Farm management for improving groundwater security in Andhra Pradesh, India: preliminary analysis of social and gender issues

A report on integration of social and gender issues in Agricultural Knowledge Initiative (AKI) projects

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**Introduction**

Nearly 60% of the irrigation requirements of India are met by groundwater (CGWB, 2002; Shah et al., 2003); therefore, irrigation from groundwater can be credited with significant responsibility for the food grain self-sufficiency achieved by India in the last three decades. Groundwater irrigated areas of India nearly tripled in extent from 11.9 million ha in 1971 to 33.1 million ha in 1999 (Mukherji and Shah, 2004). It has also been shown through analysis of over 240 districts across India that the productivity contributions ($/ha) of groundwater irrigated areas are about 35% greater than those of surface water irrigated areas (Mukherji and Shah, 2004). This can be explained by lower conveyance losses (it is withdrawn closer to the location of application), application timing is more controllable, and overall irrigation efficiencies are typically higher because applications can be more frequent (Shah et al., 2003). Throughout Asia, irrigation from groundwater has become a major contributor to agricultural improvements in recent decades. However, there are also energy efficiency concerns associated with groundwater depletion that have resulted from increased groundwater irrigated areas; scarcity of groundwater in some regions has decreased net energy ratios in agriculture (energy output / energy input) as a result of greater pumping and fertilizer inputs (Gurunathan and Palanisami, 2008).

Considering this background, water and agricultural issues are increasingly becoming a problem for livelihood security in India, and more research funds are being made available to study such issues. The findings presented here are part of the effort to integrate gender and social issues into water management projects of the US-Indo Agricultural Knowledge Initiative (AKI). The AKI project addressing sustainable water resource management in India is a cooperative investigation partnering the University of Florida (UF) Water Institute and three Indian
universities (Indian Agricultural Research Institute: IARI, Punjab Agricultural University: PAU, Acharya N.G. Ranga Agricultural University: ANGRAU). This research includes physical and simulation experiments for the purpose of finding solutions to various water quantity and quality problems at three locations in India (Ludhiana, Dehli, and Hyderabad). This report is a contribution to the study, *Integrating gender and social issues in watershed management projects of the Indo-US Agricultural Knowledge Initiative: A pilot study*, to include gender and social analyses into the process of biophysical research conducted for the AKI projects (Haman et al., 2007). The working partnership (on integration of gender and social issues into projects on watershed management) was with Washington State University, the UF departments of Agricultural and Biological Engineering and Religion, the International Crops Research Institute for the Semi-arid Tropics (ICRISAT), and ANGRAU.

As a result of this cooperation, it is hoped that the management suggestions made from research under the AKI sustainable water resource management grant will be relevant to the realities faced by the people in the study area. Makisa and Joekes write:

> Much of the mainstream literature on environmentally sustainable development has ignored the gender dimensions. In the instances where there has been specific attention to women, they have been viewed as naturally privileged managers of environmental resources with little attention paid to how gender relations systematically differentiate poor men and women in processes of production and reproduction and relegate women to environmentally-based activities and limit their access to other types of livelihood activity (Joekes and Makisa, 1997).
This research was carried out with the goal of including gender and social analysis to improve the relevance of science-based recommendations. The research project includes interdisciplinary work between departments at UF—undertaken under the guidance of the Water Institute—and collaborative work with Indian institutions as part of a joint research and capacity building effort.

An ungaged, 550 ha sub-watershed, Kothakunta, in the Wargal mandal, Medak district of Andhra Pradesh, India (see Figure 1 for location), was selected by ANGRAU scientists for analysis because it is illustrative of the common regional problem of groundwater decline, making farming systems increasingly vulnerable. About 150 households live in or have cropland in the area; average landholding size is 4 ha. Almost all residents of the research area are Muslims and Hindus who are farming marginal farms and who depend upon government rations to buy household food items, like sugar and kerosene and rice, and who buy government subsidized seeds and fertilizers. There are approximately 200 borewells in the research area. The area is served by a panchayat elected by local residents; this local governance body is in theory the first option local residents have if they want to address water issues and conflicts that may arise in their community.

The groundwater resources for the Medak district (as of 2005) included a total renewable groundwater volume of 813.19 Mm³ and a net annual draft 704.07 Mm³, leaving a balance of 109.12 Mm³ of groundwater or a stage of ground water development of 87% (CGWB, 2007). Groundwater occurs under mostly unconfined and some confined conditions predominantly in fractured granite (transmissivity: 100 to 150 m²/day) and basaltic and lateritic (transmissivity: 100 and 1100 m²/day, respectively) formations. A decade of monitoring groundwater levels in
borewells in Medak district (1996-2005) showed a pre-monsoon groundwater decline of 1.1 to 5.2 m. and a post-monsoon decline of 0.2 to 6.6 m over the 10 year period (CGWB, 2007).

