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Sustainability of Farmer-Managed Groundwater Irrigation Systems in Drought-Prone Areas: The Role of Socioeconomic Conditions

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ABSTRACT

IN INDIA, USING groundwater for agricultural purposes is one of the oldest forms of irrigation. Traditionally dugwells were the chief means of irrigation in drought-prone areas. Farmers evolved indigenous methods to lift water from shallow dugwells. Waterlifts were mostly drawn by bullocks and also by human beings, depending upon the depth of well and the area to be irrigated. Over the years economic compulsions and technological innovations seemed to have influenced to a great extent the spatial and temporal spread of groundwater irrigation. The increase in population has necessitated the optimum utilization of available groundwater. This has led to the construction of dug-cum-borewells and tubewells. Animal-drawn waterlifts were gradually replaced by diesel and electric pumpsets. Single-farm wells have become multi-farm wells, because of the division of property among brothers and other kinship members. The emergence of all these techno-economic changes in the ways and means of groundwater exploitation is believed to have posed a threat to the sustainable supply of water for agriculture. It is therefore attempted in this paper to highlight the understanding of groundwater management problems by the farmers and methods adopted by them to handle aquifer drawdown.

PROBLEM

Agricultural development in drought-prone areas is fraught with multiple risks emanating essentially from erratic and scanty rainfall. Farmers over the aeons have, however, searched out the environment for niches favorable to their own concept of welfare, and often, through centuries of long trial and error, have established farming systems with technologies (such as risk-spreading multiple cropping) suited to their needs (Dillon 1986). One such technology developed traditionally by the farmers to mitigate the adverse effects of inadequate and uncertain rainfall is groundwater harvesting for agricultural purposes. Since sophisticated technology to gauge groundwater potential in a given region was not available to farmers, their conventional wisdom and practical experience have been mainly responsible for the identification of appropriate sites for tapping groundwater. This has essentially led to the construction of shallow dugwells by

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individuals or by small groups of two or three farmers whose lands were geographically contiguous.

Farmers in drought-prone areas, having experienced uncertainties of rain-fed farming, tend to be cautious in using available water in wells judiciously to ensure a sustainable supply. This is because they can visualize the hardships if the drawdown goes beyond a level which they perceive as unsafe. Further, they are aware of the limitations of capital and technical knowhow required for deepening dugwells beyond a particular depth in a given region. Some of these factors play a crucial role in shaping up typology of wells in terms of depth, diameter, mode of water lifting and irrigation practices to be adopted, keeping in view the sustainability of the system in the long run.

In the wake of increasing population pressure and the consequent demand for more food production, the need for exploitation of groundwater has increased over time. This has necessitated technological innovations to be introduced to tap groundwater. Keeping this in view, the government has sponsored institutional credit programs to encourage dugwell irrigation. This seems to have led to an apparently paradoxical situation; for, on the one hand the technological revolution and institutional credit facilities enabled the construction of deep wells and on the other, it tended to jeopardize the traditionally established sustainability. Given this situation it is important to know how farmers manage groundwater systems keeping an altruistic view, namely, "live and let others live" in mind. What kind of strategies do they evolve to manage groundwater systems? How do they perceive drawdown conditions and plan for suitable farming systems? How do they share water scarcity? What kinds of interventions from the government are necessary to promote sustainability in groundwater exploitation? These are some of the questions that need to be examined to understand the dynamics of groundwater exploitation.

With a view to examining some of these issues a few farmer-managed groundwater schemes from I.V. Palli, a village in Anantapur District of Andhra Pradesh, India, have been selected. The issues and problems analyzed in this paper are essentially based on the experiences and views of farmers selected for this study; yet they are representative of the general conditions in the region.

