WELLS AND ILL-FARE: IMPACTS OF WELL FAILURES ON CULTIVATORS IN HARD ROCK AREAS OF MADHYA PRADESH

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Abstract

Over exploitation of groundwater water resources is causing progressive decline in water table in the arid and semi arid parts of India. The socio-economic impacts of these phenomena range from increased cost of well irrigation to reduced returns from irrigated agriculture, to growing inequity in access to groundwater depending on the aquifer conditions and the overall socio-economic conditions of the communities. In hard rock areas, over exploitation is leading to decline in yield and drying up of open wells. This forces farmers to go for either well deepening or drilling new bore wells. But due to the poor success in hitting water through bore well drilling in hard rock areas and the consequent increase in costs of setting up a bore-well based irrigation scheme, small cultivators are the worse affected. This paper focus on the phenomenon of well failure in the hard rock areas of Dewas in Madhya Pradesh. It highlights the causes of well failure and related welfare impacts on the cultivators especially small landowners. The major impacts were found to be on the cropping pattern, extent of well irrigation, crop yields, net returns and food security in the surveyed region. In addition, discussion is centered on power subsidies in the state which have promoted indiscriminate use and further depletion of groundwater from the already low yielding aquifers.

1. INTRODUCTION

In India, groundwater irrigation has emerged as a major source of irrigation since mid 1970's. This was the period when most of the country's rural population was involved in extensive agriculture as an outcome of green revolution. At present groundwater is sustaining nearly 60% of the country's net irrigated area (Source: Indiastat 2004-05). The importance of the groundwater resource in India can further be realized by the fact that about 60% of irrigated food production depends on irrigation from groundwater wells (Shah et al., 2000). Nearly all major agricultural states in India have heavy dependence on groundwater for irrigation. In states such as Tamil Nadu, Maharashtra, Madhya Pradesh, Rajasthan, Uttar Pradesh, Punjab, and Gujarat, 60-87% of the net irrigated area is through groundwater (Source: Indiastat 2003-04). A study revealed that crop yield in groundwater irrigated areas is higher by one third to one half then those irrigated by surface sources (Dhawan, 1995).

Thus in order to optimize crop yields and maximize profits from agriculture, farmers make intensive use of groundwater. This has led to overdraft of groundwater beyond the recharge potential, and lead to water scarcity across many regions in India. The first set of concerns regarding groundwater over-exploitation at various locations across India, were raised almost three decades back (Kumar and Singh forthcoming). As per central groundwater board report (2006), 37% of the total assessed *talukas* in Karnataka, 37% of the total blocks in Tamil nadu, 49% of total blocks in Haryana, 59% of the total blocks in Rajasthan and 75% of the total blocks in Punjab are overexploited. These figures are much above the 15% of the total blocks/*talukas,* which are overexploited in the country. Such a mass scale overexploitation has serious consequences for a country like India where hard rocks such as granites, gneisses, basalt etc. cover almost 75% of the total area of the subcontinent. In these hard rocks areas, recharge of aquifer is a comparatively slow process and often occurs at places having fissure or cracks in the rock. Therefore, overexploitation in hard rock areas seriously affects the groundwater availability in these regions.

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Lack of well-defined ownership rights in groundwater has also resulted in its unsustainable use. In India, groundwater ownership is attached to land rights. This means anybody owning a land can drill or dig a well in his land and utilize as much groundwater as required. Along with such ownership status, one of the major factors, which promoted the indiscriminate use of groundwater is the policy of heavy subsidy on electricity supply by government to farmers for agriculture use (Janakarajan and Moench 2006). This has accelerated groundwater abstraction, with farmers now using more advanced devices and techniques to pump water. Across many regions, farmers kept on excavating deeper wells and drilling deeper bore wells in order to have more water for irrigation. This resulted in further lowering of water table in various parts of the country. 23 districts in Andhra Pradesh, 45 districts in Madhya Pradesh, 26 districts in Karnataka, 27 districts in Tamil nadu and 34 districts of Maharashtra have groundwater level declining at the rate of 20 cm/annum (*Source: Ministry of Water Resources*).