Figure 1. Location of study area in southeast Medak district, Andhra Pradesh

The goal of this study was to identify the decision making processes involved in determining farm management practices, including the information used. A thorough analysis requires that the differences between decision making by men and women (involvement, power relations, access to and use of information) be understood. Fieldwork in the study area aimed to begin this process.

The related biophysical goal under the AKI project in Kothakunta is to find cropping system management options that improve groundwater levels and are sufficiently productive. Using a
distributed water balance model, watershed-scale analyses of groundwater and food production responses to crop selection, tillage strategy, and irrigation management will help select the best management practices for improving groundwater and food security for people of the watershed. Information from people of the community serves 3 purposes for biophysical experimentation (one before, during, and after water balance modeling):

- Validation of problem – confirms that the problem (groundwater depletion) is actually a concern to people in the watershed. Interactions with farmers in the area showed that groundwater depletion was observed by nearly everyone in the area, and it was one of their major concerns.

- Simulation of appropriate management options – participation from the community to recommend management options (alternative crops, tillage, and irrigation) that they would prefer and that they expect would reduce irrigation withdrawals. This information increases the relevance of simulation experiments. Preliminary fieldwork has provided some information on crop preferences, available tillage implements, and typical irrigation practices. These will be used to choose implementable management strategies for simulation experiments.

- Implementation and motivation to change – field trials and actual management changes by farmers in the area are expected to be easier to initiate as a result of the involvement of the community. An improved understanding of how certain farm management decisions are made (what information is used to make them) helps expose possible motivations for change. From interactions with farmers in the area, it was learned that water availability was the most dominant information used in decisions about crop selection.
The interaction of research-generated information and local management changes is nuanced and requires significant understanding of local information systems (Roncoli et al., 2002; Shah et al., 2003). As Roncoli et al. (2002) state, from their study about local rainfall forecasting in rural Africa, “Evidence shows that local knowledge can and must be integrated with research-generated information and technology in efforts to improve rural livelihoods.” For research models generated in the U.S. to have practical transferability and help improve rural livelihoods they must be able to fit into local knowledge systems, including religious belief systems and farm management decision making processes.

**Sustainability: definitions**

Broadly, the AKI project focuses on sustainable water resource management in India; in Kothakunta, the specific concern is groundwater sustainability. The definition of sustainability (or security) with reference to some biophysical quantity is generally straightforward. It is the maintenance of a state or process at a desired level or rate into the future. Given the subject of interest in this project, groundwater quantity, to more narrowly define sustainability the amount of groundwater (distance below ground level or aquifer storage volume) to be maintained must be chosen. This decision is informed by past and current levels and expert judgment. This decision will be based on consumption requirements (current and estimated future) and the groundwater balance, considering natural and anthropogenic inflows and outflows. The groundwater balance has an obvious dependence on decisions by people, which is why it was decided that an improved understanding of how the people of Kothakunta make decisions would contribute to the AKI project goal of finding ways to sustainably manage water resources in India.
Methods

Social and gender information

The plan for our fieldwork in the Kothakunta watershed was focused on meeting the following 3 objectives:

- Explore the perceptions of men and women concerning groundwater resources and changing climate
- Identify gender differences in constraints to changing farm management practices (tillage techniques, crop selection, irrigation management); and explore the local farm management decision-making processes
- Gauge the participation of men and women in water-related organizations or agencies

The intention was to meet with members of households having dependence on the study area for their livelihood sources. It was planned to meet with men and women both together and separately to discuss their decision-making processes, cropping system preferences and constraints, responsibility divisions, and perceptions of water resources and climate change.

Meetings with community-level government were planned to understand the regulation of water and land use management. The following tools were researched for use in engaging people in discussion and participation: farming systems diagram, village resources map, daily activity clock, seasonal calendar, and trendlines (FAO, 2001).

Fieldwork was done in partnership with collaborators from ICRISAT and ANGRAU.