The Study Region: Background

The study village is situated in an economically backward, semi-arid and frequently drought-prone region where annual rainfall ranges between 500-600 millimeters (mm), mainly during the southwest monsoon spread over June to September. Rainfall is not only low in the region but also highly uncertain. Therefore, shallow dugwells was the main source of irrigation. There are a few tanks located in the neighboring villages from which the village selected for the study does not get any direct benefit by way of surface irrigation. But it is benefitted indirectly as the tanks contribute to the recharge of groundwater aquifers which in turn enables a rise in water level in the wells. Since rainfall is low in the area the chances of tanks getting filled frequently are less. It was reported by the local people that the cyclonic storms in the Bay of Bengal, the frequency of whose occurrence is as uncertain as rainfall itself, are some times a blessing in disguise for this area; for, it ensures adequate rainfall enabling innumerable tanks in the region to receive full storage. Farmer experience indicates that if the tanks are filled to full capacity in one year there will be no scarcity of water in the wells at least for two years even if rainfall is low. During such years they go for water-intensive crops without much problem. It indicates farmers' ability to judge drawdown possibilities based on monsoon conditions in a given period of time.

Red soils with rocky formations are predominant in the region. This is one of the characteristic features of the soil profile in the Deccan Plateau, where the hard rock area forms about 90 percent of the geographical area (Dhawan 1986). This could perhaps explain the little scope left for the introduction of the tubewell technology. Hard rock bottom does not permit deep dugwells. However, during the last two decades the number of dugwells has increased, the externalities of which would be examined elsewhere. Rice was the chief crop under dugwell irrigation. Aquifer drawdown in successive years seemed to have effected substantial changes in cropping pattern under well irrigation. Farmers have been using the cropping pattern as one of the important means to ensure a sustainable supply when groundwater becomes scarce.

Groundwater Systems (Dugwells) Selected for Study: Salient Features

The groundwater systems selected for this study are traditionally built shallow dugwells, which are mostly a century old. The details are presented in Table 3.1.

Table 3.1. Salient features of farmer-managed groundwater systems selected for the study.

System number	Depth of well (in feet)		Whether converted into dug-cum-borewell	If yes, depth of bore (in feet)	Area irrigated (command area in acres)
	At the time of first construction	Present			
1	20	30	Yes	100	11.5
2	22	26	Yes	120	5.3
3	18	22	Yes	60	4.6
4	12	24	Yes	80	8.2
5	12	24	Yes	90	8.0
6	26	26	No	-	5.7

Note: 1 foot = 0.30 meter.
1 acre = 0.40 hectare.

The present owners of the six systems, the details of which are presented in Table 3.1, are second- and third-generation people. Therefore, none of them are able to say the year in which the well was constructed. Almost all the wells were deepened two to three times depending upon the drawdown status of aquifers over years. Further, it was reported that desilting of the wells once in five years or so, depending upon the water level in the wells, is undertaken to keep the aquifers active without allowing any clogging. This practice was perhaps followed to ensure sustainability. During the last 20 to 30 years a number of new wells have come up in the area. This has affected water availability in the old wells. All the farmers, therefore, were forced to construct borewells. The dugwells under reference have been converted into dug-cum-borewells, for the dugwell technology, as mentioned earlier, does not permit deepening of well beyond a certain depth. Further, hard rock strata in almost all the wells seems to be the major constraint to deepening the wells. Even so, some farmers (in Systems 1 and 2) did attempt to deepen wells through the blasting of the hard rock bottom, but without favorable results. Some of these natural constraints have been responsible for integrating modern tubewell technology with the traditional dugwell technology to ensure an adequate supply of groundwater. Therefore, dugwells have been converted into dug-cum-borewells.

Another interesting feature is that the number of beneficiaries per well has increased over the years making them common property because, single/twin-farm systems have been converted into multi-farm systems. This change tends to influence water use and management strategies which might affect the sustainability. Table 3.2 gives the details.

Table 3.2. Number of beneficiaries per system, their relationship, and type and number of waterlifts.

System number	Number of beneficiaries		Relationship	Type and number of waterlifts per system	
	At the time of construction	At present		At the time of construction (*Moht*)	At Present (electric pump)
1	1	7	Kinship	2	3
2	2	4	Non-kinship	1	2
3	1	2	Kinship	1	1
4	2	4	Non-kinship	2	1
5	3	8	Non-kinship	2	2
6	1	4	Kinship	2	-

Note: *Moht* = A system used to lift water from shallow dugwells.

