

WATER KNOWLEDGE NOTE

Can Participatory Groundwater Management Enhance Drought Resilience?

The Case of the Andhra Pradesh Farmer-Managed Groundwater Systems Project

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This paper investigates whether the proactive involvement of local communities in the management of groundwater can help build drought resilience, using the case of the Andhra Pradesh (AP) Farmer Managed Groundwater Systems (APFAMGS) project as an example. The 18-year project was implemented through seven districts of India's AP and Telangana states. During this period, participatory groundwater management (PGM) initiatives evolved from a focus on demand management to an emphasis on drought adaptation as links between groundwater and climate variability became increasingly conspicuous. This paper is based on a review of existing studies, field visits to the region, and interactions with communities and individual farmers. The objective of APFAMGS was to promote sustainable groundwater management by creating community awareness through training, water planning, and alternative cropping choices. The study concludes that PGM, as adopted in APFAMGS, has a limited impact on groundwater levels in hard rock areas under conditions of marginally decreasing rainfall, greatly increasing net abstraction, and groundwater dependency. However, the project improved awareness that helped communities adapt to drought. The conclusion is that to be effective in addressing drought vulnerabilities, PGM must include policy interventions that encompass incentive and regulatory mechanisms, and village-based institutions must be linked to government departments that manage groundwater.



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Background

Water resource management is the main challenge to helping people adapt to climate-induced droughts. Availability of and access to water at the household level can largely mitigate the adverse impacts of drought. This linkage is more pronounced in groundwater-dependent regions with low rainfall. In India and the wider region, groundwater is the single largest source of fresh water, meeting as much as 90 percent of irrigation and domestic needs. Groundwater rights are linked to land rights in most developing countries, including India. This fact, and relatively high capital investment costs in groundwater development, means that, despite being a common pool resource, groundwater development is left to private individuals, primarily wealthier land-owning households. Meanwhile, the adverse impacts of groundwater exploitation are often disproportionately borne by small and marginal farmers (Reddy 2005). These impacts are more conspicuous in the context of drought and climate variability. Well failure—one of the main reasons for farmer suicides in India—is, in part, an outcome of these externalities, especially in drought-prone regions (Deshpande 2002; Reddy and Galab 2006). Various approaches and methods, including demand management³ and supply augmentation,⁴ have been adopted to remedy the degradation of groundwater resources. The effectiveness of these interventions in India has been limited, and their scalability depends on the socioeconomic and political contexts (Shah 2014).

The failure of regulatory approaches in South Asia has led to community-based PGM initiatives being experimented with since the 1990s (Shah 2014). Most of these initiatives are small in scale, with participatory approaches constrained by high transaction costs. Despite their limited scale (Reddy, Reddy, and Rout 2014; Shah 2014; Verma et al. 2012), some state governments are taking a keen interest in supporting, continuing, and scaling up these initiatives.⁵

To better understand whether and how these initiatives should be scaled, it is important to understand the extent to which participatory projects have enhanced farm communities' resilience in dealing with water scarcity and climate-induced uncertainties like droughts. Hitherto, most studies that reviewed these interventions have not considered that question and instead focused on the socioeconomic impacts or the sustainability of these initiatives (Reddy, Reddy, and Rout 2014; Verma et al. 2012). Whether these initiatives have caused any long-term behavioral changes in community approaches to groundwater use and

management remains unanswered. Understanding these aspects will help in scaling these initiatives and making them more effective across hard rock aquifer regions.

The APFAMGS project in India is selected as a case study for this paper. The project is, perhaps, India's largest and longest-running community-led groundwater management initiative. APFAMGS was implemented between 2003 and 2013 in the state of AP, under different names associated with different phases of the project. It has spread to more than 650 villages with 6,500 families in seven drought-prone districts. APFAMGS evolved from a demand-management focus to a concentration on climate change adaptation over the years. Its practices are being integrated into government programs in India.⁶ A detailed examination of APFAMGS is, therefore, timely and may provide insights into the potential of PGM in building drought resilience. This study seeks to understand how sustainable management of groundwater can build communities' drought and climate resilience by building community knowledge and awareness. The specific objective is to examine the role of APFAMGS interventions from the viewpoint of their:

- Evolution over the years and role as a participatory resource management strategy;
- Performance in stabilizing resource availability, distribution, and enhancing drought resilience; and
- Linkages with other groundwater management initiatives and insights for developing appropriate resource management strategies.

Approach

This case study is mainly based on the review of the literature pertaining to APFAMGS and other participatory initiatives in the state of AP,⁷ interviews with project implementing agencies, personal discussions with the office bearers of APFAMGS (see table A.1 in appendix A), and firsthand information collected during field visits. The following section covers the evolution of APFAMGS and its activities over the years. The one after that outlines the social, economic, and environmental context. The section on Participatory Groundwater Management and Drought Resilience discusses the sociotechnical context of the APFAMGS study region. The effectiveness of the initiatives in the context of climate-induced drought resilience is assessed in *Where Do Things Stand Today in the Project Villages?* And the way forward for sustainable groundwater management is discussed in the last section.

APFAMGS: Evolution and Activities

APFAMGS has operated under several names during its long history. It originated in the AP Groundwater Bore Well Irrigation Schemes project, which was supported by the Royal Netherlands Embassy and implemented from April 1995 to March 2003 by local nongovernmental organizations (NGOs). For the first time, participatory hydrological monitoring (PHM) was introduced in the project on a pilot basis.⁸ Impressed by the effectiveness of the pilot initiatives in checking resource degradation, the Royal Netherlands Embassy funded the APFAMGS project for 30 months.² APFAMGS was implemented by a network of local NGOs under the leadership of the Bharati Integrated Rural Development Society (BIRDS). The project involved 500 villages throughout the seven drought-prone districts of Anantapur, Chittoor, Cuddapah, Kurnool, Prakasam, Mahbubnagar, and Nalgonda (see project management structure in figure A.1 of appendix A). APFAMGS introduced the participatory form of groundwater management for the first time in India at this scale. In April 2004, after a change in development priorities of the Netherlands government, the APFAMGS project shifted to the Food and Agriculture Organization of the United Nations (FAO), who supported the project until December 2009.

In April 2010, the Global Environment Facility (GEF) approved the FAO's proposed three-year project for a Strategic Pilot on Adaptation to Climate Change (SPACC),¹⁰ which was endorsed by India's Ministry of Environment and Forests. In 2014, after the separation of the state of AP, the government of AP initiated a pilot project, Groundwater Governance through Panchayat Raj Institutions in Andhra Pradesh (GwGPRI-AP). It turned into a long-term initiative supported by the International Fund for Agriculture Development (IFAD)¹¹ and was renamed again to AP Drought Mitigation Project.

Thus, the APFAMGS project evolved over 18 years (from 1995 to 2013). The PGM initiatives have been integrated into the development policies of the AP government (IFAD 2016b), which continued to support APFAMGs initiatives under GwGPRI-AP immediately after the separation of the state and approached IFAD for long-term support for drought mitigation. The following section discusses some of the most important activities of APFAMGS.

