WHEN DOES OVEREXPLOITATION REALLY MATTER?
A CASE OF GROUNDWATER EXTRACTION IN KARNATAKA, INDIA

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Abstract

The paper analyses the consequences of groundwater overexploitation by using field level data collected from 2 well irrigated districts of Karnataka. The study result shows that the consequences arising out of groundwater overexploitation are severe in high well interference area compared to low well interference area. As a result, the overexploitation of groundwater has differential impact on different categories of the farmers in terms of cost of drilling, area irrigated per well and adoption of conservation measures. The burden of well failure is more or less equally shared by all categories of farmers but small farmers are the worst victims of resource scarcity. The study suggests maintaining inter well distance to prevent 'resource mining' and to educate farmers to cultivate light water crops. Institutional reforms are necessary to restore surface water bodies and facilitate aquifer recharge.

1. INTRODUCTION

Resource scarcity was viewed at best as a major barrier to continued economic development, with the depressing implications which this has for the economies of the developing countries. At the same time it was predicted that overexploitation of natural resources stocks would cause the total collapse of society during the early part of the 21st century (Rees, 1990). It seems clear that technological progress and market forces have not acted to reduce pressures on renewable resources as they have in the stock resource case (Johnson, 1975; Dasgupta, 1982). In the advanced economies higher real consumer incomes have not only increased demands for a better quality of life and a cleaner environment but, coupled with rising levels of personal mobility, have intensified pressures on amenable natural resources such as water, forest and land resources.

Groundwater, as a natural resource, assumes a significant role either as a sole or as a supplementary source of irrigation. Although groundwater is conventionally regarded as a common pool resource, it cannot be treated as a open access resource because its availability is restricted by various socio-economic and hydro-geological factors (Janakarajan, 1997). Moreover, the over-use of groundwater poses a problem of externalities due to cumulative well interference problem. This is because a given aquifer can be shared by many and that creates the problem of competitive extraction (Ibid). This problem is due to lack of efficient legal measures in checking or regulating its use (Singh, 1992) and under pricing of its true value (CVG, 1997). In this context, the paper looks into the consequences of groundwater over exploitation confining to irrigation sector in the central dry zone of Karnataka, India.

We start with an illustration of the natural resource exploitation in the context of developing countries. After describing our study region and methodological issues we report results that are subjected to groundwater irrigation in the central dry zone of Karnataka. In the light of the reported results, the concluding section suggests measures to prevent over exploitation of groundwater resources.

2. NATURAL RESOURCE EXPLOITATION: AN OVERVIEW

Natural resources are important for sustainable development and achieving higher economic growth. Efficient and scientific utilization of these resources ensures the ecological balance of an ecosystem. The contribution of natural resources to local economy is outside the market framework, which are both its strength as well as weakness. Strength in the sense of social justice, that it supports rural families. Weakness lies in

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unsustainable exploitation of these resources, which would result in the tragedy of these resources. Further, unsustainable exploitation leads to scarcity of resources that would then be beyond the reach of the poor.

Barnett and Morse (1979) defined *increasing scarcity as increasing real cost*, which is measured by the amount of labour and capital required to produce a unit of extractive resources. They put forward the following hypothesis:

The real cost of extractive products per unit will increase through time due to limitations in the available quantities and qualities of natural resources. Real cost in this case is measured in terms of labour (man-days, man-hours) or labour plus capital per unit of extractive output (Barnet, 1979).

Barnet and Morse refer to this postulate as the strong hypothesis of increasing economic scarcity. It suggests that increasing resource scarcity will be evident if, over time, an increase in use of labour and capital per unit of extractive output.

The debate on natural resource scarcity brings us to the frontier of externalities. These externalities could be several types depending on the nature of the resources. Externalities related to groundwater resource could be stock related, cost related and strategic in nature (Provencher, 1998). Stock related externalities arise when extraction rates go beyond sustainable yield rates. In such cases, all the available resource stocks are exploited to the extent that there is no further scope for future exploitation (Reddy, 2003). In the case of groundwater, most of the negative externalities arise due to stock related aspects. In broader sense, other externalities viz., cost related, strategic and legislative externalities are associated mainly with stock related externalities. Therefore, loosing the resource base permanently is a risky sign if the non-renewable portions of the stocks are exploited (Ibid).

Most of the natural resources are common pool resources in which rights are limited to use and income deriving. In the case of groundwater aquifer, it can be sold and transferred along with land due to its link with land. Due to absence of property rights in allocating resources such as groundwater, farmers make private investment assuming that they have absolute rights over groundwater aquifer. In the course of these institutional drawbacks, everyone who has the capability to access groundwater remain in the race of exploiting the resources.

3. THE STUDY REGION: CENTRAL DRY ZONE, KARNATAKA, INDIA

The Central Dry Zone consists of 17 taluks with a total geographical area of 20,112.81 sq. km. The rainfall ranges between 455.5 to 717.4 mm in the zone. The elevation of the zone is 800-900 in major areas, in remaining areas 450-800. Table 1 provides details about the characteristics of the zone.

Table 1: Characteristics of Central Dry Zone, Karnataka

Sl. No	Characteristics	Particulars
1.	Rainfall (mm)	Ranges from 455.5 mm to 717.4 mm
2.	Elevation	800-900 in major areas, in remaining areas 450-800
3.	Soil	Red sandy loam in major areas, shallow to deep black soil in remaining areas
4.	Total Geographical area (sq. km)	20,112.81
5.	Gross cropped area (ha)	12,93,011
6.	Net Cropped area (ha)	11,27,500
7.	Total irrigated area (ha)	2,51,270

The population density (ranges between 189 persons / sq. km and 235 persons / sq. km) in the study area is high compared to other zones in the state. Agriculture is the main occupation in the area. In the central dry zone as a whole, about 60% of the working population cultivates land and another 25% is agricultural labour. The literacy rate is average reflecting medium levels of social services and social development in the area.

Because of high population density, the average operational farm holding is considerably small. Farmland in the area is privately owned and a significant portion is farmed by the owners. Sharecropping, lease in and lease out are to the tune of less than 5%. Land fragmentation is a widespread phenomenon.

4. THE METHODOLOGICAL APPROACH

Two taluks reporting high and low well interference problem were selected from central dry zone in Karnataka state[2]. These taluks represent different levels of groundwater situation and reflect the overall situation in the agro-climatic zone. Nine villages have been covered from 2 taluks in order to study the overexploitation problem of groundwater resource[3]. Chosen villages are Adrikatte and Marabaghatta (scarcity villages) and Heggere and Huralihalli (no scarcity villages) in Hosadurga taluk and Garani, Chandragiri and Madenahalli (scarcity villages) D V Halli and Kambadahalli (no scarcity villages) in Madhugiri taluk. Thus, the sample villages range from reasonably good availability of groundwater to acute shortages (including drinking water). Although tanks exist in few study villages, many of them are not filled in since 1992. Therefore, there are no alternative water sources for irrigation as well as drinking purposes.