It can be observed from Table 3.2 that the number of beneficiaries (owners) has changed over time. This shows that the groundwater systems, started with single ownership, assume common property nature in the course of time. This happens essentially due to two reasons: (i) patrilineal right to inherit property leads to division of land among brothers and hence becomes common property; and (ii) the sale of land by the original owners to others outside the kinship circle. It is interesting to note that out of the six systems under reference, three systems (50 percent) have owners who do not belong to the same kinship. This shows the prevalence of a cooperative culture for exploiting groundwater, may be in a small way. It appears that this kind of cooperation emerged out of economic compulsions. For instance, small farmers with tiny holdings find it uneconomical to have an independent well (Reddy 1988). Further, raising funds independently to construct a well may be a difficult proposition. Therefore, two or three farmers whose parcels of land are geographically contiguous used to come together and construct a well and share the costs and also water on a pro-rata basis of the land they own. In such cases land will be owned individually and the irrigation well becomes common property. The individual rights to use water in proportion to their land are registered and guaranteed under law. Any attempt to prevent members from using their individual share of water could be challenged in a court of law.

Practical Problems Faced by Farmers

The depletion of the groundwater table year after year, caused partly by the additional wells in the study area and mostly by less precipitation, made farmers realize the importance of modern technology. While attempting to adopt modern technology, namely, tubewell technology, the farmers seem to have faced many problems. The most important problem, as reported by many, was the selection of an appropriate site for a tubewell. They used their practical wisdom and also sought the help of local water diviners in selecting an appropriate site. Both the methods are not scientific and therefore, striking a potential aquifer is a chance factor. For instance, the farmers of System 1 (Table 3.1), wanted to drill a deep bore in the hard rock to augment the water supply in the well. Even after drilling to a depth of about 80 feet (24 m) the hard rock stratum continued to a further depth and they got disappointed. However, a second attempt was made to identify another site with the help of a water diviner to drill another bore, a few feet away from the first one, to a depth of about 100 feet (30 m). This time also it was not possible to clear the hard rock strata and thus the farmers abandoned all hope of striking deep aquifer and tried to manage with the available water. In both instances the investment had gone waste. Had appropriate technology been available to strike potential aquifers the wasteful expenditure incurred by the farmers could have been avoided. The demonstration effect of such failures tends to leave an adverse impact on other farmers willing to adopt modern technology. Though finance is another major constraint for deepening wells, farmers are able to overcome it if there is a guarantee of getting plentiful water.

In the case of the other four systems under reference (Systems 2 to 5) the situation is different. They also had the same problem of identifying the right site to install bore. But by trial and error methods they could successfully strike active aquifers. Especially the Systems 4 and 5 have copious supplies of water after groundwater systems were transformed from traditional to modern technology to ensure a sustainable supply of groundwater.

Technological Progress and its Impact on Sustainability

The transformation of groundwater irrigation from low-cost traditional dugwell systems to cost-intensive modern tubewell technology, and the changing ownership pattern seem to have influenced farmer attitude toward water use and management. Practical wisdom and field experiences of the beneficiaries over a period of time have enabled them to assess the availability of water in the wells depending upon the temporal and spatial intensity of rainfall in the region. Accordingly they plan cropping patterns. For instance, it was reported that when rainfall is good where tanks and ponds in the area get filled in a particular year, farmers are sure that groundwater aquifers get recharged and water in the wells will be plentiful. In such years water intensive crops like rice are grown on a large scale. If the rainfall intensity is less semi-dry crops are cultivated, so that water scarcity does not occur. Majority of the farmers are aware of the fact that excessive drawdown in successive years leads to drying up of the aquifer. Therefore, cropping pattern is used as an effective measure to ensure a sustainable supply of water. This has been the age-old practice in the study region with the result that, in none of the wells under study, as reported by the beneficiaries, have the water levels gone below critical levels, of about 2 feet (0.61 m). Even if the water occasionally depletes to the bed level of the well, farmers manage in such a way that it reaches a sustainable safe level, as perceived by them, by practicing utmost economy in water use for the crops. These practices are more true in the case of single-owner systems, though the systems with more than one owner also adopt such measures.