2. GROUNDWATER OVER-EXPLOITATION AND WELL FAILURES IN HARD ROCK REGIONS.

Figure 1: Net Irrigated Area from different sources

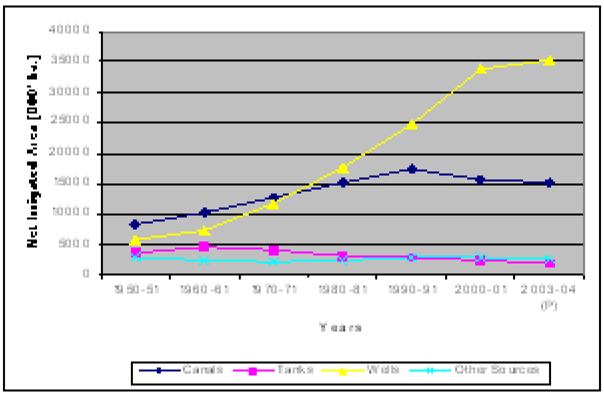
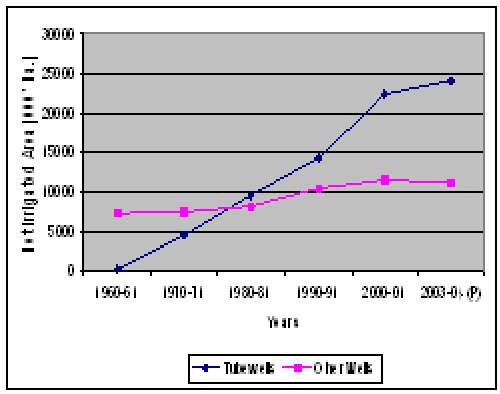


Figure 2: Net Irrigated area through wells

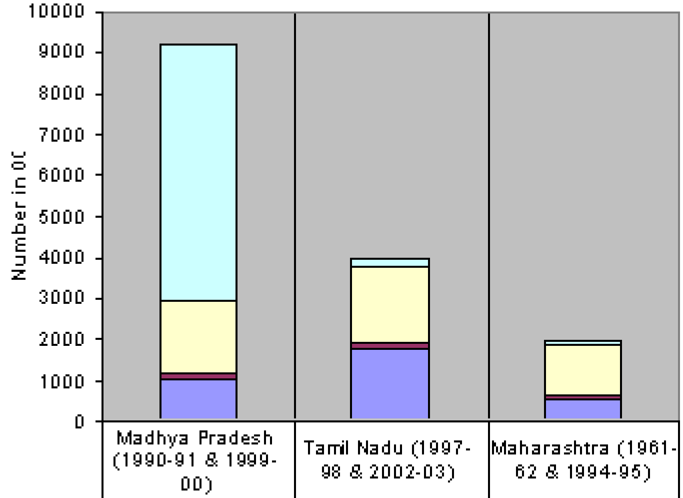


There is no doubt that groundwater use for irrigation in India is growing steadily and has overtaken the canal irrigation way back in the early 1970's (Figure 1). Since mid 1960's, energized irrigation i.e. through tube wells and bore wells has increased by much greater extent than the dug-wells irrigation (Figure 2). This increased dependence on groundwater has resulted in overexploitation of groundwater resources and caused significant increase in the number of well failures especially in the hard rock regions of the country. In fact, the problem of groundwater overexploitation has been reported by many researchers from different regions of India. These regions include parts of Andhra Pradesh (Chandra et al., 2006), Karnataka (Premchander et al., 2003), Maharashtra (Pathak et al., 1999), north Gujarat (Ranade and Kumar, 2004) and Tamil Nadu (Palanisami, 2002).

2.1 Hard rock areas Aquifer and well failures

Major source of irrigation in the hard rock region of our country i.e. Tamil Nadu, Karnataka, Maharashtra, Madhya Pradesh, and Andhra Pradesh is groundwater. Over the years, dependence on this sub-surface resource has only increased. In these hard rock areas where groundwater availability is highly dependent on degree of natural recharge through rainfall (which is only 4-10% of total rainfall, NABARD 2006) and percolation (Diwarka *et. al*., 2007), overdraft of groundwater can have serious affects on the water availability which may lead to well failures. Well failures put a range of social and economical impacts on the cultivators especially small landowners. Because of limited resources with these small landowners, these consequences include increased extraction costs, reduced well yields and quality deterioration (Kumar and Singh forthcoming).

Figure 3: Total Irrigation Wells and Well Failures



	Madhya Pradesh (1990-91 & 1999-00)	Tamil Nadu (1997-98 & 2002-03)	Maharashtra (1961-62 & 1994-95)
Year 2 Failed/Abandoned Wells (in 000')	6236	204	103
Year 2 Total Irrigation Wells (in 000')	1763	1844	1197
Year 1 Failed/Abandoned Wells (in 000')	175	148	105
Year 1 Total Irrigation Wells (in 000')	1018	1779	557

Wells failure is a common phenomenon in hard rock regions of country (Nagaraj and Chandrakanth 1997; NIH 1999; Ballukraya and Sakthivadivel 2002). The reason can either be overexploitation of water from existing wells or failure in identifying the exact water bearing zones or aquifers. Over the years, total number of irrigation wells in the hard rock regions has increased but there is simultaneous increase of abandoned or failed wells (Figure 3). In some states, increase in number of wells has not contributed to corresponding increase in groundwater irrigated area. For example in Tamil Nadu, it was found that with the increase in number of wells there is no major increase in groundwater irrigated area after 1980's (Janakarajan and Moench, 2006). Similarly, in 5 districts of Madhya Pradesh namely Balghat, Chhindwara, Shahdol, Jhabua and Betul, the average command area of energized wells was found to decline almost consistently between 1974 and 2000 (Kumar, 2007). These studies confirm that hard rock states are undergoing mass overexploitation of groundwater resource without much beneficial affect on the irrigators.