The data collection has been done at 2 levels. At the first level, Participatory Rural Appraisal (PRA) technique has been used to select respondents in all the villages. At the second level, detailed information regarding various aspects of well irrigation was collected using a detailed questionnaire from households whose wells have been interfered. This study comprises a group of villages where irrigation wells suffer from cumulative well interference (here after HWIA) and another group of villages where interference problem does not lead to high well failure (here after LWIA).

4.1 PRA approach

Understanding the situation of failed wells, due to resource scarcity, from the perspective of farmers is crucial since they are the ultimate decision makers and investors for coping with the well failure problems. The farmers' perception of well failure is different from technical definition of well failure[4]. Therefore, it is necessary to obtain information about failed wells in the study area to reveal the actual situation of the well interference problem. The PRA method was applied to choose the respondents in the sample villages.

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[2]The agro-climatic zone is reported to have serious groundwater problems next to eastern dry zone in the state.

[3]The following criterion was followed in order to choose the taluks with the highest degree of well interference. Interference of irrigation wells per ham of net groundwater availability = (No. of IP sets or wells/utilisable GW for all purposes in ham) for each taluk. Calculation of the ratio involved following steps (Shivakumaraswamy and Chandrakanth 1997). Below are the steps to calculate index of well interference. **Step 1:** In the first step, Irrigation pump sets (IP) are considered as a proxy to irrigation wells and borewells installed. **Step 2:** Net annual groundwater availability is considered to calculate index of cumulative well interference ratio in each taluk. Net annual groundwater availability in hectare meter (ham) will indicate the utilizable quantum of groundwater for all purposes in a particular year for each taluk. The data pertains to 2004-05. **Step 3:** By considering cumulative number of wells and net annual groundwater availability, cumulative well interference index has been calculated, which explains number of wells per hectare meter of utilizable groundwater in each taluk. This can be written as:

Index of Cumulative Well Interference (ICWI) = (No. of IP sets or wells/Utilizable groundwater for all purposes in ham) for each taluk.

Step 4: The taluks are then sorted in descending order of the magnitude of the above index. The taluks are later classified according to agro-climatic zones of the State in order to obtain variability in groundwater use across crop types, soil types and climatic types. Among the Agro-climatic Zones, eastern dry zone topped with respect to ICWI, followed by central dry zone, northern dry zone and southern dry zones, which have the magnitude of ICWI above one. However, we decided to choose the taluk which topped with respect to ICWI in one out of ten agro-climatic zones and which does not have substantial surface irrigation projects. The agro-climatic zone chosen was Central Dry Zone. The selected taluks were Madhugiri and Hosadurga in the Central Dry Zone. The taluks are selected based on highest and lowest magnitude of ICWI respectively.

For the selection of villages in selected taluks in selected Zone, the village-wise availability of groundwater for irrigation was computed by using the ratio. The ratio calculated as below:

(Net Sown area of the village/net sown area for the taluk) x (Utilisable groundwater of the taluk).

Villages are then sorted in descending order of the magnitude of the above ratio. The villages are later selected in order to obtain variability in groundwater use across crop types, soil types and climatic types. The selected villages are representing high and low magnitude of groundwater availability in the respective taluks.

As far as definition of failed well is concerned, various definitions have been emerging out of discussion with farmers in different areas and in different situations. However, we compile them in a holistic manner and we define failed well as:

1. the well that dries because of new well(s) coming in (but not due to lack of rainfall);
2. the well that need deepening because of new well coming in (not because of lack of rainfall); and
3. the large quantity of yield goes off because of new well coming in (but not because of lack of rainfall).

Basic features of the study villages are almost similar in terms of occupational pattern, cropping pattern, infrastructures and social services. In all the villages, small and marginal farmers are in majority. There is high concentration of bore-wells as well as open wells in HWIA compared to LWIA. The area irrigated is less than 25% of the total cultivable land in all the villages except in Heggere, where the area irrigated to total cultivable land is nearly 27%[5].

5. RESULTS AND DISCUSSIONS

5.1 Characteristics of groundwater Irrigation

Groundwater irrigation is characterized by sole ownership rights and control on its access which are quite contrast to traditional community managed or state managed surface irrigation systems. Development of groundwater based irrigation has created a way for intensive multi season agriculture in many parts of India. Since surface irrigation sources and traditionally used tanks have lost the cadence of irrigation potentiality due to various reasons[6], one can see the rapid growth of groundwater irrigation and emergence of groundwater as a crucial productive resource. Further, the status of groundwater irrigation can be understood by analyzing type of wells used, well density, ownership pattern, landholding size and crop pattern.

5.1.1 Type of wells

Prior to green revolution, the major sources of irrigation were traditional tanks, streams and dug wells. With the decline in water levels, depth of dug wells could not be restricted to the weathered zone and had to pierce the underlined fractured zone, the excavation of which was through blasting, rendering the process slow and expensive. Framers, therefore, preferred boring from the bottom of dug wells instead of conventional excavation. Such dug-cum-bore wells allowed the use of centrifugal pump sets installed on dug wells. However, dug-cum-bore wells had limited use because water levels soon declined below the suction limit of centrifugal pump sets, forcing the farmers to switch over to deeper surface bore wells and install submersible pump sets. This commenced in early 1980s and marked an important phase of groundwater development in the state (Rao, 1992). Further, easy access to technology and credit was made available for the growth of bore wells in semi-arid regions of the state. This was coupled with availability of free electricity supply for agriculture. This made multi crops in multi season possible and increased production. All these factors marked a shift of groundwater structures from simply dug-cum-bore wells to deeper surface bore well technology. It is an irony that bore wells constructed as a solution to declining water levels actually hastened the process of water table lowering. The unit draft (withdrawal) of a bore well is more than that of a dug well.

Table 2 provides the listing of different type of groundwater structures in the sample villages. Bore wells seem to be major irrigation structures followed by open wells in the HWIA. However, the contribution from the dug wells to irrigation potential is zero as they all defunct due to either bore well interference problem or decreasing quantum of rainfall in recent decades. In LWIA, nearly 95% of the groundwater structures are bore wells. This implies that the groundwater irrigation through manually lifting devices such as *yetha* was not popular in both LWIA and HWIA and most farmers depend on bore wells.

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[4] The National Bank for Agriculture and Rural Development (NABARD) defines borewells yielding less than 2 liters per second (or 1,582 gph) at the time of installation as failed wells.

[5] The actual area irrigated is higher than the figure mentioned in the official record. Besides, the area irrigated by tanks and other sources was mentioned high in the official record. However, the general picture in the sample villages is far from the reality where groundwater is the only source of irrigation due to drying up of tanks.