Besides the introduction of tubewell technology and extension of institutional credit, the supply of electricity on subsidized rates appears to have changed the outlook of farmers toward sustainability. It may be recounted here that traditionally *Moht*[10] was the chief devise used to lift water. This was replaced by diesel pumps in the study region in the late sixties. Later, when the villages were provided with electricity in the late seventies, diesel pumps were replaced by electric pumps. It is interesting to note that as long as Moht was the chief means of lifting water from wells there seemed to have never been a scarcity of water. This was because, farmers were

10 *Moht* is a system used to lift water from shallow dugwells. A long and thick rope and a big leather bucket are used and it is operated through animal labor (bullocks or buffaloes). In local parlance it is called *Kapila*.

extremely cautious in using water; for, it was a laborious job involving both manual and animal labor. The introduction of diesel pump technology has made farmers relatively more liberal as far as on-farm water use is concerned. However, the high cost of diesel oil had a built-in check on over-use of water. But, the introduction of electric pump technology, particularly the introduction of fixed tariff (demetering), based on horse-power (hp), seems to have consolidated the sense of liberalism among farmers which has left its own impact on the sustainable use of water from wells. Since power tariff is based on hp irrespective of the quantity of electricity used, farmers tend to use more pumping hours than actually required resulting in the wasteful use of water, which was not the case under Moht irrigation. This practice seems to have led to drawdown in all the wells under reference, necessitating their deepening more than once.

Further, technological progress in groundwater lifting (diesel and electric pumps) while bringing attitudinal changes among farmers in water use has also encouraged the proliferation of single-farm dugwells in the study region, contributing to the fast depletion of groundwater. Before the advent of pump irrigation, dugwell irrigation was practiced predominantly in the farms adjacent to the village. Farmers generally avoid dugwell irrigation in the farms away from the village as it requires transportation of water lifting equipment, namely, long and thick rope, a big leather bucket and also animals (either bullocks or in some cases buffaloes) daily from the village to the farm. Families with a single male member cannot afford this; because it requires at least 3 male persons (adults) to operate Moht for lifting water from wells (two persons to lift water with the help of two pairs of bullocks and one person to water crops on the field). Therefore, families with at least 2 to 3 male members used to venture to go for dugwells, that too in the farms close to the village.

With the introduction of pumpsets (diesel and electric) the scenario of groundwater systems has changed in the study region. Dugwells were constructed even in farms away from the village. The competition to use groundwater has increased. This has resulted in the depletion of the water table and created water scarcity in some of the older systems where plentiful water was available.

For instance, in System 1 (see Table 3.1), as reported by the present owner cultivators, water seems to have never been a problem. It was irrigating about 11 acres (4.5 ha) of land with 300 percent crop intensity (one semi-dry crop followed by two rice crops a year). The well was known for the plentiful supply of water in the region. Ten years ago, when a neighboring farmer had constructed a dugwell just about 100 meters away from this system the availability of water in the older well had drastically come down. Further, when the new dugwell was converted into dug-cum-borewell, the aquifer drawdown seems to have gone beyond the reach of the older well with the result that the older well has dried up completely in spite of the best efforts by the farmers to deepen the well. Unable to strike any other aquifer farmers of the older well have now switched over to rain-fed farming. While this is only an illustrative example of the externalities of new technology contributing to the over-mining of aquifers and thus endangering the sustainability of groundwater systems in the region, many farmers have fallen into a perpetual debt trap by resorting to dugwell irrigation without understanding the limitations of groundwater availability. It is in this context that the role of the government becomes important in regulating groundwater. Approximate norms to maintain spacing between wells need to be stipulated and farmers should be educated about the limitations and disadvantages of indiscriminate mining of groundwater aquifers.