2.2 Situation in Madhya Pradesh

From the period 1992-93 to 2001-02, surface irrigated area (from both canals and tanks) in Madhya Pradesh has declined while irrigation through groundwater sources has increased. Even though this was the period of investments on surface irrigation systems and involvement of end users in irrigation management, still there was a decline in the net irrigated area by surface sources. The net groundwater irrigated area in state increased to 3.70 million ha in 2003-04 as compared to only 2.23 million ha in 1991-92. Irrigation wells in the state have increased from 1.02 million in 1990-91 to 1.8 million in 1999-00. In the same period number of sprinkler devices in the state increased to 13,865 from just 150. Tube well dependence[4] in 1992-93 itself was as high as 83% in Indore, 58% in Durg, 46% in Ujjain, 41% in Dewas and 38% in Raipur, which are all hard rock districts of MP (Shah et al., 1998).

[4] Tube well Dependence Index= Gross Irrigated Area by Tube wells*100/Gross Irrigated Area

Power subsidies in the state also promoted indiscriminate use of groundwater. Between 1985- 2001, free electricity was supplied by the state to the farmers. The period 1986-2001, saw a tremendous increase in number of tube wells in the state. From the total of 29534 in 1986-87 it increased to 315422 in 2000-2001, nearly 11 times increase (Source: Minor Irrigation Census, 1993-94 and 2000-01). However, after the pricing of electricity in 2001, the growth in number of irrigations wells has ceased. From the total of 1.53 million in 2001-02, the number of irrigation wells in 2004-05 was 1.39 million, a decrease of 9% in just 3 years.

The foregoing analysis confirms that groundwater is becoming an important source of irrigation in the state. But the main problem which is emerging and may be one of the reasons (along with electricity reforms) for decrease in number of irrigation wells is the increasing number of irrigation well failure in the past decade. The number of abandoned wells in the state has increased to 6.2 million (1999-00) in comparison to only 0.17 million in 1990-91. There are increasing evidences of reducing average command area of individual energized wells in Madhya Pradesh (Kumar, 2007). As per water resource department Madhya Pradesh estimates (1998), groundwater condition is safe in 24 districts, semi critical in 12 districts, critical in 4 districts and over-exploited in 8 districts. Critical districts identified are Dewas, Khargoan, Shajapur, Tikamgarh and over-exploited districts are Badwani, Chhindwara, Dhar, Indore, Mandsour, Neemuch, Ratlam, Ujjain. These increasing well failures in hard rock areas pose serious questions of not only sustaining the recent growth in well irrigation, but also sustaining the current level of use.

3. STUDY PURPOSE AND METHODOLOGY

With this overall picture of groundwater abstraction in the country, the following research was carried out in the hard rock areas of Madhya Pradesh (MP) state. The foremost objective of the study was to analyze the impact of well failures on the socio-economic condition of the farmers.

For the purpose, block *Bagli* from district *Dewas*, MP was selected as a study site. *Dewas* was selected as this is one of the districts in the state facing serious groundwater exploitation problem. Selection of *Bagli* was more because of convenience in carrying out the field work in that block. Two villages - *Nayapura* and *Chhatarpura* were chosen from the block for the survey. As the focus of the study was on irrigation well failures, farmers owning wells (open or bore wells or both) were selected. Random sampling was followed for selecting 101 farmers from the two villages. Sample consisted of 11 small and marginal farmers, 31 semi-medium farmers, 50 medium farmers and 9 large farmers. For taking responses from the farmers, a schedule was developed. Besides this, focus group discussions were carried out with some progressive farmers to get a deeper understanding of the problem. Discussions were also done on the importance of agriculture in farmers livelihoods, with the NGO members working in *Dewas* district. Various research papers related to groundwater overexploitation and the state government reports on the hydrogeology of the regions were consulted as a reference and background material for the research study.