Activities

The key premise of APFAMGS is to promote behavioral change by well owners leading to voluntary self-regulation

(Reddy, Reddy, and Rout 2014). Capacity building of groundwater-dependent communities is at the core of the program—that is, users are equipped with data, skills, and knowledge to manage available groundwater resources in a sustainable manner, mainly by monitoring the supply and managing their own demand. The project provides the necessary means (equipment and skills to collect and analyze rainfall and groundwater data) to increase community knowledge about groundwater resources. However, it does not offer any incentives, disincentives, or regulations to bring about participatory groundwater management. Awareness about water-saving techniques, improving agricultural practices, and water use efficiency has been enhanced (Reddy 2012) by:

- Demarcating hydrological units to be used as operational units;
- Discussing the local groundwater situation at the hydrological unit and village level;
- Demystifying the science of climate and hydrology through farmer water schools;
- Changing the perception of groundwater from private property to that of a “common good;”
- Carrying out participatory crop water budgeting exercises and sharing information across hydrological units;
- Adopting water-saving techniques and reducing the use of chemical fertilizers; and
- Enabling farmers to voluntarily adopt sustainable practices such as reduced pumping, prevention of drilling new wells, and crop diversification.

Three noteworthy APFAMGS activities are interconnected:

- **Farmer water schools (FWS).** FWS adopted an informal and participative approach for information sharing and group learning to improve skills and capacities of farmers. A total of 10,000 farmers attended 300 schools. FWS meetings were held once every 15 days to understand local groundwater changes for the area's entire hydrological unit. Based on learnings, farmers adopted suitable modifications in their agricultural practices that have the potential to lead to significant reductions in groundwater use.
- **Data collection techniques.** Farmers were trained at FWS to measure groundwater levels, rainfall, pumping capacity of bore wells, and water requirements for different crops. Farmer volunteers (both women and men) carried out fortnightly water-level monitoring in 2,026 observation wells (about one well for every

square kilometer). Daily rainfall measurements were collected from more than 190 rain gauge stations (one station for every 5 square kilometers). Discharge measurements were collected from about 700 observation wells to assess the pumping capacity and well performance, among other things. Seasonal groundwater-quality measurements were taken from public drinking water wells. To qualify to be a volunteer, farmers had to attend four training modules at FWS, and only successful candidates were eligible to become (unpaid) PHM volunteers. Volunteers received measuring tools like an electrical water-level indicator, a stopwatch, and measuring drums. Hydrological monitoring records were maintained for public viewing on display boards at strategic village locations. Community-operated weather stations were also incorporated during the SPACC project. The information generated was discussed at committee meetings and FWS (which became farmer climate schools).

- **Crop water budgeting (CWB).** CWB is a technical exercise in which farmers collectively make crop plans based on water availability. The project did not seek to limit the crop choices that farmers could make in a particular hydrological unit and did not necessarily advocate changes in crops being grown. It was assumed that farmers have enough knowledge to make relevant decisions, though in some cases, a village groundwater management committee (GMC), or a hydrological unit network (HUN) composed of several GMCs within a common hydrological boundary, pressure farmers to advocate crop changes and other practices.

These activities resulted in real-time monitoring of soil moisture during the cropping season, enabling farmers to make informed decisions on irrigation schedules. Soil-quality analysis was taken up to develop a package of practices for specific crop options that suit agroclimatic and soil situations. A climate adaptation fund was created at the HUN level near the end of the project to sustain the initiatives. The fund could be used only to operate and maintain the weather stations, crop-specific adaptation pilots, and farmer climate schools (Govardhan Das, Priya, and Kenmore 2015). The effectiveness of the climate adaptation funds has yet to be assessed.

Social, Economic, and Environmental Context

APFAMGS operated in a region characterized by vulnerable populations. The scheduled caste population accounts for 18 percent of the total population, a higher proportion of

poor households (IFAD 2016a), and low literacy rates. It is also one of the most climate-vulnerable parts of India,¹² with low and unreliable average rainfall (600 millimeters or less) and frequent droughts. The APFAMGS districts are covered under the Drought Prone Areas Programme and Desert Development Programme, reflecting their vulnerability to droughts. These districts experience drought in 30 percent of years (GoI 1981). But between 1876 and 2006, 66 of the 133 years were recorded as drought years with a more than 20 percent deficit in rainfall (IFAD 2016a). Although this region is expected to experience higher temperatures and reduced rainfall—especially from the southwest monsoon that provides the bulk of rainfall (IFAD 2016a)—recent rainfall data do not indicate a worsening drought incidence in the region (figure 1).

Irrigation is limited, with average area under irrigation below 30 percent. Groundwater is the main water source (used for 70 percent of irrigation), and dependence on it has increased since the 1980s.¹³ This region accounts for more than a million bore wells, but only 10 percent of them provide year-round supplies (IFAD 2016a) because of deep water tables and regular well failure. Where water is available, farmers opt to grow paddy crop. Rainfed crops are predominantly oilseeds, followed by pulses and cotton. The agricultural economy is characterized by low crop yields, with only about one-third of household income derived from them. Livestock contributes substantially, followed by migration. The government is promoting horticultural crops in these areas, and farmers are shifting to cash crops such as vegetables. Managing the available groundwater resource continues to be the only option in the short to medium run¹⁴ for sustaining agriculture and livelihoods in the region.

Groundwater Development and Degradation

Over the 18 years of the project between 1995 to 2013 (for which data is available), the groundwater situation has deteriorated across AP. The stage of groundwater development¹⁵ across districts ranged from 7 percent to 41 percent and, for the state as a whole, it was 28 percent in 1985, which went up to 45 percent in 2011 (inferred from information provided in Groundwater Resource Estimation Reports, Ground Water Department, GoAP). Because the latest data are available for only five districts of the newly formed AP, only these five, instead of all seven districts of APFAMGS, are considered here.

The AP Groundwater Department provides information separately for command areas (those served by surface

canal systems) and non-command areas. Because APFAMGS interventions were limited to non-command areas, a separate analysis of command and non-command areas would provide a closer assessment of APFAMGS achievements. Additionally, the coverage of APFAMGS at the district level accounts for a marginal share in area, so it is difficult to get a clear picture. However, the trends in groundwater development show that when the APFAMGS districts are categorized as command (non-APFAMGS) areas and non-command (APFAMGS) areas, the overall stage of groundwater development in command areas is higher than that of non-command areas in all the assessment years (table A.2 in appendix A).

The area under groundwater irrigation was nearly equal to the area under irrigation by all surface water sources put together, especially during the years of low rainfall. The number of wells in AP increased from 0.8 million (0.7 million dug wells and 0.1 million bore wells) in 1971 to about 2.2 million (1.0 million dug wells and 1.2 million bore wells) in 2007. The area under groundwater irrigation increased from 0.8 million hectares to about 2.8 million hectares during the same period. The area irrigated per well was almost constant, but water was drawn from deeper depths (Reddy, Reddy, and Rout 2016). The average density of wells increased from five to more than 10 wells per square kilometer. However, in hard rock areas (APFAMGS districts), it was more than 20 wells per square kilometer,

whereas in some pockets, it was as high as 100 wells per square kilometer. Consequently, well yields decreased considerably, and water levels went down at an alarming rate (Reddy, Reddy, and Rout 2016).