Water Distribution: Methods and Practices

It is obvious that single-owner systems do not have problems of sharing water. The management strategies adopted to regulate drawdown and ensure a sustainable supply of water for irrigation were, as mentioned already, essentially linked with the cropping pattern and its intensity (high water-intensive crops followed by higher intensity of cropping when water is plentiful). But it would be interesting to note how water is shared between the farmers when a system takes the form of common property in the course of time for reasons explained above. As seen from Table 3.1. the systems under reference are small in scale in terms of area irrigated and also number of participants. Before we discuss water sharing methods adopted by the group-owned and -managed systems, let us look at the status of water lifting devices in the groundwater systems under reference (see Table 3.2).

Traditionally, Moht was the chief source of water lifting from dugwells. If a system is owned by two persons they used to provide for two Mohts, so that each partner can use them independently or some times interchangeably depending upon the location of farm plots. As long as water supply in the well is abundant unrestricted use is allowed to partners, though legally, water right is linked to area owned by a farmer under a given well. In times of scarcity, strict measures are adopted to share available water equally between partners by fixing rosters based on time sharing if watering is to be completed in a single day; and if watering is spread over a week or a mutually agreed period the roster will be based on sharing days. In either case the share is linked to area owned or any other norms of entitlement. In olden days, since it was difficult to share the time in terms of hours, farmers followed the movement of the sun. For instance, if there are two partners, one is allowed to use water up to sun-rise and the other from sun-rise to sun-set. The order will be reversed in the next day or for the next watering, so that the advantages or disadvantages, if any, are shared equally. If there are more than two partners, the rostering would be up to sun-rise, sun-rise to noon and noon to sun-set. This roster goes on changing. In case water is very scarce where the entire area cannot be irrigated in a single day, they resort to a roster where each partner uses a full day. This again is based on a pro-rata basis of each partner's entitlement for water in a given well. These rosters also change according to cropping pattern. If it is for rice the roster is invariably based on time sharing in a day, for rice needs watering every day. If it is for semi-dry crops the roster is based on sharing of days in a week or in a stipulated period of a roster. This kind of strict rotation has a built-in check on excess use of water. It also ensures economy and efficiency in water use which in turn contributes to sustainability.

With the advent of pump technology, Moht has become redundant. It can be noted from Table 3.2 that the increase in number of pumpsets is not commensurate with the increase in number of partners in each system. This shows that one pump is shared by two or three farmers. As reported by the farmers, to have a pumpset independently for each tiny plot is not economically viable and also many cannot afford it. Therefore, they are in a sense compelled to think of collectivism. Since each one of them understands local dynamics well it is easy to arrive at mutually agreeable terms and conditions in operation, use and maintenance of a collectively owned pumpset. Water sharing from the common source has, however, remained more or less on the same lines as it used to be under Moht irrigation days.

Water use methods and land preparation for irrigated farming have changed after the introduction of pumpsets. For instance, it was reported that farmers were very particular about uniform leveling of land while the Moht System was in operation, to enable smooth and quick spread of water with minimum wastage. Under pump irrigation they seemed to be not very particular about this aspect. They do not bother much even if it takes more energy, time and water. The liberal attitude developed by the farmers toward water use has led to drawdown conditions necessitating periodic deepening of wells, where some are successful in striking potential aquifers and some not. While nature plays its own role in recharging the groundwater aquifers, man has greater responsibility to maintain the balance by resorting to judicious use of groundwater. Unplanned growth of wells has resulted in the depletion of groundwater level, the externalities of which, have affected many resource-poor farmers adversely. For example, they have had to abandon the shallow wells and be out of irrigated farming. In effect, area under irrigation has not increased commensurate with the increase in wells. It shows that additional area claimed to have been brought under irrigation by the new wells is not an addition in real terms. The gain of new entrants is the loss of old ones or the gain of resourceful farmers is the loss of resource-poor farmers. This raises the question of equity, the answer for which, may be difficult to find under the existing socioeconomic conditions.

Tragedy of the Commons

Many of the groundwater systems, as seen above, acquire common property nature over time. Though the groundwater systems have had established norms and practices to share water without affecting sustainability, it is well known that common properties, whether it is land, water, forest or any other resource, are fraught with several crises associated with their operation, maintenance and use by the members, leading some times to temporary or may be permanent disuse. This phenomenon is generally known as "tragedy of the commons" (Hardin 1968). It was reported that the majority of the systems under reference were the victims of the tragedy of the commons at one time or the other. Many farmers take it as a natural process that might some times last for two to three years. Established social authority and the rural ethos help in finding solutions for such problems.