Translation and transportation were provided by ICRISAT; translation and introduction to the
study area and community members was facilitated by ANGRAU partners. The plan for fieldwork was adapted. In early interactions with participants we found that the expected use of participatory tools was not possible. We attempted the participatory tools in three different occasions with little success. This may have resulted from the timing of interactions with farmers; typically, meetings with them were during a break in their on-farm work, and it may be that it was important for them to rest during this time. Therefore, the adapted toolset became: informal interviews of open-ended questioning and participant observation. Typically, interviews began with introductions and continued with discussions about main concerns in the community, changes in groundwater supply and climate, and how decisions were made and who was responsible for certain farm operations. Observations were regularly made of who was doing farm operations (tillage, weeding, planting, transplanting, controlling borewell pump).

Total number of participants: total (71), men only (19, men responding while no women present), men mixed (6, men responding while a smaller number of women were present), women only (32, women responding while no men present), women mixed (14, women responding while a smaller number of men were present). The reason respondents were organized into these groupings reflects that at times the groups present for discussion consisted of only men/individual men; only of groups of women/individual women; and also of groups of both men and women. However, at times these groups had more men present than women, and others more women present than men. The assumption was that in the mixed groups there may be different answers from men and women depending on if men were in the majority or not. Ages of research participants ranged from 18 to 72, with participants living either in the sub-watershed directly, or in the closest neighboring towns of Wargal or Ausunpalli. Some
respondents were direct owners of the farm we were visiting and these respondents were either alone or with family members (both men and women) who were working on the farm. As it was the time of season for busy planting and weeding, many farms had hired day labor present in the fields when we were conducting research. Most of the hired labor was female and these workers tended to be local residents of the Wargal area and/or other farmers finished with their own needs and who were seeking extra income. The hired day laborers also participated in the discussions summarized here. For much of the results presented here, sample sizes of women are slightly larger than those of men (these numbers are totals, including responses in gender-separated and mixed groups). The larger numbers of women reflects the special efforts made to include women in discussions; also, due to the nature of many of the field operations for which they were responsible, women were more likely to be found working in groups.

**Social and biophysical analysis connections**

During experiment design, decisions have to be made by the user of the water balance model about the number and the types of management practice scenarios to simulate. Based on preliminary interactions with community members and accepted water conservation strategies, the following management options are to be considered:

- Tillage – tied-ridging, contour ridging, conventional tillage; 3 choices
- Crop selection – rice/maize, sunflower/peanut, maize/potato, cotton/chickpea; 4 choices

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1 Women agricultural day laborers received around 40 Rs/day, men received around 60 Rs/day (personal communication, day laborers)
• Irrigation – full, deficit, rainfed; 3 choices (with depths estimated from published crop water use information; amounts different for different crops)

All the combinations of these 3 management options give 36 management scenarios. The hydrologic (groundwater recharge) responses to these scenarios will be simulated individually over the total cropland areas of the subwatershed and in several spatially distributed combinations of scenarios. The parameters or inputs resulting in the hydrologic responses from the management options of tillage, crop selection, and irrigation are: depression surface storage (tillage); duration, LAI, growth rate (crop selection); withdrawal volume (irrigation).

Additionally, management scenarios as recommended by the community will be simulated and compared with those generated by the model user. For management scenarios generated by the community, additional fieldwork and participation of farmers would answer the following questions:

• What are the 5 most preferred crop rotations (with associated seasons), and why? What are the associated tillage and planting strategies/implements for each crop?

• What are the 5 most preferred crop rotations (with associated seasons) if all minimum support prices (MSP) were the same, and why? What are the associated tillage and planting strategies/implements for each crop?

• Why is rice grown? If the government no longer provided MSP for rice, would farmers continue to grow it? What would farmers grow (3 preferences) in place of rice seed was no longer available?
What times of year do farmers irrigate? What crops are typically irrigated? How many days per week do farmers irrigate? For what amount of time do farmers irrigate each day? If electricity was available at all times, what amount of time would farmers irrigate each day?

If all borewells in the area stopped working, what would farmers grow (5 most preferred crop rotations), and why? Would they expect to survive or have sufficient income without borewell irrigation?

What are the various tillage options/implements for field preparation and weed control? What are the most preferred tillage options/implements? Would farmers invest twice the labor in tillage if they could expect 50% greater yields?

The above questions capture the majority of information required for use in developing farm management scenarios directly from farmer participation. It is hypothesized that management scenarios from farmer-generated information would have higher productivity, greater chance of implementation, and lower groundwater level increases than those from researcher-generated information. Comparisons between the results of water balance simulations having management scenarios from different sources will help test this hypothesis and will offer a more realistic range of hydrologic and productivity responses to management recommendations.

**Results**

Findings from interviews with community members were grouped into the following 3 themes: main concerns, changes in groundwater and climate, and management and decision making. Main concerns were responses about the most pressing issues in the community. Changes in
groundwater and climate captured responses about direction of changes observed, how they are measured, and what the causes of the changes are. Management and decision making explores the information used to make farm management decisions and who is responsible for selected management activities.