Although small- and medium-size farmers can now invest in groundwater extraction because of cheap pumping technologies, they cannot compete with large farmers in investing in deepening wells (Reddy 2005). As a result, they become the first victims of groundwater depletion and pay a huge price.

APFAMGS Versus Non-APFAMGS Areas

Over the 18 years of data, groundwater levels and rainfall have shown a declining trend (figure 1), though there is no evidence of worsening drought.¹⁶ The decline in annual average rainfall is marginal, but the post-monsoon groundwater depth has recorded a sharper decline when compared to pre-monsoon decline and the declines are not clearly associated with drought years. These fluctuations are not specific to the APFAMGS period or regions because these trends could be observed at the regional level even before APFAMGS, between 1985 and 1995 (Reddy, Reddy, and Rout 2016), nor does disaggregation by command and non-command area (considering APFAMGS interventions were limited to only the non-command areas within the APFAMGS districts) demonstrate any positive impact of

FIGURE 1. Trends in Average Rainfall and Groundwater Depth in the Five APFAMGS Districts of Andhra Pradesh

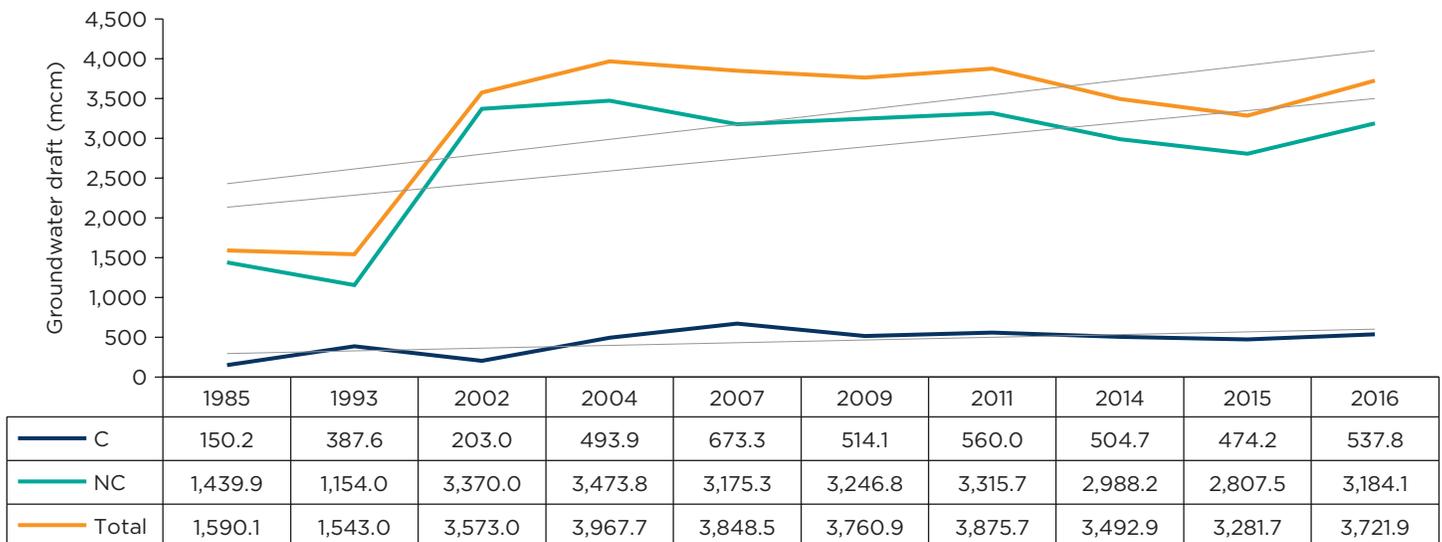


Sources: Groundwater development data compiled from Groundwater Resource Estimation Reports, Government of Andhra Pradesh, Groundwater Department, Hyderabad, India; rainfall data compiled from Directorate of Economics and Statistics of Andhra Pradesh, Hyderabad, India.

APFAMGS on groundwater resources. As the groundwater draft has shown an increasing trend (figure 2) even after 2000 (APFAMGS period), the water balance¹⁷ has recorded a declining trend (figure 3). In both cases, the non-command (APFAMGS) areas recorded a steeper trend. Furthermore, an internal study assessed indicators of the groundwater situation in the project's 63 hydrological units from 2006 to 2011 (Govardhan Das and Burke 2013).

In only 13 of the 63 hydrological units has the groundwater balance improved, and the decline in groundwater draft was attributed to generous rainfall in the respective years. Thus, there is no clear evidence to indicate that APFAMGS interventions have improved the groundwater situation in these districts. A more disaggregated assessment is required because the coverage of APFAMGS within these districts is limited (less than 10 percent of sown area).

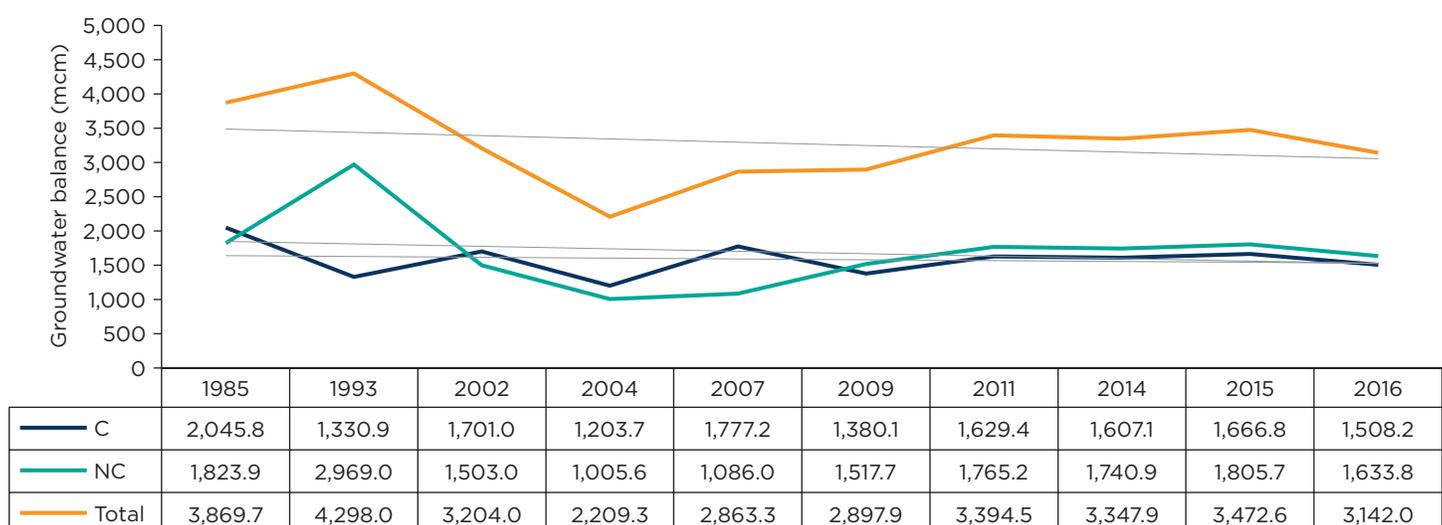
FIGURE 2. Trends in Groundwater Draft in APFAMGS (Non-Command) and Non-APFAMGS (Command) Areas (Five Districts)



Source: Data compiled from Groundwater Resource Estimation Reports, Government of Andhra Pradesh, Groundwater Department, Hyderabad, India.