[6] Declining irrigation potentiality of surface water bodies are on account of two major factors in the study area– (i) factors related to human intervention and (ii) factors related to nature intervention.

Table 2: Type of Wells in the Sample Villages

Villages	No. of Borewells	No. of Openwells	Total Number of wells
Adrikatte	61 (96.8)	2 (3.2)	63
Heggere	60 (96.8)	2 (3.2)	62
Huralihalli	44 (95.7)	2 (4.3)	46
Marabgatta	55 (90.2)	6 (9.8)	61
LWIA	220 (94.8)	12 (5.2)	232
Chandragiri	89 (69.5)	39 (30.5)	128
D. V. Halli	39 (75.0)	13 (25.0)	52
Garani	70 (66.7)	35 (33.3)	105
Kambadahalli	25 (64.1)	14 (35.9)	39
Madenahalli	49 (69.0)	22 (31.0)	71
HWIA	272 (68.9)	123 (31.1)	395

Source : Primary survey
Note : Figures in parenthesis indicates percentage to the total number of wells.

5.1.2 Type of wells across landholding size

It is important to understand the effect of landholding size on farmers in opting for bore well technology. This aspect is important because of 2 reasons: firstly, landholding size is a decisive factor to understand wealth status of a household as land treated as a productive asset as well as status symbol; secondly, landholding size is a major factor for cultivating variety of crops in different seasons thus, extracting heavy amount of water to sustain the crops.

Table 3 illustrates that as the landholding size increases the preference to have borewell technology increases and *vice versa*. It is clearly visible in the case of LWIA, where the proportion of bore wells is an increasing trend as we move towards larger landholding sizes. However, the ownership of different types of groundwater structures in HWIA reveals a different picture as this is highly affected by well interference problem.

Small farmers in HWIA own the highest number of ground water structures because majority of them are late comers in the resource extraction activity. Therefore, area in which small and marginal farmers install groundwater structures may not strike water as the area is already suffering from acute well interference problem. Even if they are able to mop the capital required for additional well, they bear the risk of not striking (adequate) groundwater. In this situation small farmers tend to have more wells as they are not able to deepen their existing wells because of high equipment cost as well as operation and maintenance cost.

After the dug wells run dry, the farmers biggest priority is to restore well irrigation at any cost. Oblivious to the risk involved, farmers incur heavy expenditure on drilling bore wells, most of them making repeated attempts. Even in case of successful bore wells, many farmers have to incur expenditure on deeper bore wells because the bore wells, which succeeded initially were dry after running for a few years.

5.1.3 Ownership of wells across size class of farmers

In the study area, the ownership rights over borewells and open wells were enjoyed by a single owner and not by joint well owners. Understanding emerging ground water problems and finding potential solutions emerge from this central point. As the bore well owners enjoy ownership rights as well as freedom to extract groundwater as and when required, it increases its rate of extraction.

Table 3: Type of Wells Across Landholding Size in LWIA and HWIA

Landholding size (Ha)	No. of Borewells	No. of Open wells	Total No. of wells
Marginal Farmer (Up to 1) N=10	11(5.0)	0(0.0)	11(4.7)
Small Farmer (1.01 to 3.0) N=37	52(23.6)	3(25.0)	55(23.7)
Medium Farmer (3.01 to 5.0) N=26	58(26.4)	4(33.3)	62(26.7)
Large Farmer (More than 5.0) N=29	99(45.0)	5(41.7)	104(44.8)
LWIA (N=102)	220(100.0)	12(100.0)	232(100.0)
Marginal Farmer (Up to 1) N=15	27(9.9)	19(15.4)	46(11.6)
Small Farmer (1.01 to 3.0) N=73	168(61.8)	74(60.2)	242(61.3)
Medium Farmer (3.01 to 5.0) N=22	49(18.0)	20(16.3)	69(17.5)
Large Farmer (More than 5.0) N=13	28(10.3)	10(8.1)	38(9.6)
HWIA (N=123)	272(100.0)	123(100.0)	395(100.0)

Source : Primary survey
Note : Figures in parenthesis indicate percentages to total

The survey conducted in 9 villages in 2 extreme regions (high well interference and low well interference areas) of Karnataka shows that about one-third of large farmers owned nearly 50% of wells in LWIA (Table 4). Similarly, In HWIA, maximum number of wells were owned by small farmers. It is an indication of high well failure due to well interference problem.

The relevant question is to what extent is it rational to classify the sample well owners according to size of landholding. This is important to get new insights into the characteristics of well owners and their access to groundwater. For instance, a simple fact is that the larger the land area owned greater the possibility of striking groundwater. Further, the scope of sustaining groundwater irrigation is far better for large land owners compared to small holders. But it is imperative to ask for how long will the small (resource poor) farmers sustain the problem of competitive deepening? While the threat of getting eliminated from the race of competitive deepening is seemingly just around the corner for farmers, the resource rich farmers have the capability of sustaining the adverse effects of competitive deepening. Resource rich farmers are not constrained in mobilizing finance for well drilling or well deepening activities as resource poor farmers.

Small farmers in HWIA owns larger number of wells. At the surface it appears as though groundwater irrigation is quite diffused across farming community. The success of the green revolution, greatly attributed to the development of well irrigation. In this setting, the large farmers perhaps entered into groundwater extraction activity much before that of small and marginal farmers. As a result, large farmers have not only exploited groundwater much early, but have done substantial damage by mining the aquifers. Therefore, poor well owning farmers though appear to own large number of wells, are indeed late comers in the race of groundwater extraction.

Sole ownership indicates claim of property rights over groundwater. The law of inheritance perpetuates the problem of ground water extraction. From one generation to the next, the land gets fragmented further. With each fragmentation, additional bore wells are introduced. In their competitiveness to bring more area under irrigation, small and marginal farmers drill more wells even though they may not strike groundwater. If they do strike groundwater, it may be less in quantity.

The area irrigated per well by small and marginal farmers is comparatively low in comparison to medium and large farmers (Table 4). For instance, in both LWIA and HWIA, the area irrigated per well is less than 1 ha in the case of marginal farmers, less than 1.5 ha in the case of small farmers, and more than 2 ha in the case of large farmers. For the same investment in drilling or deepening, small farmers get a lower return because of the smaller size of land holdings in cocmparison to large farmers.

To this there is the increased threat of over exploitation from a common pool – the aquifer. Medium and large farmers continue to enjoy ownership over groundwater as they can compete with declining water tables by deepening wells. But, for small and marginal farmers, the financial burden of drilling and deepening activities is very high with little or no assurance of striking water.