While it may be true that the tragedy of the commons relating to a system's operation and use of water is taken care of by the existing social ethos of a village, certain other problems are some times left uncared for, which affect the sustainable supply of groundwater. For instance, System 6 in this study is totally abandoned due to conflicts among partners. This would have been resolved, as stated by the local farmers, if it were only a local problem of conflict resolution. It is a different issue and more pertinent one in the context of sustainable groundwater recharge. There is a long bund diverting a rivulet just upstream of the well under reference. A few years ago because of heavy rains the bund got breached and the rivulet now flows straight into the well. This has caused silting up of the well. Though several other farmers are also affected by the breach they do not show much interest in its reconstruction. Before the breach took place the bund was enabling water storage in a fairly big pond which was in a sense a percolation tank to recharge groundwater. Because of this breach, the water supply in System 1 and also in other wells adjacent to the pond belonging to farmers of a nearby village have been greatly affected. Since the cost of reconstruction is high and many farmers are otherwise occupied, it is left unattended to with the result that the water supply is affected in some wells and some other wells in the downstream are abandoned. In all, about 15 to 20 acres (6 to 8 ha) of hitherto irrigated land has gone out of irrigation. In spite of the attempts made, by some of the affected farmers to date it has not been repaired. If the breached bund is restored to facilitate water storage as it used to be before breaching, a minimum of six wells will be benefitted by it, and about 40 acres (16 ha) of land gets assured irrigation.

While this is a single micro-level example of how the tragedy of the commons affect groundwater levels, a serious view of the ramifications of such tragedies at the macro level is necessary. It is in such matters that the government's intervention becomes more important. The government should not only take up such repairs but must also educate farmers on preserving traditional ponds and tanks which are the main sources of percolation in drought-prone areas.

It is often recommended that the government should stipulate stringent measures to ensure equity and sustainability in groundwater exploitation. One should appreciate the limitations to regulate groundwater through appropriate spacing between wells (Dhawan 1990). In a democratic policy where a major proportion of land is owned by private individuals, it is not possible to regulate spacing between wells. The indirect means such as not providing institutional finance, electricity for pumpsets and so on would not be effective checks, for, many farmers can raise their own funds or borrow from private money lenders to construct wells. Similarly, diesel pumps can substitute electric pumps if electricity is not supplied. Therefore, the only option open for the government is to educate farmers about the ways and means to regulate groundwater use, encourage community wells to extend groundwater irrigation for small and marginal farmers and promote watershed management to recharge groundwater aquifer.

Resumé

The discussion so far brings out certain interesting findings. Traditionally, dugwell irrigation was popular in drought-prone areas. When dugwell technology was the prerogative of a few farmers whose lands were located nearer to the village, plentiful water was available even in the shallow dugwells. When the number of dugwells increased over time the necessity to strike deep aquifers arose. The limitations of deepening dugwells beyond a particular depth have made farmers look out for an alternative technology to tap groundwater. The emergence of tubewell technology enabled a few rich farmers to convert traditional dugwells into dug-cum-borewells. The negative externalities of modern technology on traditional dugwell irrigation were many. Farmers in the traditional systems were careful and judicious in using groundwater. They used to maintain a minimum depth of water in wells to keep aquifers active. A judicious combination of crop mix suitable to water levels in wells has been used as one of the means to sustain water supply. The emergence of tubewell and pump technology has encouraged the liberal use of water resulting in wastage. This has necessitated deepening of wells at regular intervals, which has increased the cost of irrigation. Though farmers have evolved strategies to manage groundwater by appropriate methods of irrigation and sharing of water, the tragedy of the commons strikes often resulting in temporary or some times permanent disuse of irrigation systems. Thus, the government should take an initiative to construct percolation tanks and encourage watershed management to ensure sustainable recharge of groundwater aquifers.

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