**Main concerns**

One topic of interactions with farmers was their main concerns in the community. This was approached in a very broad, open-ended manner to include information related to agriculture or other aspects of the livelihood system. Percentages of various responses are presented in Table 1. A few key themes stand out and warrant attention. The data suggests women are more concerned about social livelihood issues like education and adequate health care for their children, bus routes to town for easier access to markets, and clean and abundant water for domestic use. Public transportation (bus route accessibility) was one of women’s top concerns, suggesting they more regularly use public transportation. Meanwhile, men seem to be more concerned with job/economic livelihood issues regarding their profession as farmers with concerns over issues such as affordable fertilizer, reliable and inexpensive seed, adequate electric power for running irrigation pumps, and availability of local non-farm employment.

The interviews generated the following concerns that are shared equally by both men and women of the Wargal area. Both genders expressed concern about there being less groundwater and an increasing rate of failing borewells and both are concerned with power shortages that impact the functioning of irrigation pumps.
Table 1. Concerns of community members ranked (for women) in order of decreasing frequency of reporting

<table>
<thead>
<tr>
<th>Issues most concerning to participants</th>
<th>Women % of total responses</th>
<th>Women rank</th>
<th>Men % of total responses</th>
<th>Men rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>No local higher education</td>
<td>59</td>
<td>1</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Bus routes are limited into Wargal</td>
<td>55</td>
<td>2</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Limited power for irrigation</td>
<td>41</td>
<td>3</td>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>Water quality for drinking in homes</td>
<td>41</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Limited service at healthcare clinic; no staffed doctor</td>
<td>41</td>
<td>3</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Less groundwater, failed bores, water availability</td>
<td>31</td>
<td>4</td>
<td>28</td>
<td>5</td>
</tr>
<tr>
<td>Vulnerability due to irregular rains</td>
<td>28</td>
<td>4</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Seed is expensive and not reliable</td>
<td>14</td>
<td>5</td>
<td>34</td>
<td>3</td>
</tr>
<tr>
<td>No available non-farm work</td>
<td>14</td>
<td>5</td>
<td>31</td>
<td>4</td>
</tr>
<tr>
<td>Lack of affordable fertilizer</td>
<td>10</td>
<td>6</td>
<td>59</td>
<td>1</td>
</tr>
<tr>
<td>Labor availability/rising cost of labor</td>
<td>10</td>
<td>6</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td>Less land, more children</td>
<td>10</td>
<td>6</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Total number of participants</td>
<td><strong>29</strong></td>
<td></td>
<td><strong>32</strong></td>
<td></td>
</tr>
</tbody>
</table>

Overall, a few tentative conclusions can be drawn from this analysis of preliminary, rapid appraisal interviews with farmers and residents of the research area. As stated, the most prevalent concerns of women tend to coalesce around their domestic roles of providing care and education for their children and their roles of going to market. Some women did express concern about lack of groundwater and electricity for powering irrigation pumps. This concern shows that some of the women are knowledgeable about the water issues facing the community and how this impacts farming and livelihood security. As stated, the men we interviewed are most concerned about farming and job livelihood issues. Their concerns tend to overlap with cultural gender roles of men being economic providers and farmers. As such, they are mostly concerned with issues that directly impact their ability to be successful farmers and wage earners.

Overall, there is a large discrepancy in the concerns between the men and women we interviewed. This is evidenced when we see that four of the five top concerns for women are not mentioned as concerns by men except for one male respondent who did mention concern about
cleanliness of and access to water for domestic use. Comparatively, women do seem to share a more limited base of concern with the dominant male concerns. This is most likely because the overall economic prosperity of the family depends on farming issues like seed, fertilizer, electricity, and water availability and this is something that men and women talk about together. Some women have also taken out loans through local women’s self-help groups and this money is often used for farm inputs so that women have an added stakeholder concern in the success of their family farm.

It should be noted that these questions were left open, so that although men did not respond that they are concerned with education and health care this does not mean that these issues are not actual concerns they also have. Rather, their immediate concerns in the context of our interviews were farming related while women’s immediate concerns were socially and family health related.