Table 4: Ownership of Wells Across Size Class of Landholding in LWIA and HWIA

Landholding size (Ha)	Number of well owners	Total number of wells owned	Total extent of land irrigated (ha)	Average extent irrigated per well (ha)
Marginal Farmer (Up to 1)	10	11	5.58	0.62
Small Farmer (1.01 to 3.0)	37	55	44.08	1.13
Medium Farmer (3.01 to 5.0)	26	62	51.16	1.42
Large Farmer (More than 5.0)	29	104	106.11	2.12
LWIA	102	232	206.93	1.54
Marginal Farmer (Up to 1)	15	46	6.99	0.64
Small Farmer (1.01 to 3.0)	73	242	73.43	1.41
Medium Farmer (3.01 to 5.0)	22	69	36.54	1.52
Large Farmer (More than 5.0)	13	38	38.05	2.00
HWIA	123	395	155.01	1.46

Source: Primary survey

5.1.4. Well Density[7]

The well density per unit area is 1.2 in HWIA, which is very high as compared to 0.5 of LWIA (Table 5). Higher number of borewells per unit of area in HWIA indicates well failure rates and consequently more investments on bore wells due to high well interference problem. Well density is one of the indicators to measure the sustainability of groundwater resources. In over exploited area, if proper isolation distance and optimum well density in relation to the recharge capacity is not maintained, it is bound to create cumulative well interference problem. As a result, the surrounding wells would dry up. In case of HWIA, the well density is very high reflecting the un-sustainability of the groundwater resource. Though the well density in terms of increased number of wells indicates wider access, the resource needed to own a well and pumps are beyond the reach of small and marginal farmers considering high capital cost. The village-wise analysis indicates that the villages in LWIA are having lower well density compared to HWIA. In HWIA, the well density is high in scarcity villages compared to other villages (Figure 1 and 2). It is not surprising that in villages where well density is high land irrigated per well is low. This leads to the problem of cumulative well interference because small size of land accommodates larger number of wells and water is ebstracted beyond sustainable limits.

Table 5: Well Density in LWIA and HWIA

Villages	Land (ha)	Well density	Area per well
Adrikatte	122.82	0.5	1.9
Heggere	89.87	0.7	1.4
Huralihalli	75.5	0.6	1.6
Marabgatta	147.51	0.4	2.4
LWIA	435.7	0.5	1.9
Chandragiri	46.58	2.7	0.4
D. V. Halli	43.12	1.2	0.8
Garani	117.06	0.9	1.1
Kambadahalli	65.3	0.6	1.7
Madenahalli	53.38	1.3	0.8
HWIA	325.44	1.2	0.8

Source: Primary survey

Figure 1: Well density and area per well in LWIA

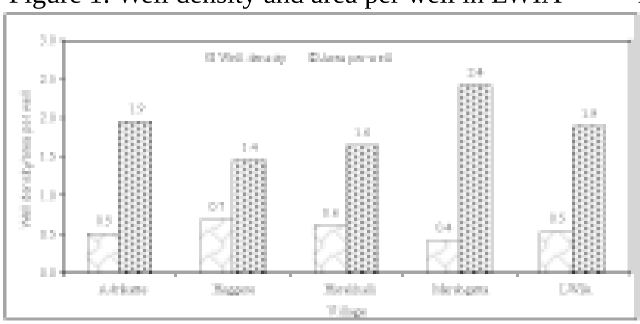
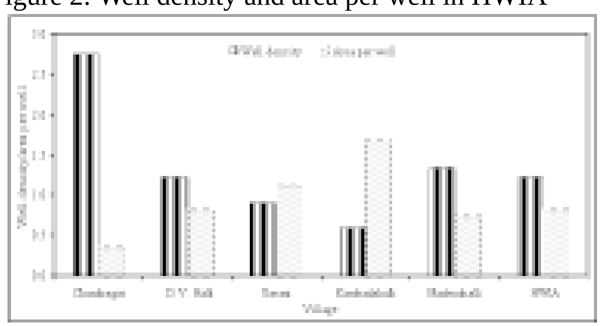


Figure 2: Well density and area per well in HWIA



5.2. Area irrigated, crop pattern and yield

In this section, we present the area irrigated, crop pattern and yield rate of different crops in the study area. It is necessary to mention that HWIA is under severe stress due to over exploitation of the resource compared to LWIA. As a result, cropping pattern is shifting from high water intensive crops to low water intensive tree and plantation crops. Further, the situation in these 2 areas can be comparable to examine the cumulative well interference problem.

5.2.1. Area irrigated

Water yielding characteristics and area irrigated by wells vary between villages affected by severe well interference problem and those, which are not. For instance, in LWIA, nearly 37% of the wells are irrigating

[7] Well density refers to the number of wells per unit area and the area per well is the reciprocal of the well density. While calculating well density total land holdings of the entire sample farmers and total number of all types of wells were considered whether working or failed.

gross area of more than 10 acre compared to 11.3% in HWIA (Table 6). Similarly, almost 7% of the wells are irrigating more than 5 acre of net irrigated area in both LWIA and HWIA (Table 7). The higher gross irrigated area (GIA) and net irrigated area (NIA) of LWIA is due to low well interference and the cropping pattern. However, in HWIA, the area irrigated per well (both GIA and NIA) appears to be low due to low yield rate of aquifers and mining the aquifers beyond threshold level.

Table 6: Gross Area Irrigated Per Well in LWIA and HWIA

GITA (Acre)	LWIA Number of wells					HWIA Number of wells						
	Adrik Ate	Heggere	Huraliha	Maraba gatta	Total	Chand Ragiri	D V Hall	Garani	Kambada Halli	Madena Halli	Total	Grand Total
0.01-2.5	1	1	0	3	5 (3.73)	3	3	10	4	7	27 (25.5)	32 (13.3)
2.51-5.0	8	9	0	9	26 (19.4)	4	12	13	4	1	34 (32.1)	60 (25.0)
5.01-7.5	9	18	2	10	39 (29.1)	3	6	9	4	1	23 (21.7)	62 (25.8)
7.51-10.0	7	1	2	5	15 (11.2)	0	4	4	1	1	10 (9.43)	25 (10.4)
> 10.0	9	17	12	11	49 (36.6)	3	0	5	4		12 (11.3)	61 (25.4)
Total	34	46	16	38	134 (100)	13	25	41	17	10	106 (100)	240 (100)

Source : Primary survey
Note : Gross area irrigated has been calculated only for those wells that are in working condition. Scarcity villages: Adrikatte and Marabgatta in LWIA and Chandragiri, Garani and Madenahalli in HWIA

The cumulative well interference induced water scarcity comes out clearly from Tables 6 and 7. In LWIA, area irrigated per well is higher than that irrigated per well in HWIA. In HWIA, gross area irrigated per well is declining as we move from smaller to larger landholding size. The difference is quite sharp between scarcity villages and non-scarcity villages in terms of gross irrigated area and net irrigated area. Such difference in the area irrigated by wells between scarcity and non-scarcity villages in HWIA is also reflected on crop productivity. We learned from our survey that majority of the farmers in HWIA removed arecanut plantation, which they depended on earlier, due to severe water scarcity problem. This is a clear indication of negative externality which poses severe threat to welfare of peasant families in terms of loss of income, food insecurity, employment insecurity and migration[8].