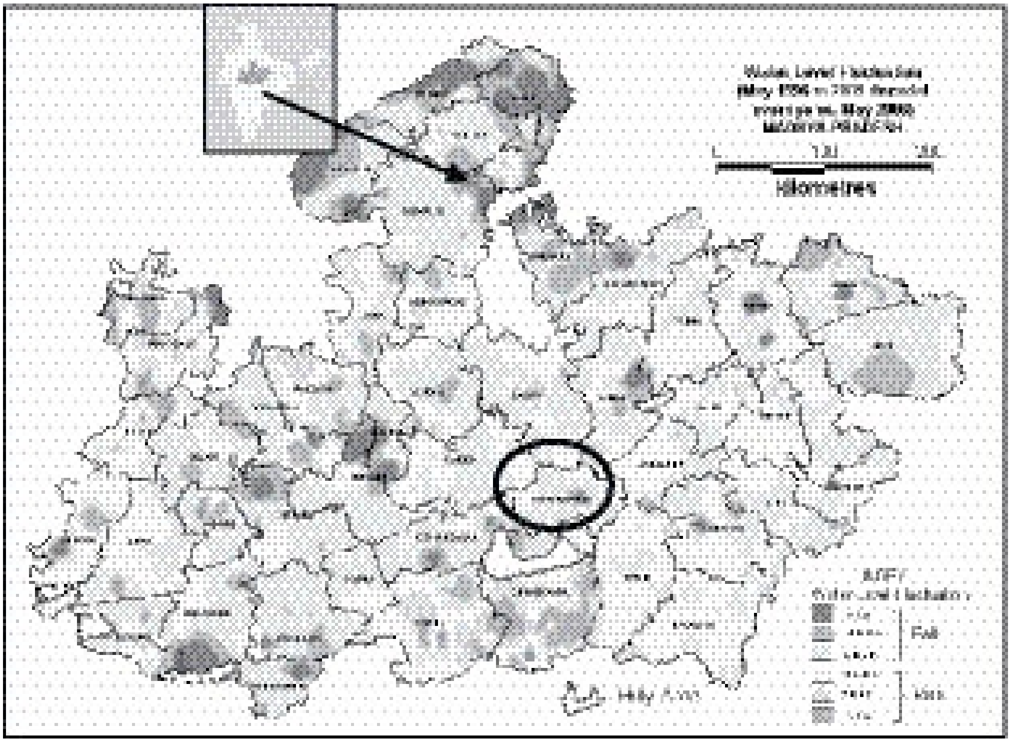
4. GENERAL FEATURES INCLUDING GROUNDWATER DEVELOPMENT IN *DEWAS*

Dewas is situated between 75º55’ and 77º09’ longitude and 22º19’ and 23º19’ latitude. The population of the district is 1.3 million (2001 census) which is roughly 2.15% of total population of Madhya Pradesh. Total area of the district is 7020 sq. kms. and it has 6 blocks or *tehsils*. The average rainfall in the district is 1067 mm. But owing to impervious nature of the soil (predominantly black soil) in most of the area, rainwater does not percolate. Also because of the topography (rolling terrain) of the region, most of the rainwater drains away into rivers. Major crops grown in the area include soyabean, cotton, wheat and gram.

The district has 0.43 million hectares of land under agriculture, out of which 0.17 million ha is covered by irrigation facilities. About 83% of this agricultural area covered under irrigation, is irrigated through groundwater sources i.e. dug wells and bore wells. There has been a rapid and progressive increase, both in number and depth of bore wells in the region (Shah et al., 1998). Number of bore wells in the district increased from only 3887 in 1990 to 14172 in 1998. Increased number of wells, impervious nature of soil and the rolling terrain topography of the area has resulted in depletion of groundwater table at the rate of 2 cm/annum (Figure 4).

Because of overexploitation and decrease of groundwater level at such an alarming rate, the district has been identified as “critical” (groundwater development >90% but <100%) by the Central Groundwater Board.

Figure 4: Groundwater Level Fluctuations, Madhya Pradesh
(Source: Central Groundwater Board)



4.1 Groundwater situation in Bagli block

Bagli lies in the *Malwa plateau* region of Madhya Pradesh. Majority of the agricultural land is irrigated through groundwater resources. The hydro-geological set up of the region is such that groundwater occurs in two distinct aquifer layers i.e. shallow and deep. Shallow aquifer layer is between 12-18 m deep and gets recharged with the rain water in the monsoon season. On the other hand, deep aquifer layer varies between 60-200 m and its occurrence depends mainly upon the location of the fissures in the rock. Rate of recharge in this deeper zone is a gradual and slow process. Groundwater is mainly tapped by the construction of open wells (to a depth of 12-18 m) and deep bore wells (maximum boring depth going up to 213 m). As per CGWB (1998), groundwater development in the block is within safe limits. However, because of irregular rainfall and increasing over exploitation of groundwater in the last few years, the block faces acute shortage of water during the later part of Rabi (winter) and whole of summer season. Also, there is increasing number of well failures in the block mainly because of seasonal variations (mostly in case of open wells) and failed drillings (mostly in case of bore wells). Major crops cultivated in the block include soyabean (in Kharif or monsoon season), wheat and gram (in Rabi season). A decade back, sugarcane was grown as the major perennial crop. But less availability of groundwater especially in summer season, have forced farmers to discontinue with cultivating sugarcane.

Collected data from the block indicates that about 91% of small farmers have joint ownership of wells as compared to only 31% of semi-medium and medium farmers and nil for large farmers (Table 1). Thus larger the size of landholding, lesser the incidence of joint well ownership. Also, the average number of wells owned by small farmers (1.09/farmer) is less than large land owners (3.9/farmer). This implies that number of owned wells is a direct function of land size.