**Changes in Groundwater and Climate**

Resource security and sustainability, namely sustaining groundwater levels, is an important objective of the broader research that this project is a part of. Therefore, it was decided that the perceptions of farmers about groundwater and climate changes should be explored. Farmers were asked if they had noticed any changes in groundwater levels in recent years; the question was always open, not assuming any resource depletion. Participants were asked to consider methods of noticing groundwater depletion, expected causes of groundwater depletion, and expected cause of reduced rainfall. Tables 2, 3, and 4 summarize their responses.
Table 2. Ways of observing groundwater depletion

<table>
<thead>
<tr>
<th>Methods of observing groundwater decline</th>
<th>Women % of total responses</th>
<th>Men % of total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failed drilling attempts</td>
<td>71</td>
<td>20</td>
</tr>
<tr>
<td>Time of continuous flow, pressure of flow visually noted</td>
<td>57</td>
<td>80</td>
</tr>
<tr>
<td>Not observed</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Total number of participants</td>
<td>21</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 2 summarizes the groundwater sensing or measurement options; without instrumentation changes in groundwater levels are still noticed by men and women in the research area. More women cited failed drilling attempts as a method of observing groundwater decline. This method likely has the most severe economic consequences. Only a small percentage of responses indicated that groundwater decline was not observed; this gives more support (in addition to published groundwater decline data) to the effort to find farm management options for improving groundwater levels. Those that responded that they had noticed groundwater decline were asked what they thought was causing the decline. Few different responses were given and it sometimes took about one minute for participants to choose a cause.

Table 3. Perceived causes of local groundwater depletion

<table>
<thead>
<tr>
<th>Suggested causes of groundwater decline</th>
<th>Women % of total responses</th>
<th>Men % of total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less rain</td>
<td>58</td>
<td>75</td>
</tr>
<tr>
<td>More borewells</td>
<td>83</td>
<td>50</td>
</tr>
<tr>
<td>Total number of participants</td>
<td>24</td>
<td>12</td>
</tr>
</tbody>
</table>

Participants who suggested reduced rainfall as a cause of groundwater decline were asked why rainfall amounts were less than average. Similar to the responses about cause of groundwater decline, there was little variability among responses. Shoulder shrugging was common and some suggested such a thing could not be known.
Table 4. Suggested reasons for recent reductions in local rainfall amounts

<table>
<thead>
<tr>
<th>Reasons for observed changes in rainfall</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>gods, more population, people doing bad things</td>
<td>86</td>
<td>63</td>
</tr>
<tr>
<td>Less greenery (forest plantations logged; trees around croplands cut)</td>
<td>3</td>
<td>26</td>
</tr>
<tr>
<td>Unknown</td>
<td>10</td>
<td>32</td>
</tr>
<tr>
<td>Total number of participants</td>
<td><strong>29</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>

As seen in Table 4, local knowledge, especially for women, explains changes in rainfall as “people doing bad things,” which they also called “sin.” As the U.S. ethnologist Anne Feldhaus cautions, the Indian notion of sin should not be equated with the Western, Christian-influenced notion of sin: “not all the theological implications [sin] has in English are applicable in a traditional Indian context. The topic of sin must be considered, I believe, in the more general context of evil” (Feldhaus, 1995; 173). For the Indians she studied in western India, she notes that violence and sex (incest, adultery, and lustful acts) are the two biggest causes of sin. Future research should clarify what these respondents meant by “gods” and “sin,” but interpreters from ICRISAT mentioned that the list of bad things is very similar to what Feldhaus claims are sinful for the Indians she studied. This finding suggests that community dynamics and social and religious mores factor into local interpretation of weather patterns and resource availability.

The following overall conclusions can be drawn from the above data about groundwater and climate:

- There is local knowledge about this important resource
- Gaps and limitations, at least about groundwater and climate, can be found in this knowledge base and future capacity-building measures can be used to fill in these gaps
If noticed changes in groundwater are a cause of concern, then there may be interest in the community undertaking capacity building measurements to help deal with perceived and measured changes in groundwater and climate.

A clear majority of research participants, whether female or male, have perceived a change in groundwater. An equal number of both men and women claim to have noticed this change because of visually noting the rate and strength of flow coming from pumps. This shows that both men and women have an interest in observing flow rate. It also suggests that both men and women most likely see the importance of having a working pump with adequate water flow and how a working pump impacts the overall health of their crops. A clear majority of women have noticed changes in groundwater because of failed drilling attempts. Similarly, more women associate groundwater depletion with the proliferation of borewells over the last ten to fifteen years: of the 23 people who were asked about reasons for changes in groundwater, 15 associated this with more borewells being drilled, 12 were women. What is more relevant is that this recognition of correlation shows that there is community knowledge about current farming systems and management decisions and how these may be contributing to groundwater depletion.