Note: APFAMGS = Andhra Pradesh Farmer Managed Groundwater Systems; C = command areas; mcm = million cubic meters; NC = non-command areas.

FIGURE 3. Trends in Groundwater Balance in APFAMGS (Non-Command) and Non-APFAMGS (Command) Areas (Five Districts)



Source: Data compiled from Groundwater Resource Estimation Reports, Government of Andhra Pradesh, Groundwater Department.

Note: APFAMGS = Andhra Pradesh Farmer Managed Groundwater Systems; C = command areas; mcm = million cubic meters; NC = non-command areas.

Groundwater development and degradation have been closely linked to the energy policies of the state (Reddy, Reddy, and Rout 2016). However, it should be noted that the impact of the free power policy does not show any significant change in important indicators like service connections, proportion of energized wells, and the power consumption in any of the districts, including APFAMGS (Reddy, Reddy, and Rout 2016). This implies that changes observed in groundwater resource status are not a result of the free power policy alone.

Participatory Groundwater Management and Drought Resilience

Although there has not been significant enhancement of groundwater resources, perhaps because of the larger number and more dominant influence of non-APFAMGS villages, there has been moderate improvement in drought resilience associated with APFAMGS interventions.

APFAMGS Interventions Influencing Drought Resilience

Two changes in farmer behavior are considered to influence drought resilience in the APFAMGS villages.

Reduction in Groundwater Pumping

Groundwater pumping was reduced in 23 of the 63 hydrologic units, with moderate reduction in nine other units. Overall, the reduction is not significant enough to have a wider-scale (district-level) impact.

Reduction in Area under Paddy

Reduced water pumping has a direct bearing on the area under paddy (during kharif as well as rabi) cultivation because paddy is water-intensive and the most preferred crop. CWB helped farmers understand groundwater deficiencies and the contribution of paddy in aggravating the problem (box 1). The budgeting estimates revealed that annual groundwater balance was in deficit in 59 of the 63 hydrologic units. Farmers' experiences showed that they incur crop losses when they do not follow the collective advice following water scarcity. Because the shift from paddy to less water-intensive crops has not triggered the expansion of area under irrigation, as a result of the continued water stress, there is an aggregate reduction in water pumping.

These impacts have been endorsed by most evaluation studies, though sustainability of these achievements is

questioned (Reddy 2012; Reddy, Reddy, and Rout 2014; Verma et al. 2012). Some of the important and sustained impacts pertaining to drought resilience are also a result of follow-up initiatives and interventions, noted in the following section.

Follow-up and Related Interventions Influencing Drought Resilience

Water-saving devices such as sprinkler and drip methods have been introduced for groundnut, sunflower, bengal gram, chilies, and horticultural crops. It is estimated that groundwater pumping was reduced by more than 8 percent (equivalent to 5 million to 10 million cubic meters per year) over the project area with water-saving techniques. Issues of conveyance through pipelines, reduction in evapotranspiration, and increased retention of soil moisture have been successfully addressed. Techniques for improving the moisture retention have been adopted, including border strips, ridge and furrow check basins, alternate furrows, vermicompost, mulching, double ring method, and paddy husk mulching. These methods helped farmers stabilize and increase yields and incomes. Although farmyard manure and vermicompost boost organic matter, microbial populations, and the soil's water-retention capacity, critical irrigation practices save crops from prolonged moisture stress. As a result, higher crop yields and profits were reported on the pilot plots for all four crops assessed when compared with control plots. Moreover, average yields of SPACC farmers (in the entire area) are higher than district average yields for all four crops, except tomatoes (Govardhan Das, Priya, and Kenmore 2015). Other drought mitigation and adaptation programs have been promoting similar interventions, however, so attributing the drought resilience impacts of these initiatives and their sustenance solely to APFAMGS may not be credible.

In place of paddy, farmers have started adopting more-diversified cropping such as pulses, oilseeds, fruits, vegetables, and flowers. Farmers try to offset the losses from the reduction in paddy by growing high-value crops that require less water. An increase in less-water-intensive crops was also observed during the APFAMGS period (Garduño et al. 2009; van Steenberg 2010). Crop diversification has spread throughout the region since the 1980s because of increased water stress and better prices for other crops. An increasing incidence of drought and delayed and untimely rains have further prompted farmers to move away from monocrops like groundnut and paddy.

BOX 1. Farmer Comments on Sustainable Groundwater Management through Self-Learning

“Groundwater pumping in the Yadavagu Hydrological Unit is much more than that is being replenished by rainfall recharge, as revealed by the PHM. GMCs in the HU have decided not to grow crops that require much water. The members also realised that maximum lowering of groundwater levels takes place in the months of April and May and so they have decided to take up crops that can be harvested before the beginning of April. All the members have decided to stop operating bore wells for 2 to 3 months between April to June every year.”

–Narasimha Reddy,
groundwater management committee member,
Yadavagu hydrological unit,
Kethagudi (village), Prakasam (district)

“Measuring water levels, discharge from bore wells and calculation of annual water balance helped us in gaining good understanding on water resource availability and crop water requirements. I have now calculated that I have to make available 12 million litres (12,000 m³) of water to raise one hectare of paddy while I need to pump only 3 million litres of water for growing one hectare of green gram. This understanding along with knowledge on water balance in the HU has helped me to plan my cropping system.”

–P. LaxmanSwamy,
groundwater management committee member,
Thundlavagu hydrological unit,
Mukundapuram (village), Allagadda (mandal), Kurnool (district)

“Before the APFAMGS project came, we did not have any idea about groundwater levels. We used to pump groundwater indiscriminately and cultivate more land than was possible and used to incur heavy losses. Now we have observation bore wells to estimate the available volume of water and plan our crops. There are changes in farming methods. There is awareness of chemical fertilizers. We used to spray chemicals suggested by shop-keepers. But now we know the names of the chemicals. We even prepare our own organic fertilizers solutions and pesticides.”

–Srinivasula Reddy,
secretary of hydrologic unit network committee of
Gram Vikas Samstha, APFAGMS

Source: Bharati Integrated Rural Development Society internal documents, Nandyal, Kurnool district.

Note: APFAMGS = Andhra Pradesh Farmer Managed Groundwater Systems; GMC = groundwater management committee; HU = hydrological unit; HUN = hydrological unit network; m³ = cubic meters; PHM = participatory hydrological monitoring.

Where Do Things Stand Today in the Project Villages?

Field visits to five villages conducted as part of this study indicated that APFAMGS physical activities, such as measuring groundwater levels, stopped because of a lack of resources and follow-up support. However, some of the resource management practices, like water budgeting, are being continued. Similarly, there is still some momentum regarding social organization and groundwater management institutions. Nonetheless, farmers only informally discuss

issues and do not carry out formal FWS or climate school meetings, which confirms the observations on sustainability of the initiatives of the earlier evaluation studies (Reddy, Reddy, and Rout 2014; Verma et al. 2012).