Table 1: Details of Selected Farmers from the two Villages

	Selected Villages							
	Chhatarpura				Nayapura			
	Small & Marginal Farmers (Land <2 ha.)	Semi-Medium Farmers (Land 2-4 ha.)	Medium Farmers (Land 4-10 ha.)	Large Farmers (Land 10 ha. or above)	Small & Marginal Farmers (Land <2 ha.)	Semi-Medium Farmers (Land 2-4 ha.)	Medium Farmers (Land 4-10 ha.	Large Farmers (Land 10 ha. or above)
Total Number of Selected farmers	8	17	16	6	3	14	34	3
Farmers with only Individual Wells(IW)	1	9	14	5	0	4	13	2
Farmers with only Shared Wells (SW)	7	5	1	0	3	7	12	0
Farmers with both IW & SW	0	3	1	1	0	3	9	1
Major Crops Grown								
Kharif	Wheat, Gram, Garlic, Potato				Wheat, Gram, Garlic, Potato			
Rabi	Soyabean				Soyabean			

5. MAIN REASONS OF WELL FAILURE IN THIS REGION

Over the years, there has been tremendous increase in groundwater pumping for irrigation in *Dewas* district. From 50% in 1996-97, groundwater irrigated area increased to 87% of the total net irrigated area by 2004-05. There was increase of 14% in the number of irrigation pumps in the district between 1998-99 and 2002-03. Groundwater development in *Dewas* increased to 66% in 2004 (an increase of over 100%) as compared to only 32.9% in 1988 (Source: CGWB). This increase is significant considering that relatively lower level of groundwater development in hard rock areas can have significant impacts than the similar level of groundwater development in other areas.

In the selected block, shallow aquifers are the most common source of irrigation (i.e. irrigation by extracting water through constructing open wells) until early part of the Rabi season. After that, most of the open wells dry up (as reported by 100% of the respondents). In the remaining half of the Rabi season, those having access to bore wells continue with irrigation by extracting water from deeper groundwater aquifer. Almost 100% of the respondents agreed that the major cause of well failure (referring to open wells here) is the seasonal drop of water levels in the wells. During monsoon, these wells fill up with water and most of them dry up by November-December. As these open wells are popular with the small farmers, they are affected most by such failures. Other most common type of well failure is during the drilling of bore well itself. Because of the presence of hard rock strata beneath sub-soil surface (below depth of 18-20m), it is very difficult to find exact water bearing zone. Water bearing zones in such settings will only occur at points where there are fissures or cracks in the rock. On an average, it requires nearly 4-5 drillings before finally hitting the water bearing zone.

Some farmers (only 2 respondents from the selected farmers) are of the view that well interference is also making impact on the availability of water and hence causing well failures. Well interference is a condition occurring when the area of influence of a water well comes into contact with or overlaps that of a neighboring well, as when two wells are pumping from the same aquifer or located near each other. However, the phenomenon is not making such a significant impact in *Bagli* block yet.

6. IMPACT OF WELL FAILURE ON COST OF WELL IRRIGATION

Well failures in the region have more pronounced effect on the small landowners most of who have shared wells (91% of the surveyed small farmers). Looking at the cost economic side, it costs approximately Rs. 114000 to dig open well (diameter 8m and depth 14m) with 3HP submersible pump. As most of these open wells are shared among small farmers, the cost to the farmers get reduced to Rs. 57000/open well. This cost is 65.6% less than the bore well installation (depth of 87m with 10HP submersible pump) which costs around Rs. 165800 (Table 2). But because of seasonal drying of the open wells, small landowners suffer from increased cost of irrigation, low crop yields and low net returns (discussed in next section).

In contrast, large landowners believe that investments in open wells are not putting pressure on them. They get water from these open wells in the early part of Rabi season. Bore wells are used to provide supplemental irrigation to the winter crops in the later part of the season. Because of limited resources with small farmers, even the seasonal water drop makes a big impact on their irrigation cost and crop yields. Since most of the surveyed small farmers do not have access to bore wells, in case of less rainfall and early drying of open wells these farmers either purchase water or do not irrigate their fields in the remaining part of the season. Purchase of water (average cost Rs.80/hr.) further increases their cost of cultivation and no irrigation affects their overall crop yields (up to 25% less than the irrigated crops as reported by farmers). Further, because of the less probability (0.2) of hitting the exact water bearing zone and less discharge (1-2 lt/sec), installation of workable bore well is a difficult process. Therefore, bore wells are not a popular option among small farmers for irrigation and they restrict themselves to getting water from open wells only.