Lastly, all research participants in the watershed, both men (N = 12) and women (N = 27), have noticed changes in rainfall. Rainfall data from nearby Patancheru indicates a decline in rainfall from the long term mean (880 mm annually) of less than 3% over the period from 1999 – 2008 (ICRISAT, personal communication). However, data from India’s Central Groundwater Board suggests greater rainfall declines in the Wargal mandal where Kothakunta is located. These data show a decline in rainfall from the long term mean (873 mm annually) of about 30% over the
period from 2001 – 2006 (CGWB, 2007). Water balance simulations will help answer the questions about cause of groundwater depletion being related mostly to rainfall changes or irrigation increases. A few farmers even shared with us that they remember when there used to be puddles and little ponds all over the fields in the past but in recent years the fields dry up earlier because there is less rain. When asked the reason why they think there is less rain today, most respondents, and especially women, blamed it on the gods punishing people for “sinning.”

Spiritual methods of predicting or summoning rainfall have been observed by numerous investigators and are typically available to selected individuals or groups (Roncoli et al., 2006). It should be noted that some of the questions to be asked to the research participants concerned investigation of the religious aspects of the management and belief systems of those working and residing in the sub-watershed. The few times religion was brought up occurred when discussing why there is less rain now than in the past and also when seeing coconut husks and other shrines at various places throughout fields. The coconut was part of an offering to the field to help with successful crops. It was decided that, given the limited amount of time most research participants had available, this time would best be spent discussing the core, mutually identified issues (main concerns in the community, changes in groundwater and climate, management and decision making processes/information) that would help meet as many of our research objectives as possible. This means that questions about religious beliefs and practices and how these impact/do not impact crop and water management decisions were not pursued; furthermore, planned meetings with local Hindu and Muslim religious leaders were not arranged. Future research should aim to remedy this gap in our initial research. Therefore, this report makes no
claims about the role religion plays in the sub-watershed regarding either gender and farming issues.²

Management and decision making

Management of farming systems in the study area is adaptive, considering diverse information from which decisions are made. Questions were asked of farmers about what information is used to make decisions about crop selection and irrigation management. Tables 5 and 6 present common responses and their percentages of total responses.

Table 5. Information used to decide about crop selection: ranked (greatest to least – women’s column) percentages of responses

<table>
<thead>
<tr>
<th>Decision information: crop selection</th>
<th>Women % of total responses</th>
<th>Men % of total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observe water availability</td>
<td>81</td>
<td>80</td>
</tr>
<tr>
<td>Talk with family</td>
<td>65</td>
<td>50</td>
</tr>
<tr>
<td>Talk with neighbors</td>
<td>38</td>
<td>40</td>
</tr>
<tr>
<td>Market price information</td>
<td>8</td>
<td>30</td>
</tr>
<tr>
<td>Personal experience</td>
<td>0</td>
<td>45</td>
</tr>
<tr>
<td>Total number of participants</td>
<td>26</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 6. Information used to decide about irrigation management: ranked (greatest to least – women’s column) percentages of responses

<table>
<thead>
<tr>
<th>Decision information: irrigation timing and depth</th>
<th>Women % of total responses</th>
<th>Men % of total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observing plants, soil</td>
<td>85</td>
<td>77</td>
</tr>
<tr>
<td>Irrigate when power is on; occasional shutoff if sufficient rain</td>
<td>40</td>
<td>62</td>
</tr>
<tr>
<td>Rainfall depth and timing</td>
<td>30</td>
<td>23</td>
</tr>
</tbody>
</table>

² The literature indicates that religion can potentially play an important role in resource management decisions, especially in rural areas with low levels of literacy and that have strong religious sensibilities, whether Muslim, Hindu, or adivasi. See, for example, Shah, et al 2001, regarding the influence Muslim religious leaders had on water use in rural Pakistan. However, it must be noted that religion may not play a very decisive role and that instead directives from the government can influence environmental behavior so that conservation is internalized (Agrawal, 2005).
Keeping 3 inches of water in paddy fields  

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of participants</td>
<td>20</td>
<td>13</td>
</tr>
</tbody>
</table>

Agreement in the responses of men and women is illustrated in Table 5. Responses for each question are ranked in the table from highest to lowest frequencies of occurrence. Talking with family and neighbors meant that people asked what their neighbors were planting and men and women within a household asked each other what to plant and how much of it. Both men and women reported that observations of water availability and conversations within the family and community are the most important sources of information for decisions about crop selection. A much higher proportion of men indicated that produce price would be considered, suggesting that men are more likely than women to consider expected market values of crops in decisions about what to plant. In discussions of timing and depth of irrigation, women were significantly less likely than men to give the response: electricity is on; therefore, irrigation happens. That response was the most frequently occurring response by men. This supply-side management method may be partly the cause of the local groundwater depletion.

