soil moisture – reducing the amount of irrigation required

- Substantial sums spent on electricity subsidies dwarf all efforts at promoting efficient irrigation or sustainable water resource use. This is another sector where things need to be revisited.

A reorientation in the public investments that incentivizes sharing of groundwater, larger protective irrigation covering many farmers, efficient use of water and capture of soil moisture in tandem with evolving appropriate community level institutions and an enabling legal framework can provide a much larger impetus to sustainable groundwater management. The critical factor is substantial public investments into these structures and processes.

In summary sustainable groundwater use in Andhra Pradesh is possible and the instruments are within reach. It requires gradual and controlled up scaling of community based groundwater management and the right incentive system for sustainable water resource use. It is useful to develop a matrix of policy and institutional adjustment to support sustainable groundwater use – not just for balance water use but for economic development and drought adaptation as well.

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