5.2.2. Change in area irrigated per well

The area irrigated by wells has been changing radically over time in both LWIA and HWIA. The change in area per well has been calculated by taking present extent of area irrigated by a well minus initial irrigated area

[8]These are the different forms of securities for human development in the world. Food security is said to be there when people have access to sufficient, safe, and nutritious food at all times to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996a). Social security is a combination of economic, political and personal security, including equity and justice, that is necessary for life, liberty and pursuit of happiness. Similarly, Environmental security ensures that the eco-system and the environment are able to support the healthy pursuit of life, liberty, and happiness by present and future generations.

for working wells. A negative change is observed in HWIA compared to LWIA (Figure 3). Similarly, rapid change is taking place in terms of area irrigated per well in LWIA due to fast developing aquifer mining. In HWIA, the aquifer condition is deteriorating in terms of recharge capacity due to overexploitation of the aquifer since long time. Added to that the cropping pattern, soil condition, climatic condition are playing an important role for rapid change in area irrigated per well.

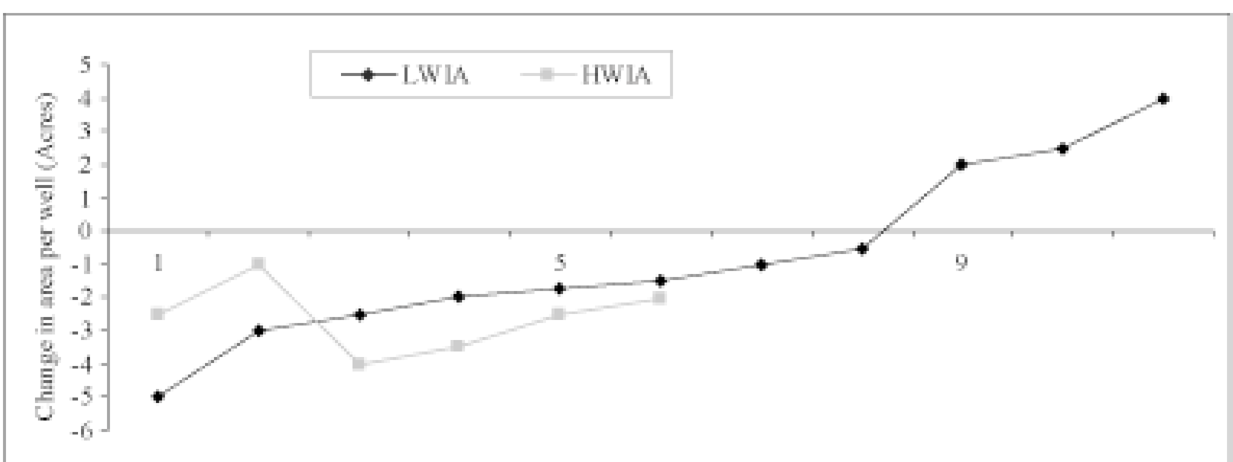
Table 7: Net Area Irrigated per Well Across Villages in LWIA and HWIA

NIA (Acres)	LWIA Number of wells					HWIA Number of wells						
	Adrik Ate	Heggere	Huraliha Halli	Maraba gatta	Total	Chand Ragiri	D V Hall	Garani	Kambada Halli	Madena Halli	Total	Grand Total
0.01-1.0	3	4	0	3	10 (7.5)	4	2	10	3	3	22 (20.8)	32 (13.3)
1.01-2.5	15	24	2	17	58 (43.3)	6	13	13	5	4	41 (38.7)	99 (41.3)
2.51-5.0	9	17	10	12	48 (35.8)	1	10	14	7	3	35 (33.0)	83 (34.6)
5.01-7.5	5	1	1	3	10 (7.5)	2	0	4	1	0	7 (6.6)	17 (7.1)
> 7.5	2	0	3	3	8 (6.0)	0	0	0	1	0	1 (0.9)	9 (3.8)
Total	34	46	16	38	134 (100)	13	25	41	17	10	106 (100)	240 (100)

Source : Primary survey
Note : Net area irrigated has been calculated only for those wells that are in working condition.
Scarcity villages: Adrikatte and Marabgatta in LWIA and Chandragiri, Garani and Madenahalli in HWIA

The cropping pattern in LWIA indirectly promotes resource conservation since it is dominated by plantation crops such as coconut and other tree plants. However, the water intensive crop such as paddy is a major hindrance in HWIA which consumes major share of and puts pressure on groundwater aquifer. We shall discuss this in the next section.

Figure 3: Change in area per well in LWIA and HWIA



5.2.3. Crop pattern

Paddy is by far the most important crop during kharif in HWIA along with arecanut, coconut and ragi. However, the major crop in LWIA is coconut. Although coconut is a perennial crop most of the time, due to infrequent rainfall, groundwater is the chief source of water during kharif season too. Water intensive crops such as paddy, arecanut/coconut and vegetables are to the tune of 7.1, 6.3 and 2.9 ha respectively (Table 8). The area under water intensive crops in the HWIA (39.4 %) is much higher than that in LWIA (6 %). Thus, crops selected also reflect the competitive extraction behavior in exploiting groundwater.

There are wide varieties of crops grown in both LWIA and HIWA. The cropping pattern of the area is due to location advantages, marketing facilities and availability of timely water sources. For instance, coconut is the predominant perennial crop grown largely in LWIA because weather condition and soil type encourages the production as well as crop growth. Similarly, paddy is the predominant food crops grown largely in HWIA due to its comparative advantage over other crops and traditional association with paddy as a staple food crop.

Table 8: Cropping Pattern in HWIA and LWIA (Area in Ha)

	LWIA				HWIA			
	Kharif	Rabi	Summer	Total	Kharif	Rabi	Summer	Total
Maize	0	0	0	0	7.5	0.8	3	11.3
Paddy	7.1	0	0	7.1	30.4	0	5.5	35.9
Ragi	2.9	0	0	2.9	14.8	0.9	1.6	17.3
Food crops	10.0	0	0	10.0	52.7	1.7	10.1	64.5
Areca/coconut	6.3	6.3	6.3	18.9	15.6	15.6	15.6	46.8
Banana	0.2	0.2	0.2	0.6	0.8	0.8	0.8	2.4
Coconut	154	154	154	462	14	14	14	42
Groundnut	4.6	0	0.2	4.8	5.4	0	21.5	26.9
Sapota	1.6	1.6	1.6	4.8	0.8	0.8	0.8	2.4
Other crops*	8.0	5.1	5.9	19.0	18.6	9.3	15.3	43.2
Cash crops	174.7	167.2	168.2	510.1	55.2	40.5	68.0	163.7
Gross area irrigated				520.1				228.2
Net area irrigated				184.7				107.9

Source : Primary survey
Note : * other crops include sunflower, floriculture, lemon, mulberry vegetables, mango and pomegranate.