Considering the biophysical goal of improving groundwater levels, the prevalence of water availability as an important influence on crop selection decisions means that people in the community would be responsive to management scenarios that are designed to do well under limited water availability. This suggests that water balance simulations should be designed to find management options that broaden the range of crops under consideration when there is low water availability. Some tillage techniques which result in greater rainfall infiltration (and greater estimated yield) could achieve this. However, observations in the field and participation of community members have revealed that there is limited labor availability and very little
mechanization available for field operations. Therefore, management scenarios must be designed with consideration of these constraints.

Figure 2. Some women take a break for lunch and to participate in discussions for this research.

Regarding this issue of gender and irrigation management, the feminist resource management scholar and researcher Margeet Zwarteveen points out:

Even though women are active as farmers in irrigated fields, their responsibilities and visibility in the formal and public parts of irrigation management are often restricted.
Some researchers suggest that the definition and delimitation of irrigation as something masculine is one way of reconfirming masculine status, and vice versa: defining irrigation management as masculine lends it with prestige (Zwarteveen, 2008; 126).

Our initial research suggests that informal, on-farm irrigation responsibility is restricted to men for the majority of farmers we talked to, but for some farms, women did have some irrigation responsibility. In the area where we conducted research, almost all of the people who drill wells, hook up electricity to the wells, and who engineer and manage power and water stations are men.

Based on conversations with farmers, information used for decision making could be grouped, based on the data (Tables 5 and 6), into the following 8 categories; ranked in order of decreasing frequency of occurrence:

**Decision support information**

- Water availability
- Observation of plants and soil
- Family communication
- Discussion with neighbors
- Expected market price of produce
- Personal experience
- Labor availability
- Suggestions from input (fertilizer, seed) vendors

This information was used to shape decisions about crop selection, irrigation, and fertility management. Decision-making information that could be categorized as water availability was
reported by nearly all farmers involved, suggesting that groundwater decline and rainfall variability are significant concerns. Water availability is observed by impressions of rainfall of the previous year, water tank levels, soil moisture, plant appearance, and flow rate (intermittency) of borewells. Figures 3 and 4 are photographs of a water tank after a recent rain and an operating borewell.

![Figure 3](image-url)  
**Figure 3.** One of six water harvesting structures (tanks) in the Kothakunta watershed
Figure 4. A local farmer and landowner; borewell irrigating rice paddy

In areas where agriculture is the dominant livelihood activity, attention to water availability and other limiting factors is universal among stakeholders of agriculture (Roncoli et al., 2002). Tools used to predict risk of agricultural activities typically have some measure of water availability being the most sensitive input (Kazianga and Udry, 2006), so it should be expected that farmers indicate that water availability is the most important factor in decisions about crop selection. Table 7 illustrates the consistency between men and women in the most frequently observed responses concerning decision making. Based on Tables 5 and 6 and additional data, Table 7 lists the most frequently given responses for various types of decisions. Only in the replacement
of paddy crop did responses diverge; the men suggesting growing cotton and the women opting for a cover crop or fallow, which would require much less labor and management but would provide no direct cash income. In a report on the changing roles of men and women in response to desertification Gurung et al. (2006) suggest that women are more responsible for food crop production and land conservation and men are typically more responsible for cash crop management. The data presented here is consistent with this: women responding that they would prefer a cover crop or fallow (which would likely improve productivity of future plantings of food crops) and men suggesting cotton (which would increase short term household income).

Table 7. Decision category and associated most important responses

<table>
<thead>
<tr>
<th>Decision type or responsibility</th>
<th>Dominant response</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>crop selection</td>
<td>observe water availability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>irrigation management</td>
<td>observe plants, soil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>paddy extent</td>
<td>1/8 to 1/4 of cropland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>paddy replacement if insufficient water</td>
<td>cover crop, fallow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pump responsibility</td>
<td>men</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Questions were asked of farmers about who turns on and off the borewell pump used for irrigation withdrawals and who goes to the market to buy seeds and fertilizer. The following tables summarize responses to these two questions.