Drought Resilience in Uppara Vanka

Before the APFAMGS project, most farmers in the area predominantly cultivated paddy and groundnut crops using flood irrigation methods. Currently, there is no paddy cultivation (during kharif as well as rabi) in 16 villages of

the Uppara Vanka HUN. Most of these villages shifted to horticulture crops during 2003–04 droughts and did not go back to paddy cultivation. Despite the ongoing severe drought, farmers can cultivate horticultural crops, though to a lesser extent, with drip irrigation. The drip method is used for all crops grown in the HUN: green chilies, brinjal, tomato, ladies fingers, country beans, cauliflower, cabbage, onion, floriculture, and fruit crops like sweet cucumber and watermelon. Farmers switched to drip from sprinkler irrigation because the consecutive droughts, and overuse of groundwater has reduced the pressure/inflow of bore wells.

Farmers said they can cope with drought because of a shift from monocrop culture to mixed/multiple crops. Before APFAMGS, the entire hydrological unit grew mainly groundnut, with red gram as an intercrop in rainfed conditions. After 18 years of APFAMGS, the majority of rainfed farmers are cultivating bajra, korra (foxtail millet), jowar, cowpea, red gram, castor, and groundnut as mixed or single crops. One farmer said some are now growing more than 30 different crops, compared with fewer than five crops before APFAMGS. Mixed/multiple cropping has proved to be a fruitful climate adaptation and drought mitigation strategy (box 2). The shift to less-water-intensive horticultural crops and mixed/multiple cropping has also created more employment throughout the year—an average of 100 additional days of employment per household compared to previous crops—and substantially reduced migration among landless, marginal, and small farmers.

When asked about reverting to paddy in the future if water became more available, farmers said that in short duration, less-water-intensive crops such as vegetables are more profitable. Farmers said they were happy to get income on a regular basis and feel that price shocks are less intense when compared to non-vegetable crops. None of the vegetable farmers interviewed were deeply in debt as opposed to farmers growing commercial crops like cotton, which are more expensive to grow and more exposed to market price risk.

Crop rotation and border cropping are also being practiced in these villages. Application of chemical fertilizers, especially on rainfed crops, has declined substantially from about 30 bags per acre per year to 12 bags (two crops). Farmyard manure is used extensively on rainfed crops. Some farmers are even moving toward organic or natural farming (boxes 3 and 4). The SPACC project introduced the application of vermicompost, and the farmer climate schools built awareness about drought management.

It may be noted that most of these practices were not part of the APFAMGS initiatives. For instance, the government of AP has introduced several drought mitigation initiatives including farm ponds, mini-percolation tanks, and zero budgeted natural farming (ZBNF) as part of drought adaptation (IFAD 2016a). The APFAMGS villages embraced these programs thanks to the readily available, existing social capital, which can be attributed to APFAMGS.

BOX 2. Mixed Cropping: A Drought Adaptation Strategy

Mixed cropping is a traditional farming practice in rainfed conditions. Farmers with one or two hectares of land traditionally grew as many as nine crops, including cereals, pulses, and oilseeds. These crops provide the subsistence needs of the family.

Some crops fix nitrogen in the soil, and others draw various nutrients and soil moisture from different layers. Mixed cropping creates a good balance in soil nutrient and moisture management because each crop matures at a different time and has varying moisture requirements at different stages. Even if one or two crops fail from moisture stress or untimely rainfall, the remaining crops could survive and provide at least some returns to the farmers. The failure of all crops occurs rarely, perhaps once in 40 or 50 years.

By returning to a mixed cropping approach, farmers in the Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) project area became less vulnerable to droughts. Furthermore, as crops stand for longer periods in the field, the soil exposure to wind erosion is minimized. Mixed cropping is also highly labor-intensive and reduces migration, which is a positive indicator given the high levels of migration in these regions. It is one of the best strategies to meet drought and other climate-related uncertainties.

Source: Bharati Integrated Rural Development Society internal documents, Nandyal, Kurnool district.

BOX 3. Farmer Fights Drought with Organic Crops

Mallikarjuna, a 40-year-old farmer, is a native of Dharmapuram village and gram panchayat in Gooty mandal of the Anantapur district. He studied until the 10th grade and belongs to the Backward Caste community. His family consists of five members—himself, his wife, his elderly father, and two school-age children. Agriculture is the family’s main income. Mallikarjuna owns 12 acres of land with no access to irrigation water because his well dried up a few years ago. He was president of the Uppara Vanka hydrological unit network (HUN) under Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) and later continued under the Strategic Pilot on Adaptation to Climate Change (SPACC) project. He has practiced organic farming through mixed/multiple cropping for 10 years. With these practices, he reduced growing costs and maintained crop yields, though they are lower in drought years. He is a local expert on groundwater management, rainfed agriculture, and organic farming. A comparison of his crop yields in drought and normal years is presented in table B3.1.

TABLE B3.1. Crop yields in drought and normal years

Crop	Drought year yield (kg/ha)	Normal year yield (kg/ha)
Bajra	450	900
Groundnut	1,350	2,475
Korra	675	1,350
Red gram	337	450

Note: kg/ha = kilograms per hectare.

BOX 4. Drought-Resilient Natural Farming Overcomes Failed Wells and Related Debts

M. Savitramma, 40, also a native of Dharmapuram village in Gooty mandal of the Anantapur district, is one of seven family members—two school-aged children, one elderly person, and four workers—and is barely literate. She was involved in Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) and the climate change projects (Strategic Pilot on Adaptation to Climate Change [SPACC] and zero budgeted natural farming [ZBNF]) and is leader of the village self-help group. The family has four acres of rainfed land and receives income from M.’s husband’s work as a factory laborer. Their bore well tended to quickly dry up.

She practices mixed/multiple cropping and natural farming and grows oilseeds (groundnut, castor, and sesamum); millets (cowpea, korra, jowar, and bajra); and pulses (green gram, black gram, and red gram). She follows this crop rotation: If bajra is sown, korra is avoided, and vice versa. One year before APFAMGS began, she spent nearly ₹ 210,000 (US\$3,000) borrowed from informal credit sources to build two bore wells (60 to 150 meters deep). Both wells failed because of low groundwater levels. She repaid the debt through savings, her husband’s wages (₹400 to ₹500 per day, about US\$ 6 - 7), and income from growing mixed/multiple crops.

With or without APFAMGS Situation

A comparative assessment of APFAMGS villages and nearby non-project villages in 2018 clearly showed that APFAMGS villages are less vulnerable and more resilient to drought risks. For instance, investments in new wells and well deepening continues in the non-APFAMGS villages. Similarly, adoption of micro-irrigation is at a lower scale in non-APAMGS villages (LNRMI and AF-EC 2018). These differences are attributed to the following:

- Farmers in APFAMGS villages are more aware of the groundwater situation and practice sustainable management.
- Farmers are aware of issues related to climate change.
- Crop diversification and improved crop management and irrigation methods, such as drip systems, are being used.
- Villagers are promoting social development activities.
- Because of communities' capacities and awareness, these villages have become the first choice of any new programs or initiatives of the government.