Why is paddy cultivation popular in HWIA despite groundwater scarcity? This seems to be a very crucial issue from a resource economics point of view. Firstly, paddy is by far the most preferred staple food crop in this area along with ragi. Secondly, paddy is labeled as a lazy man crop. It doesn't require more attention and frequent human labours to monitor crop growth as it requires in other crop cultivation. However, because of rising groundwater scarcity, a majority of farmers have shifted from paddy to ragi, groundnut and other low water intensive dry land crops[9].

In principle, access to bore well irrigation enables rural households to engage in agricultural operations throughout the year and enhance returns from land. Groundwater ensures reliable water supply throughout the year (at least for some farmers), productivity of land is quite remarkable. Well owning farmers normally take 2

[9]In two out of nine villages, two farmers have shifted totally from high water intensive food crops to low water intensive tree crops such as Teak, Mango, Sapota and Lemon and two farmers planted eucalyptus due to water scarcity and cope with high expenditure on farming. They seem to maximize their marginal productivity by planting crops of longer duration. This reduces their operational cost as well as maintenance expenditure.

crops; and some times, a third crop as well, thereby maximizing the gross returns from farms. However, in practice, groundwater irrigation is working adversely for the resource poor farmers by posing severe threat to their living condition.

5.3. Consequences of groundwater overexploitation

Groundwater depletion is by far the most widely debated issue in the resource economics literature. Groundwater depletion problems are related to the question of resource management and the coalition of powerful property owners protecting their interests, under a capitalist society. Overexploitation of groundwater and its social consequences are the result of certain processes of development in irrigated agriculture that occur at the cost of depletion of aquifers and sustainable farming systems. The state intervened initially through agrarian reforms, and later by providing credit facilities and supporting marginalized groups to have irrigation facilities by implementing Million Well Schemes, Ganga Kalyan Yojana and politically influenced free power supply. All these led to rise in groundwater structures, shifting cropping pattern towards water intensive crops as well as resource abuse by overexploitation of the aquifer.

The distinctive impact of irrigation, in general, and groundwater irrigation, in particular, on farming begins to emerge more clearly and recognizably where irrigation permits extension of cultivation to additional seasons (Rao, 1978). This allows farmers' to benefit from surplus production which otherwise would not have been possible. As a result, groundwater became a chief source of irrigation primarily in arid and semi-arid areas and at the same time several problems emerge due to heavy pumping.

5.3.1. Growth, depth and cost of bore wells

Growth of groundwater structures (wells) is infouenced by many factors, the most notable being dropping water levels and competition among farmers. They have a variety of impacts. There has been a change in the type of wells. Traditional openwells/dug-cum-borewells cannot be used when water levels fall. Now large numbers of defunct open wells have turned into storage tanks in the wake of infrequent power supply and voltage fluctuations.

The growth of wells seems to be high in HWIA compared to LWIA (Table 9). The fast growth is because of frequent well failure problem. Since HWIA is suffering from cumulative well interference problem, frequent well failure and declining yield rate is quite common. Similarly, the depth of borewells is increasing constantly with the number of bore wells both in HWIA and LWIA but with more severity in HWIA. Table 9 reveals that the depth of bore wells in HWIA is always higher than that of LWIA. The difference is almost two times. This clear indicates the competitive extraction behaviour of farmers in HWIA.

Table 9: Depth and Cost of Bore Wells in LWIA and HWIA

	LWIA				HWIA			
Year	No. of borewells	Av. Depth	Av. Drilling cost	Av. HP	No. of borewells	Av. Depth	Av. Drilling cost	Av. HP
Prior 1985	8	154.4	7023	4.5	9	353.3	15448	7.5
1986 - 1990	12	164.2	9338	4.5	13	404.6	20008	9.1
1991 - 1995	36	187.1	8671	4.5	71	373.5	16485	8.4
1996 - 2000	80	179.2	8969	4.2	85	382.6	17836	9.4
2001 - 2005	71	209.6	10439	4.5	83	494.2	24469	9.2
2006 - 2007	13	247.7	13354	4.4	11	461.4	25441	9.2
Total	220	192.6	9602.81	4.43	272	417.6	19839.68	9.0

Source: Primary survey

Declining groundwater table and availability of drilling technologies has major implications for the cost of obtaining access to groundwater. The cost of drilling bore well is much lower in LWIA compared to HWIA because water tables are higher. Along with this, the water required by the crops is less in LWIA compared to HWIA due to cropping pattern.

The major implication of cumulative well interference is ever increasing cost. Primarily, our attempt is to estimate the cost of drilling bore wells in different situations across landholding size. Our survey results show that cost incurred on well drilling by individual farmers is quite high in HWIA compared to LWIA. In particular, cost incurred on well drilling looks quite disproportionate to landholding size (Table 10). For instance, amount spent per well located in the HWIA works out to Rs. 17152 compared to Rs. 9624 in LWIA. Further, the rate is disproportionate in in terms of landholding size as well. The current average cost of drilling per well is highest among small and marginal farmers in HWIA compared to their counter parts in LWIA. This implies that the implications of cumulative interference problem on access to resource are severe in HWIA.

Table 10: Cost of Drilling per Well Across Landholding Size

Year	LWIA		HWIA		Total	
	Total No. of farmers	Average cost per well (Rs.)	Total No. of farmers	Average cost per well (Rs.)	Total No. of farmers	Average cost per well (Rs.)
Marginal Farmer (Up to 1)	10	10978 (11)	15	21583 (46)	25	19537 (57)
Small Farmer (1.01 to 3.0)	37	9392 (55)	73	22723 (242)	110	20254 (297)
Medium Farmer (3.01 to 5.0)	26	9125 (62)	22	19220 (69)	48	14442 (131)
Large Farmer (More than 5.0)	29	9900 (104)	13	18509 (38)	42	12204 (142)
Total	102	9624 (232)	123	21573 (395)	225	17152 (627)

Source : Primary survey
Note : Figures in parenthesis indicate no. of wells (all types of wells).

Dropping water levels and competition have major implications for the types of well technology that can be used. This has had a variety of impacts. Well deepening and use of high power motors have huge impact on energy demand. Until 1990s, *yetha* was the main method of water extraction from open wells. That practice is extinct now. It was followed by pumping with low capacity (3.5 HP) pump sets. Later, with borewell technology, depending on the depth of well and horse power used. Maximum horse power used in the study area is 12.5 HP.

Such steep increase disturbed the balance between groundwater recharge and extraction resulting in decline of water levels in areas characterized by high well density. As a result of sharp and secular decline of water tables, the saturated thickness is reduced resulting in lower aquifer transmissibility. This implies that in the future even at the same rate of pumping, the rate of water table decline will be much faster. Water tables will stabilize only if pumping is reduced drastically.