Table 2: Cost of digging/drilling Wells

	Cost of Open Well in INR (dia. 8m and depth 14m)	Cost of Bore well in INR (depth of 87 m)*
Cost of digging (inclusive of labor)	100,000	78,300
Cost of casing (required up to 15m)	Nil	17,500
Cost of Pump (inclusive of pipe system)	14,000 (3HP Pump)	70,000 (10HP Pump)
Total	114,000	165,800

* Cost estimation also includes failed bore holes

Regarding the operational cost, at present two types of electricity connections are available for agricultural usage. One is the fixed line collection for which farmers need to pay under fixed rate year around and second is the temporary connection for 1-3 months. Under fixed line connection, a flat rate of Rs. 220/HP/ month is given by farmers. Majority of bore well owners have fixed line connections as they use water for nearly 8 months. Under temporary connection, the amount of Rs. 1027 has to be given for one-month up to 3 HP water pump and amount of Rs. 2821 for the three months. The amount of Rs. 1625 is charged for the 5 HP water pump for one month and Rs. 4615 for three months. Electricity rate, electricity charge (tax) application fee, electricity line connection charge and disconnect charge have been included in the selected charge. These temporary connections are more popular among open well owners as they have water only for 3-4 months. But, the supply of electricity is of poor quality and untimely. Most of the block receives only 6 hours of 3-phase electricity (necessary for running pumps) and there is no fixed time of supply. Considering the discharge from the wells and quality of electricity, it takes around 15 hours to irrigate 1ha of land. Thus, most of the large farmers use diesel gensets as a backup to irrigate their fields in the absence of electricity supply. Only a few small farmers can afford gensets and it takes around 2-2.5 lt of diesel/hr of pump working which significantly increases the cost of irrigation.

In the event of seasonal well failure, farmers especially with small land holdings, have to bear additional cost of well irrigation besides their normal operational expenditure (Table 3)[5] . These extra costs can be expenditure on new well installations (refer Table 2), cost on well deepening's (Rs. 180/m), cost on purchase of water (Rs. 80/hr) or losses in crop yields if farmers decide to leave their field with no irrigation.

Table 3: Normal Operational Cost of Well Irrigation/Month for a hectare of land with Wheat Crop (in Rs.)

	Under Fixed Line Connection (10 HP Pump)	Under Temporary Connection (5 HP Pump)*
Electricity Charges	1150	1625
Diesel Charges	630	630
Total	1780	2255

* Majority of Fixed line connection are for bore wells and temporary connection for open wells

7. MEASURES ADOPTED IN RESPONSE TO WELL FAILURES

The seasonal well failures in the region have forced farmers to take some corrective measures. Majority of farmers (32 % of the respondents) have gone for open well deepening over the years to have more water storage. This deepening is both vertical and horizontal. Maximum vertical deepening was found to be up to 22.5m and maximum horizontal deepening up to 30m for the surveyed farmers. Farmers opting for horizontal deepening mainly restrict it to below their farm lands only. This plays a major role in avoiding any kind of conflict arising from such deepenings. Of those having bore wells, no one has attempted deepening and very few farmers (only 2 respondents) opted for drilling new bore well once their earlier bore well started to give less discharge.

All the farmers had undergone cropping pattern changes as a result of no or less availability of water in late Rabi and summer season. Sugarcane was the major perennial cultivated crop but now it has been replaced with soyabean in Kharif (monsoon season) and wheat in Rabi season. The main reason for such shift was water shortage and comparatively better return in soyabean and wheat in comparison to sugarcane crop. Few farmers (total of 5 respondents) purchased water from other farmers having bore wells in case their open wells ran dry. The rate of water is on average Rs. 80/hr. Although it created an extra input cost burden on buyer farmers but they were satisfied in getting comparatively better crop yields than the un-irrigated farmers. A small fraction of farmers (2 in our sample) have also adopted sprinkler irrigation mainly for irrigating wheat but that had little success. One farmer has dug a recharge pond in his field. He learned about recharge ponds in one of the demonstration sites under National Rural Employment Guarantee Act (NREGA). The farmer looked quite optimistic about the benefits of the recharge ponds in the years ahead.

8. SOCIO-ECONOMIC IMPACTS OF WELL FAILURES

Socio economic impacts were mainly analyzed with focus on agricultural livelihoods only. These are discussed in detail in this section.

8.1 Impact on Cropping Pattern

Farmers in the surveyed area were mainly found to grow soyabean in Kharif and wheat and gram in Rabi season. Most of the farmers leave their land fallow in summer months. Surveyed data shows that soyabean is sown in 100% of the cultivated area across all landholding classes in the Kharif season. But cropping pattern

[5]While inferring Table 3, it has to be kept in mind that farmers will be paying year around for the fixed line connection but for a temporary connection they have to either pay for a 1 month or for three months depending upon the duration for which connection is taken.

varies during the Rabi season. Almost equal proportion of the cultivated land is diverted for wheat and gram crop by small and large landowners. However, for potato and garlic crop, small farmers divert less land in comparison to large farmers. Large landowners divert 73% more land for potato and 37% more land for garlic crop than the small farmers do. For more details, refer to Table 4. This particular cropping pattern explains the measures adopted by small farmers in response to scarcity of groundwater. Since potato and garlic are more water intensive crops than wheat and gram, small landowners refrain from diverting their land for these crops. However, because of better access to groundwater, large landowners divert their land in more proportionate manner across all the four Rabi crops.