Constraints for APFAMGS

Despite being more resilient, not all farmers can benefit equally from improved conditions. Access to water is distributed unequally, especially during severe droughts. Farmers with large farms and deeper wells can maintain stable incomes through judicious use of water and crop mixes. Shallower wells owned by small and marginal farmers dry up first. There is no practice of sharing and selling water to other farmers. Most farmers felt that constructing recharging structures like rainwater harvesting and soil moisture conservation measures could ease the situation to a large extent. Farmers are also hoping that watershed programs, *Mahatma Gandhi National Rural Employment Guarantee Act* works, or linking local streams to dug wells could be directed toward enhancing groundwater recharge. At the same time, addressing equity requires more-concerted efforts of targeting disadvantaged communities (LNRMI and AF-EC 2018).

Participatory Groundwater Management: Can It Enhance Drought Resilience?

The sustained interventions of APFAMGS initiatives over more than 18 years have created science-based knowledge and awareness among the groundwater communities in the study region. Communities were provided with the technical capacity to understand and assess groundwater

potential, crop water requirements, water accounting, and budgeting—and to apply this information in village planning. These aspects were hitherto considered only within the mandates of technical agencies. This awareness has resulted in cutting down on water pumping in these villages, some limiting of water-intensive crops, shifting to irrigated dry crops, and adopting water-conserving irrigation methods. It has also been foundational for making the best use of follow-up activities and interventions and responding to markets by changing cropping patterns. Over time, farmers have adopted more-profitable horticultural crops and appear ready to continue this practice in coming years.

These behavioral changes cannot be attributed solely to APFAMGS. They also depended on post-APFAMGS interventions, continued water stress, and growing market demand for fruits and vegetables. The follow-up projects, apart from continuing the earlier initiatives, helped expand communities' awareness about climate-induced drought adaptation practices like mixed/multiple cropping, critical irrigation, reduced chemical fertilizers, and natural inputs such as manure. Farmers have indicated the effectiveness of these practices for enhancing drought resilience. Changes to cropping patterns can also be observed across the region, irrespective of the APFAMGs interventions, because of frequent and severe droughts and changes in market demand for fruits and vegetables.

Sustainability of the initiatives continues to be a problem. All project-related activities stopped after the SPACC project ended in December 2013. Awareness has not translated into improved groundwater resources at household, village, or regional levels. This disconnect could be caused by the lack of any regulation. It could also be a result of collective initiatives—such as more investments in recharge structures or water sharing—that have perpetuated inequity among farmers, especially during drought years when groundwater levels are deeper. In the absence of any tangible improvements in groundwater, the APFAMGS interventions were not sustained after the project and external support ended. Informal peer pressure from fellow farmers did not work in the post-project period in the absence of any social or economic regulations. Economic instruments, incentives, and market forces that were observed in the later years appear to be more effective in groundwater demand management and were absent in the APFAMGS case. Moreover, the APFAMGS approach does not include all farmers. The result is that a lot of useful water information generated at the appropriate scale helps only well-owning farmers. Limited membership

hinders the collective ownership and commitment to the common good. In some villages, farmers not affiliated with APFAMGS refuse to talk about the initiative, indicating divided participation and support.

Our interactions with farmers indicated that continuing the initiatives with external institutional support would help manage groundwater in the long run. It was hoped that maintenance support under the pilot project, GwGPRI-AP, would help to continue the activities following the 2013 end of SPACC, but it did not materialize as expected. The climate adaptation fund created under SPACC was not intended to support project activities outside regular meetings and the like.¹⁸ To sustain these initiatives and protect the social and natural capital created in the region, existing community institutions need to be linked to a formal structure with funding.

Complementary Initiatives

Some post-APFAMGS initiatives in AP have integrated the knowledge-based approach with social regulation to manage groundwater. These interventions include the Social Regulation in Groundwater Management and AP Drought Adaptation Initiative (APDAI).¹⁹ Although building awareness and generating data by the villages were important components, the most important aspect of the two models was to bring consensus to share water between well owners and others. Incentives such as reduced risk of well failure (because no new wells were allowed), subsidies for micro-irrigation, and provision for protective irrigation were put in place. Social regulations showed clear impacts in stopping the construction of new bore wells plus more households, especially the marginal and small farmers, benefiting from sharing water with well owners (Reddy, Reddy, and Rout 2014). A recent study in the Chittoor district of AP has also observed that groundwater governance improves with increasing community awareness about the linkage of cropping patterns to groundwater use and social capital, where participants consider group gains (Meinzen-Dick et al. 2016).

Lessons for Scaling up

The review of studies and experiences clearly shows that the APFAMGS model of participatory management neither improved the groundwater situation nor promoted sustainable groundwater management practices but still, somehow, increased drought resiliency. Evidence from the APFAMGS case study indicates that the model falls short on some aspects, such as sustainability, equity, incentives, and regulations. However, the experience from AP indicates

that an integrated approach of knowledge and regulation/incentives is required to make participatory groundwater management effective in addressing drought and climate vulnerabilities. The experience, so far, indicates that designing such an approach with government-provided capital support, subsidies, or price incentives for local farmers is required to make it effective and suitable for scaling up.

The main achievement of APFAMGS and the follow-up interventions is improved awareness and behavioral changes that helped the communities adapt to drought. The impacts observed in the earlier assessments (Reddy, Reddy, and Rout 2014; Verma et al. 2012; World Bank 2010) are different from the observed behavioral changes now. Common resource management requires institutional support, which takes time to evolve and stabilize.²⁰ These institutions need to be nurtured until they are self-sufficient. Moreover, they need to be evolved or tuned to reflect changing climatic and market conditions. The most important and difficult aspect of sustainability is ensuring equity in the distribution of benefits, which is missing in the APFAMGS model. Equity is critical for broader community participation, though achieving it is difficult, if not impossible, because of the structural aspects of land distribution, aquifer geometry, and distribution of capabilities. Approaches to bypass or overcome these structural dimensions—rather than correcting them—need to be explored at the policy and institutional levels. These approaches could be in the form of incentives, compensation, or cross-subsidies. In this regard, learnings gathered from social regulation approaches could help.

Unless there are substantial economic gains over the short run, proactive participation is unlikely to materialize (Mansuri and Rao 2013). Externally induced participation is unlikely to be sustained without tangible benefits, policy-backed incentives, and regulatory mechanisms. Although improving communities' awareness and knowledge about groundwater is a necessary precondition, it is not enough to make communities drought resilient. Policy and legal support systems are required to ensure enhanced benefits and equity in their distribution.

When adopting participatory initiatives, such as APFAMGS, on a wider scale, state governments need to consider the following aspects:

- Initiatives to increase community awareness and knowledge about groundwater by adopting scientific approaches and location-specific attributes is critical for understanding the resource status. The ongoing national aquifer mapping program focuses on

participatory groundwater mapping and management through local communities. Successful completion of this project could help provide the necessary knowledge base at the community level.