Competitive deepening created incentives for use efficiency and movement away from ground water irrigated agriculture for some time. Until 1980s, open channels were used for conveying water from wells to fields. Now farmers often use underground pipelines and hose pipes. Over-ground storage tanks are common in HWIA to store water due to frequent power cuts and low voltage power supply.

5.3.2. Incidence of well failure

The total number of wells distributed across villages is given in Table 11. It is clear from the table that the total number of wells possessed was one and half times more in the case of HWIA (395) as compared to LWIA (232). It was observed that around 73% of the wells (bore wells+open wells) had failed in HWIA whereas in the LWIA the proportion of total failed wells was around 42%. Among the total failed wells, the rate of failure is high in the case of bore wells compared to open wells. For instance, in LWIA, around 89% of failed wells belong to bore well category and 11% belong to open wells. Similarly, in HWIA, the share of bore wells to total failed wells is about 58% and the share of open wells is about 42%. However, of late, all the open wells are defunct in both HWIA and LWIA.

In the LWIA, the proportion of still functioning wells is around 58% compared to 27% in HWIA. This negative externality could link with social and economic condition of the rural agrarian livelihood system. The most visible implications of well failure problem are increasing cost on additional wells, cost on well deepening, reduction in area per well and loss of gross and net income from agriculture.

Table 11: Incidence of well failure in LWIA and HWIA

Villages	Total No. of Borewells	Total No. of open wells	Completely failed borewells	Completely failed open wells	Total failed wells	Total working wells	Total wells
1	2	3	4	5	6	7	8
Adrikatte	61 (96.8)	2 (3.2)	28 (96.6)	1 (3.4)	29 (46.0)	34 (54.0)	63
Heggere	60 (96.8)	2 (3.2)	14 (87.5)	2 (12.5)	16 (25.8)	46 (74.2)	62
Huralihalli	44 (95.7)	2 (4.3)	28 (93.3)	2 (6.7)	30 (65.2)	16 (34.8)	46
Marabgatta	55 (90.2)	6 (9.8)	17 (73.9)	6 (26.1)	23 (37.7)	38 (62.3)	61
LWIA	220 (94.8)	12 (5.2)	87 (88.8)	11 (11.2)	98 (42.2)	134 (57.8)	232
Chandragiri	89 (69.5)	39 (30.5)	76 (66.1)	39 (33.9)	115 (89.8)	13 (10.2)	128
D. V. Halli	39 (75.0)	13 (25.0)	14 (51.9)	13 (48.1)	27 (51.9)	25 (48.1)	52
Garani	70 (66.7)	35 (33.3)	30 (46.9)	34 (53.1)	64 (61.0)	41 (39.0)	105
Kambadahalli	25 (64.1)	14 (35.9)	8 (36.4)	14 (63.6)	22 (56.4)	17 (43.6)	39
Madenahalli	49 (69.0)	22 (31.0)	39 (63.9)	22 (36.1)	61 (85.9)	10 (14.1)	71
HWIA	272 (68.9)	123 (31.1)	167 (57.8)	122 (42.2)	289 (73.2)	106 (26.8)	395

Source : Primary survey
Note : Figures in parenthesis indicate percentage to total wells.

5.3.2.1. Incidence of well failure across landholding size

In the HWIA, the burden of failed open well due to well interference fell equally on small and large farmers, as more than 50% of the failed wells in both categories were owned by small farmers. The ability of small farmers in bearing the burden of well failure is limited by the size of their holding, savings, re-investment and economic resilience potentials. Even if they are able to mop the capital required for additional well, they would bear greater risk of not striking (adequate) groundwater since their area is already suffering from acute well interference problems.

The proportion of bore wells owned in LWIA by small farmers is low due to the heavy investment requirement for bore wells. Our data shows that although small and marginal farmers own less number of wells in LWIA, this proportion is significantly high in HWIA. As a result, the groundwater *resource mining* is taking place.The extraction of groundwater resources is precarious in this area to the extent that even the low water required plantation crops have also gone dry due to unavailability of timely water to the crop[10]. The following are the observation from Table 12:

1. The burden of well failure is more or less equally shared by all farmers but small farmers are the first victims of *resource mining* in HWIA.
2. The burden of well failure is comparatively less in LWIA.
3. Only about 28% of the wells are working in HWIA. The proportion of working wells in LWIA is nearly 58% although the problem of interference is moving towards peak, the problem of well failure is less than that of HWIA.

Table 12: Incidence of well failure across landholding size

Landholding size (ha)	Borewells	Open wells	Completely failed borewells	Completely failed open wells	Total failed wells	Total working wells	Total wells
Marginal Farmer (Up to 1) N=10	11(100)	0(0.0)	2(100)	0(0.0)	2(18.2)	9(81.8)	11
Small Farmer (1.01 to 3.0) N=37	52(94.5)	3(5.5)	13(81.3)	3(18.8)	16(29.1)	39(70.9)	55
Medium Farmer (3.01 to 5.0) N=26	58(93.5)	4(6.5)	22(84.6)	4(15.4)	26(41.9)	36(58.1)	62
Large Farmer (More than 5.0) N=29	99(95.2)	5(4.8)	50(92.6)	4(7.4)	54(51.9)	50(48.1)	104
LWIA (N=102)	220(94.8)	12(5.2)	87(88.8)	11(11.2)	98(42.2)	134(57.8)	232
Marginal Farmer (Up to 1) N=15	27(58.7)	19(41.3)	16(45.7)	19(54.3)	35(76.1)	11(23.9)	46
Small Farmer (1.01 to 3.0) N=73	168(69.4)	74(30.6)	117(61.6)	73(38.4)	190(78.5)	52(21.5)	242
Medium Farmer (3.01 to 5.0) N=22	49(71.0)	20(29.0)	25(55.6)	20(44.4)	45(65.2)	24(34.8)	69
Large Farmer (More than 5.0) N=13	28(73.7)	10(26.3)	9(47.4)	10(52.6)	19(50.0)	19(50.0)	38
HWIA (N=123)	272(68.9)	123(31.1)	167(57.8)	122(42.2)	289(73.2)	106(26.8)	395

Source : Primary survey
Note : Figures in parenthesis indicate percentage to total wells

5.3.3. Declining water markets

Groundwater aquifers in the central dry zone are characterized by hard rocks and have low potential recharge capacity. These aquifers are mainly recharged through monsoon rainfall. Low yield levels, low storage and high risk nature of hard rock aquifers have important implications for the nature of water markets. Groundwater markets are disappearing in hard rock areas where well yields are low and often vary greatly across seasons. Surpluses are too smaller and tend to vary across seasons and locations (Janakarajan and Moench, 2006).