Table 8. Percentages of responses concerning who is responsible for irrigation pump control

<table>
<thead>
<tr>
<th>Responsibility for borewell pump control</th>
<th>Women % of total responses</th>
<th>Men % of total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Either</td>
<td>89</td>
<td>100</td>
</tr>
<tr>
<td>Women</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total number of participants</td>
<td>19</td>
<td>8</td>
</tr>
</tbody>
</table>
Managing irrigation (turning the borewell pump on and off) and buying seed and fertilizer was largely the responsibility of men (see Table 8). This arrangement seemed to work well and appeared satisfactory to all involved. However, some investigators have suggested that the dominance of men in water control marginalizes women’s water rights (Lambrou and Piana, 2006; Zwarteveen, 2008). Considering what a productive resource groundwater is, it may be that women’s limited management experience with it does afford them less power than men (Pangare, 1998). Women usually reported that they were afraid of the electrical box where the pump switch (or wire connectors) was located. Similarly, the purchasing and delivery of seed and fertilizer was typically the responsibility of the men (Table 9), possibly increasing their access to information about marketing and crop suggestions from vendors. Some participants indicated that women could manage pump control and buying of seed and fertilizer if required.

**Discussion and Conclusions**

Some investigators have suggested that the groundwater socio-ecology in Asia, and particularly in India, is at a critical point. Shah et al. (2003) organize the progression of groundwater use in agriculture into 4 stages: expansion of tubewell installations, groundwater-based agrarian boom, onset of groundwater depletion concerns, and collapse of groundwater-based systems. Observations (from groundwater level measurements and local household perceptions) in
Kothakunta suggest that this area is in stage 3 of the progression; groundwater depletion is an observed and growing concern. Our data suggest that farm management decisions do consider this and that this management is influenced by social and gender roles, but farmers are understandably still trying to maximize their groundwater irrigated areas.

Sufficient groundwater in the near future for Kothakunta residents will likely require changes in the way farming systems are managed. The types of changes and how they are achieved is an important part of the broader AKI project on sustainable water resources in India. Considering this context, the main findings of this initial assessment of social and gender issues in the area follow:

- Groundwater availability is a concern for most people; of all their concerns in the community it ranks in the middle (for both men of women) in terms of frequency of responses from participants. If the 4 stages of groundwater-based agrarian societies are correct, the stage that follows the current one (observation of depleted groundwater) is a rapid decline in productivity and livelihood security. It seems now is an important time for finding the best ways to increase productivity that require the least groundwater-based irrigation.

- Households have observed groundwater depletion by noticing more failed drilling attempts and more intermittent, lower pressure flow from borewells. If substantial management changes are achieved which reduce groundwater withdrawals, these means of measurement will be important indicators to farmers of the increases availability of groundwater. Without any preemptive management changes, local methods of groundwater measurement will require management changes to reduce groundwater use,
but there would likely be a period of high vulnerability as local people adjust to the very limited availability of groundwater. Our data suggest women are more likely to attribute the cause of groundwater depletion to increased borewells, so it may be that women are more likely than men to adapt management to reduce dependence on borewells.

- For both men and women, water availability was the information most commonly used to make decisions about crop selection. Concerning irrigation management: a common response was that irrigation timing and depth depended mostly on electricity supply (if power is on, irrigation happens); this supply-side management perspective may be part of the reason for groundwater depletion in the area. It was almost exclusively the responsibility of men to control borewell pumps, but participants indicated that both men and women were involved in decided when to turn pumps on or off.

Presently, efforts to find combinations of management options that are most promising for improving groundwater levels are focused on improvement and use of regional and local water balance simulations. The storm generation function used to provide hourly rainfall intensities for periods beyond the present will be calibrated to reflect the more episodic rainfall regimes of monsoonal India. Also, the infiltration equation in the model will be modified to allow for surface depression storage to represent conservation tillage options. Simulations at the regional scale (Krishna basin, of which Kothakunta is a part) will be used to evaluate model accuracy using available streamflow data. Regional water balance simulations will also be used to evaluate changes in recent years in the groundwater balance (recharge – estimated irrigation withdrawals) in response to changes in rice cropland extent. It is expected that simulated trends in rice extent and groundwater balance will match the measured trends in regional groundwater
decline. Groundwater and tank levels will be used to validate simulation accuracy at the local (Kothakunta watershed) scale. It is hoped that field trials of the management options most likely to improve groundwater quantity (based on simulations) will be initiated. The information presented here on decision-making information and involvement should help with initiation of field trials.

Groundwater depletion is a growing concern in regions all over the world, both in highly developed and resource poor areas. The methods and results of this research may find application in other systems where improving groundwater levels is a goal. Developing some understanding of social issues related to farming system management and the participation of local farmers in development of management scenarios should result in more relevant management scenarios being considered, and therefore, a greater likelihood of on-farm implementation of management recommendations.

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References