- Linking the community-based institutions to groundwater/irrigation departments with funds, functions, and functionaries could help sustain participatory groundwater management initiatives in the longer term. Groundwater departments can take the lead in promoting PHM and crop-water budgeting at the village level.
- Integrating top-down incentive structures and bottom-up regulatory mechanisms, and building community awareness, are likely to be effective in the short to medium term. These include price incentives for less-water-intensive rainfed crops, price stabilization (lowering price risk) for horticultural crops, and pricing of water and energy by treating them as economic goods. It also includes regulating groundwater extraction through community-based approaches and regulating bore holes, such as through the enforcement of the AP Water, Land and Trees Act, as well as other laws.
- Integrated policies are needed to make incentive and regulatory mechanisms effective for farmers. Input and output pricing policies should work in tandem to promote sustainable resource management. Current support price policies are biased in favor of water-intensive crops such as paddy, wheat, and sugarcane. These policies, complemented by free or subsidized power and water pricing policies, act strongly against the basic policy objective of sustainable groundwater management. Apart from correcting the policy distortions, price incentives are needed for drought-resilient and rainfed crops and water conservation practices.
- In the long run, ensuring groundwater equity among farmers will require policy changes that recognize groundwater as a common resource. That obligation involves changing the property rights regimes and delinking land and groundwater rights.
- A “business as usual” or policy inaction scenario would extend overexploited areas imposing constraints on quantity as well as quality. This scenario, in turn, would aggravate farmer distress in these regions and push farmers out of agriculture.

NOTES

1. Livelihoods and Natural Resources Management Institute (LNRMI), Hyderabad, India.

2. Centre for Economic and Social Studies (CESS), Hyderabad, India.
3. Demand management includes market-based methods such as property rights and pricing, technology-based interventions like micro-irrigation and other water-saving technologies, and nonmarket-based command and control (direct and indirect) systems.
4. Supply augmentation includes managed aquifer recharge structures such as check dams, farm ponds, and percolation tanks.
5. For instance, the government of AP has continued the APFAMGS under a new program, Groundwater Governance through Panchayati Raj Institutions in AP (GwGPRI-AP), with the support of the Food and Agriculture Organization of the United Nations (FAO) in 2015–16.
6. For more information about Atal Bhujal Yojana (ABHY), a ₹6000 crores (US\$860 million) scheme, for sustainable management of groundwater with community participation, see <http://pib.nic.in/newsite/PrintRelease.aspx?relid=188193> and <https://projects.worldbank.org/en/projects-operations/project-detail/P158119?lang=en&tab=results>
7. Studies have reviewed and assessed the achievements and impacts of APFAMGS over the years: AFPRO 2006; APFAMGS 2006; Govardhan Das and Burke 2013; FAO 2008; FAO 2010; Reddy, Reddy, and Rout 2014; Reddy 2012; Verma et al. 2012; World Bank 2010.
8. The project provided 3,462 groundwater irrigation facilities to small and marginal farmers, bringing an additional 35,000 acres under irrigation for about 14,000 small and marginal farming families in seven drought-prone districts of the erstwhile AP.
9. From July 1, 2003, to December 31, 2005, an estimated total cost of ₹20.02 (US\$5 million).
10. The formal title of the project was Reversing Environmental Degradation and Rural Poverty through Adaptation to Climate Change in Drought Stricken Areas in Southern India: A Hydrological Unit Pilot Project Approach. It was cofunded by GEF (US\$0.9 million), FAO (US\$1.3 million), and partner NGOs (US\$1.6 million) (in kind) at a total budget of US\$3.8 million.
11. IFAD provided a loan of US\$75.5 million with a matching finance (total project cost of US\$151.9 million) to fund the project for seven years in the five districts of AP (Anantapur, Chittoor, Cuddapah, Kurnool, and Prakasam) (IFAD 2016b).
12. APFAMGS districts fall in the category of drought- and desert-prone areas created by the government of

- India during the early 1980s. These areas or districts are identified based on rainfall (less than 750 millimeters), limited irrigation support (usually less than 30 percent), and frequency of droughts (crop failures in at least three of 10 years) (GoI 1981). These areas are given priority in implementing developmental programs like watershed development and provided with additional funding support.
13. Based on data between 2001 and 2015 given by statistical abstracts of different years for combined AP until 2014 and for the separate AP and Telangana states afterward.
 14. There are long-run options of bringing surface water through interlinking of rivers, which is costly. The government of AP is keen and initiated the process of interlinking the rivers in the state.
 15. Stage of development is defined as the ratio of groundwater extracted to its annual availability.
 16. The AP Groundwater Department provides information on groundwater draft and balance separately for command and non-command areas, whereas information about water table depth is available only at the district level. The average groundwater depth and rainfall data (for five districts) indicates that groundwater depths are fluctuating along with average rainfall (especially post-monsoon), with a one-year lag in some cases (figure 1). This fluctuation could be a result of the rainfall distribution across months and the timing of groundwater measurement.
 17. Water balance is calculated by annual recharge minus withdrawal (pumping).
 18. As indicated by local NGOs.
 19. For a detailed discussion on these interventions, see Reddy, Reddy, and Rout (2014). In fact, APDAI is a state government-supported program.
 20. Even 15 years is considered short in this regard.

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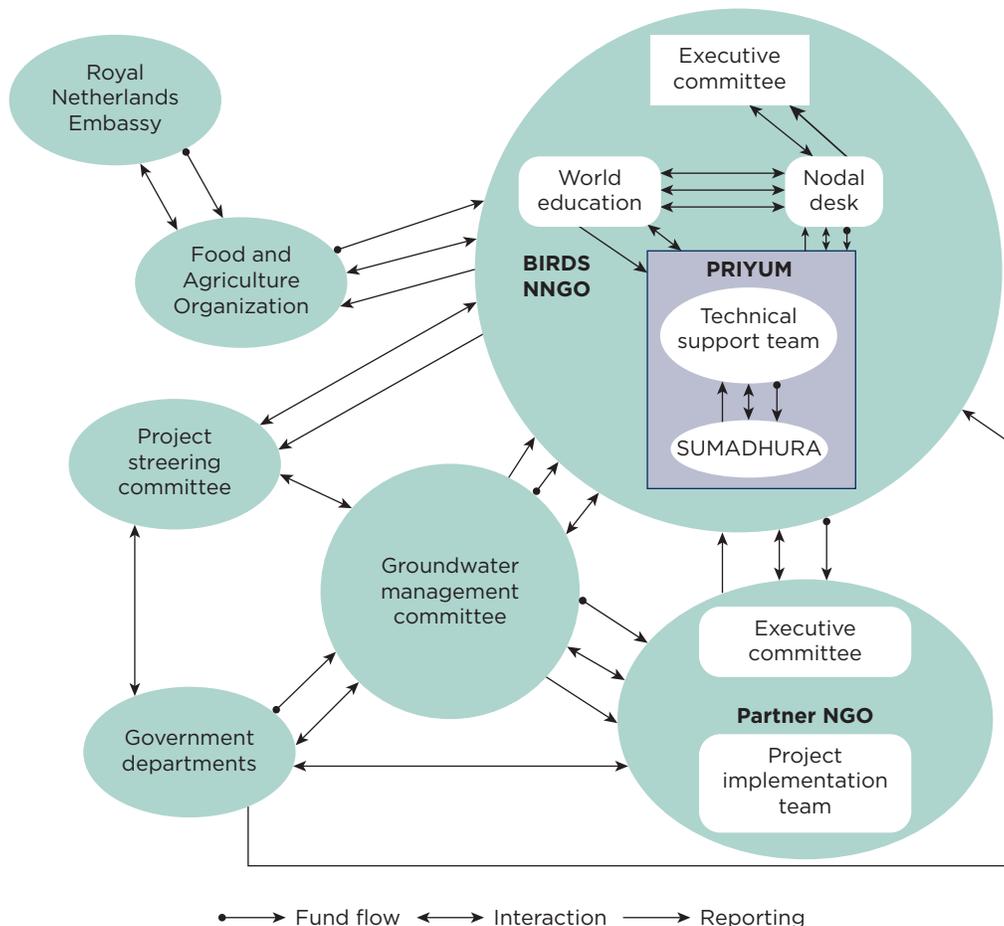
Appendix A