Table 4: Cropping Pattern Across different Landholding Classes

	Total Cultivated Area(in Ha.)	Sown Area for Different Crops (in Ha.)				
Farmer Class		Soyabean	Wheat	Gram	Potato	Garlic
Small Landowners	20.25	20.25	4.75	4.25	2	1.75
Semi-Medium Landowners	88	88	37.25	18.75	6.75	14.25
Medium Landowners	282.5	282.5	97.5	69.75	34	36
Large Landowners	103.75	103.75	28.75	14.5	17.75	12.25
Total	494.5	494.5	168.25	107.25	60.5	64.25

8.2 Impact on Well Irrigation

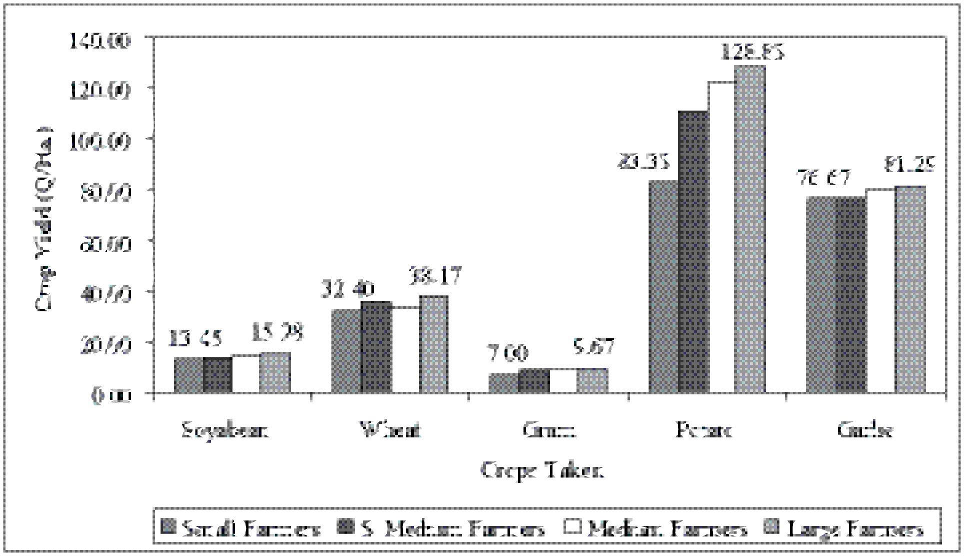
In absence of any surface irrigation source in the area, groundwater irrigation plays a major role especially for irrigating wheat. Irrigation is also required for other not so major crops like ginger and potato grown in the area. Well failures in these circumstances puts economical and social constraints on the farmers. Survey data shows that small farmers have more number of wells per unit of land (0.78) as compared to large farmers (0.32) but they irrigate only 3.25% of the total area. On the other hand, medium and large farmers own 68% of total number of wells, which are irrigating 78% of the total area. Since the average irrigated area per well is better in larger landholding classes (Table 5), the wells in these categories may be more productive as compared to small landowners. Thus, small landowners continue to suffer on account of less well irrigated area in comparison to the large landowners.

Table 5: Wells Ownership and Irrigated Area Across Different Categories of Surveyed Farmers

Farmer Class	Number of Well Owners	Total number of Wells Owned	Total Irrigated Area (in Ha.)	Average No. of Wells /farmer	Average Irrigated Area/ Well (in Ha.)	Average Irrigated Area /Well Owner (in Ha.)
Small Landowners	11	12	12.75	1.09	1.06	1.16
Semi-Medium Landowners	31	67	74	2.16	1.10	2.39
Medium Landowners	50	132	231.75	2.64	1.76	4.64
Large Landowners	9	35	73.25	3.89	2.09	8.14
Total	101	246	391.75	2.44	1.59	3.88

8.3. Impact on Crop Yields

Figure 5: Crop Yields (qtl/ha) for different group of Farmers



Crop yields (in qtl/ha) were different between small and large farmers. Yields for small farmers were 16% less for soyabean, 15% for wheat, 27% for gram, 35% for potato and 6% for garlic, in comparison to the large farmers (Figure 5). It might be possible that the current practice of well irrigation in this hard rock region is not able to provide significant support and benefit especially to small landowners. Also, less discharge from the bore wells, difficulty in installing successful bore well and seasonal nature of open well failures are putting extra burden on farmers. Now the question is - until what time farmers can continue to have the existing cropping pattern and afford the present irrigation sources, returning low yields and profits.

8.4. Impact on Net Returns

Similar story was observed in the net return from irrigated crops. Because of the hydro-geology and seasonal nature of well failures, the investment on irrigation is high. It costs on an average Rs. 15000/hectare as a cultivation cost for growing wheat. For open wells owners having temporary connection (5 HP Pump), 19% of cultivation cost is for getting irrigation and for farmers owning bore wells with fixed line (5 HP Pump), 19.5% of the cultivation cost is for irrigation[6] . Like crop yields (as discussed in section above), net return from crops were less for farmers with smaller landholdings. Aggregate net returns per farm for small landholders were 41% less than that of large landowners. Similarly aggregate net returns per well for small landholders were 39% less than for large landowners (Table 6). These differences were mainly due to the differential cropping pattern and well number between these two categories of farmers. Majority of these small landowners have only open wells (82% of the surveyed small farmers) with limited access to water and other resources. In fact because of recurring expenditure on well deepening and cost associated with drilling functional bore wells these returns further come down for both the small and large landowners.