TABLE A.1. Field Visit Interviews

No	Person/institution	Position
1	Mr. V. Paul Raja Rao	Executive director, BIRDS, Gnanapuram, Nandyal, Kurnool (district)
2	Mr. Hassain Syed C.	CEO and secretary, SYA, Gooty Field Office, Anantapur (district)
3	Miss Purnima	Manager in charge, BIRDS, Hyderabad Office/PMU, APFAMGS and SPACC, and other projects, Habsiguda, Hyderabad
4	Mr. Hussain Saheb	Field coordinator, SYA, Gooty, Anantapur (district)
5		Joint director of agriculture, Gooty, Anantapur
6		Mandal agricultural officer, Gooty, Anantapur
7	Molakala Mallikarjuna	President, APFAMGS HUN (Uppara Vanka), SPACC, and GwGPRI projects; president, Anna Data RMG; member, ZBNF project committee of Dharmapuram (village and GP), Gooty (mandal), Anantapur (district)
8		Member, GWMC (APFAMGS) and SPACC, Dharmapuram (village and GP), Gooty (mandal), Anantapur (district)
9	Mrs. M. Savitamma	Member, GWMC (APFAMGS), SPACC, Chetana, and ZBNF; leader, SHG, Dharmapuram (village and GP)
10	Mr. Goddumudi Ramakrishna	Member, APFAMGS, HUN (Uppara Vanka), GMC, and SPACC, Pododdi (village and GP), Gooty (mandal), Anantapur (district)
11		Member, GWMC (APFAMGS) and SPACC, Pododdi (village and GP), Gooty (mandal), Anantapur (district)
12		Member, GWMC (APFAMGS) and SPACC, Uppara Vanka, HUN
13		Member, GWMC (APFAMGS) and SPACC, Vajrala Vanka, HUN
14	Mr. NarayaNaik	Kalajatha artist, Japla Thanda, Gooty (mandal), Anantapur (district)
15	Mr. N. Srinivasulu	Farmer; member, GWMC (APFAMGS) and SPACC, Chetnepalli (village), Gooty (mandal), Anantapur (district)
16	Mrs. M. Lakshmidevi	Farmer; member, GWMC (APFAMGS) and SPACC, and SHG, Chetnepalli (village), Gooty (mandal), Anantapur (district)
17	Mr. J. Kambagiri	Farmer; beneficiary, APFAMGS, K. Ubicherla (village)
18	N. Siva Prasad	Farmer, Basinepalli (village), Gooty (mandal), Anantapur (district)
19		ZBNF, project area, Gooty, Anantapur (district)
20	Mr. PineniSunder	Member, GWMC (APFAMGS), SPACC, and GwGPRI projects; member, ZBNF, Dharmapuram (village and GP), Gooty (mandal), Anantapur (district)
21	Mr. Ramakrishnudu	Cluster resource person, Dharmapuram, ZBNF, GoAP, Gooty, Anantapur (district)

Note: APFAMGS = Andhra Pradesh Farmer Managed Groundwater Systems; BIRDS = Bharati Integrated Rural Development Society; CEO = chief executive officer; GoAP = government of Andhra Pradesh; GP = gram panchayat; GwGPRI = Groundwater Governance through Panchayat Raj Institutions; GMC = groundwater management committee; HUN = hydrological unit network; PMU = Project Management Unit; RMG = Rythu Mitra Group; SHG = self help group; SPACC = Strategic Pilot on Adaptation to Climate Change; SYA = Star Youth Association; ZBNF = zero budgeted natural farming.

FIGURE A.1. APFAMGS Management Structure



Note: APFAMGS = Andhra Pradesh Farmer Managed Groundwater Systems; BIRDS = Bharati Integrated Rural Development Society; NGO = nongovernment organization; NNGO = nodal NGO; PRIYUM = Priyum advisory and Consultancy Services Private Limited; SUMADRA = Sumadhura Geomatica Private Limited.

TABLE A.2. Groundwater Resources in APFAMGS and Non-APFAMGS Regions of Five Districts in Andhra Pradesh

Year	Annual groundwater availability (mcm)			Groundwater draft (mcm)			Groundwater balance (mcm)			Stage of groundwater development (%)		
	C	NC	Total	C	NC	Total	C	NC	Total	C	NC	Total
1985	2,196.0	3,263.8	5,459.8	150.2	1,439.9	1,590.1	2,045.8	1,823.9	3,869.7	6.8	44.1	29.1
1993	1,718.5	4,123.0	5,841.0	387.6	1,154.0	1,543.0	1,330.9	2,969.0	4,298.0	22.6	28.0	26.4
2002	1,904.0	4,873.0	6,777.0	203.0	3,370.0	3,573.0	1,701.0	1,503.0	3,204.0	10.7	69.2	52.7
2004	1,697.6	4,479.4	6,177.0	493.9	3,473.8	3,967.7	1,203.7	1,005.6	2,209.3	29.1	77.6	64.2
2007	2,450.5	4,261.3	6,711.8	673.3	3,175.3	3,848.5	1,777.2	1,086.0	2,863.3	27.5	74.5	57.3
2009	1,894.2	4,764.5	6,658.7	514.1	3,246.8	3,760.9	1,380.1	1,517.7	2,897.9	27.1	68.1	56.5
2011	2,189.3	5,080.9	7,270.2	560.0	3,315.7	3,875.7	1,629.4	1,765.2	3,394.5	25.6	65.3	53.3
2014	2,111.8	4,729.1	6,840.8	504.7	2,988.2	3,492.9	1,607.1	1,740.9	3,348.0	23.9	63.2	51.1
2015	2,141.0	4,613.2	6,754.2	474.2	2,807.5	3,281.7	1,666.8	1,805.7	3,472.6	22.1	60.9	48.6
2016	2,046.0	4,817.9	6,863.8	537.8	3,184.1	3,721.9	1,508.2	1,633.8	3,142.0	26.3	66.1	54.2

Source: Data compiled from Groundwater Resource Estimation Reports, Government of Andhra Pradesh, Groundwater Department, Hyderabad, India.

Note: APFAMGS = Andhra Pradesh Farmer Managed Groundwater Systems; C = command; mcm = million cubic meters; NC = non-command.

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