8.5. Impact on Domestic Food Security

About a decade back sugarcane was grown as a major perennial crop in the surveyed area. But because of increasing well failures and thus low net returns, sugarcane crop no longer remained the feasible option.

[6] Considering that farmer with open well will do on average 3 watering and farmer with bore well will do 4-5 watering for wheat crop.

Consequently, there was shift in cropping pattern with soyabean emerging as a major Kharif crop and wheat as the major Rabi crop. This was surely an attempt by the farmers to overcome the groundwater scarcity problem and sustain their food security. Small landowners in particular give more importance to food crops like wheat and gram in their cropping pattern (Table 4). This indicates that they are more concerned regarding the availability of sufficient food and surplus crop for sale, which can sustain their other household requirements. Although the net returns for small landowners are much lower than the large landowners but they continue to have this cropping pattern to maintain their food sufficiency.

Table 6: Net Returns per Hectare (in Rs.) across Different Landholding Classes

	Wheat Small Landowners	Gram Large Landowners	Small Landowners	Large Landowners
Average Cost of Cultivation (Rs./Ha)	15000.00	15000.00	11350.00	11350.00
Yield (Q/ha)	32.40	38.17	7.00	9.67
Minimum Support Price 2006-07 (Rs./Q)	750.00	750.00	1445.00	1445.00
Gross Return (Rs./Ha)	24300.00	28627.50	10115.00	13973.15
Net Return (Rs./Ha)	9300.00	13627.50	-1235.00	2623.15

Table 7: Aggregate Net Returns for Wheat and Gram (in Rs./ha)

	Small Landowners	Large Landowners
Aggregate Net Returns/farmer	6058.46	10241.55
Aggregate Net Return/well	6290.00	10326.20

8.6. Other Social Impacts

In regards to equity and conflict over groundwater use, no problems were reported by the farmers. However, because of the current growth in the number of open wells and bore wells in the region, there are signs that equity in groundwater use may become an important issue. At present, good rainfall in the region (normal average of 984 mm/year) assure farmers of getting water from the open wells (till the early part of Rabi season), even if they carry on with deepenings of existing open wells. But certainly the horizontal drillings of open wells will have its impact in years of below average rainfall. These horizontal drillings may lead to well interference in the coming years. Less discharge and low probability of hitting exact water bearing zone, has limited the bore well installations to large farmers only. In the surveyed data, 89% of the large farmers had bore wells as compared to only 18% of small farmers. But, increase in the number of bore wells will definitely have an impact on the already low discharge from these wells. Surely net returns from agricultural practice in these hard rock areas are below that of other areas of the country where discharge from the wells and crop yields are comparatively better.

9. IMPLICATIONS

Increasing dependence on the groundwater, especially in context of hard rock areas has posed tremendous threat to the aquifer systems. A much lower level of groundwater development in the hard rock regions could be as serious as a higher level elsewhere (Vijayshankar and Shah, 1997). In fact because of some not so rational groundwater development assessments, number of over-exploited districts in hard rock areas where high incidence of well failures is found, are very low (Kumar and Singh forthcoming).

In the surveyed villages of *Bagli* block, over dependence on groundwater has started to pose problems in respect of depleting groundwater aquifer, lesser discharge and low crop yields. Also, the seasonal and geological nature of well failures has left farmers with little net returns. These impacts are more pronounced for the small landowners who have limited resources and access to groundwater. Further, free of cost electricity supplied to Madhya Pradesh farmers for nearly 16 years has promoted the growth in the number of wells, especially bore wells. However, this growth in number of wells does not resulted in increase in irrigated area per well (Kumar, 2007), only increase in incidences of well failures. In order to have maximum irrigation from the available resource, farmers resort to deepening of wells (both vertical and horizontal), which impacts the total cost associated with well irrigation. Well deepening has potential for inequity and conflict among well owners in the years ahead.

Although government has priced electricity for agricultural consumption from 2001 onwards, payments from rural areas remained low. As per one estimates, annual loss to the Madhya Pradesh State Electricity Board on revenue account alone until 2002 was between Rs.150 to Rs.250 crore. State government should place effective enforcement mechanisms, in order to check the non-payment of electricity bills, which will not only restrict the increase in well numbers but will also restrict groundwater use. There is also a big scope for constructing recharging structures and intervening with micro-irrigation techniques like sprinklers in the region. Few farmers had even gone ahead with them, but it requires more sincere and dedicated effort from the government to promote and make popular such water efficient systems among farmers. Future reforms in context of hard rock areas are required, which will promote the use of more water efficient practices and reduce the groundwater overdraft.

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