[10] Chandragiri - a village in Madhugiri taluk – bearing the brunt of well failure since 2003. The village was once arecanut and paddy granary, now became dry land due to water scarcity. Nearly 25 acres of areca plantation have gone dry in the village. Farmers who were realizing the problem adopted water saving methods such as drip irrigation. However, by the time they adopted such methods, entire crop area had become dry. This created a lot of debates among farmers themselves about interlinking of rivers to store water bodies such as tanks to facilitate aquifer recharge in the area. Unfortunatley nothing has happened.

Past studies on water markets have shown that since power is charged at a flat rate based on pump horsepower, marginal cost will be zero and sale of any surplus at any rate reduces average costs. In many such cases, the bargaining position of both buyers and sellers is relatively equal. Anantha and Sena's (2007) study in West Bengal reveals that diesel pump owners sell water to recover historical investment made on the equipments while electric motor owners sell to reduce annual average costs of operation and maintenance. In these situations, the bargaining power of both sellers and buyers is equal. However, the situation in hard rock areas is different from that of water abundant regions in India.

In the study area, the size of water market is insignificant and based on mutual understanding (Table 13). In most of the cases water sale is on kind transaction. Importantly, market exists between neighborhood farmers or relatives whose land is adjacent. In these instances the market operates on the basis of social obligations. Therefore, the purpose of profit maximization or reduction in average cost is negligible in all the situations.

Table 13: Distribution of Farmers by Water Selling Activity

Area	Water sale		Total
	Yes	No	
LWIA	2 [2.0] (11.8)	100 [98.0] (48.1)	102 [100] (45.3)
HWIA	15 [12.2] (88.2)	108 [87.8] (51.9)	123 [100] (54.7)
Total	17 [7.6] (100)	208 [92.4] (100)	225 [100] (100)

Source : Primary survey

Note : The figures in parenthesis indicate row and column-wise percentages to total respondents, respectively.

Increasing water scarcity poses severe threat to existence of water markets in the study area. In this situation, well owners cannot get surplus water to sell to potential buyers.

6. COPING MECHANISMS

To mitigate the groundwater scarcity problem most of the farmers adopted coping mechanisms and these mechanisms entailed sizable investments. These coping mechanisms include well deepening, additional well drilling, adoption of water saving technologies such as drip irrigation and shifting cropping pattern.

6.1 Well deepening/drilling additional wells

Well deepening or drilling an additional well is a common phenomenon in HWIA compared to LWIA. Drilling an additional well is a capital intensive mechanism adopted by large farmers (Table 14). The small and marginal farmers are constrained due to their poor capital base.

Most of the large farmers adopted coping mechanisms on a larger scale compared to small landholders. All large farmers in the area went for additional well due to the failure of previous well. More than 75% of the small and marginal farmers could venture in drilling additional well in HWIA compared to their counterparts in LWIA. The transfer of water from far off places to the arecanut garden was adopted by large farmers in HWIA[11].

The field observation during the data collection confirms that most of the small farmers who had gone for additional well, mobilized capital from their friends and relatives since institutional finance is not coming fourth[12].

[11] Few farmers in Chandragiri village are transferring water from neighboring village since 2002 to protect arecanut plantation. Initially, group of households were coming together and hiring tractors to transfer water on daily rental basis. Later, they discovered that it is not economical. Therefore, they have installed pipeline for obtaining water. However, this mechanism could not sustain due to several reasons.

[12] The other sources of capital investment on well irrigation are sale of assets such as livestock, trees (eg., eucalyptus, teak etc.) and land. Gold Mortgage was also observed. Crop loan was used for repayment of old loans by several small and marginal farmers.

Table 14: Distribution of Farmers by Drilling Additional Well

Landholding size (ha)	LWIA		HWIA		Total	
	Total No. of farmers	No. of farmers drilled additional well	Total No. of farmers	No. of farmers drilled additional well	Total No. of farmers	No.of farmers drilled aditional well
Marginal Farmer (Up to 1)	10 [40.0] (9.8)	1 [6.7] (1.8)	15 [60.0] (12.2)	14 [93.3] (12.5)	25 [100] (11.1)	15 [100] (8.9)
Small Farmer (1.01 to 3.0)	37 [33.6] (36.3)	12 [15.6] (21.4)	73 [66.4] (59.3)	65 [84.4] (58.0)	110 [100] (48.9)	77 [100] (45.8)
Medium Farmer (3.01 to 5.0)	26 [54.2] (25.5)	18 [46.2] (32.1)	22 [45.8] (17.9)	21 [53.8] (18.8)	48 [100] (21.3)	39 [100] (23.2)
Large Farmer (More than 5.0)	29 [69.0] (28.4)	25 [67.6] (44.6)	13 [31.0] (10.6)	12 [32.4] (10.7)	42 [100] (18.7)	37 [100] (22.0)
Total	102 [45.3] (100)	56 [33.3] (100)	123 [54.7] (100)	112 [66.7] (100)	225 [100] (100)	168 [100] (100)

Source : Primary survey
Note : Figures in parenthesis indicates row and column-wise percentages to total.

6.2 Adoption of Drip Irrigation

The resource conservation through water saving technologies is taking place. Table 15 shows that the drip irrigation system is a recently adopted phenomenon.

Table 15: Distribution of Farmers by Adoption of Drip Irrigation

Area	1993	1994	1997	1998	2000	2002	2003	2004	2005	2006	Total
LWIA	0 [0.0] (0.0)	1 [3.2] (100)	2 [6.5] (66.7)	1 [3.2] (20.0)	1 [3.2] (100)	3 [9.7] (60.0)	7 [22.6] (100)	6 [19.4] (75.0)	5 [16.1] (100)	5 [16.1] (83.3)	31 [100] (72.1)
HWIA	2 [16.7] (100)	0 [0.0] (0.0)	1 [8.3] (33.3)	4 [33.3] (80.0)	0 [0.0] (0.0)	2 [16.7] (40.0)	0 [0.0] (0.0)	2 [16.7] (25.0)	0 [0.0] (0.0)	1 [8.3] (16.7)	12 [100] (27.9)
Total	2 [4.7] (100)	1 [2.3] (100)	3 [7.0] (100)	5 [11.6] (100)	1 [2.3] (100)	5 [11.6] (100)	7 [16.3] (100)	8 [18.6] (100)	5 [11.6] (100)	6 [14.0] (100)	43 [100] (100)

Source : Primary survey
Note : Figures in parenthesis indicate row and column-wise percentage to total respectively.

Interestingly, in HWIA, large majority of small farmers adopted drip irrigation as a coping mechanism though it is capital intensive (Table 16). This indicates resource exhaustion and way out for them to sustain agriculture. During our field visit, we learned that a large majority of farmers have adopted drip irrigation due to crop failure because of water scarcity. It is a welcome change that they have realized the importance of water saving technologies such as drip irrigation.

In the LWIA, scarcity of groundwater forced them to adopt drip irrigation system, which is effective as a water saving technology. The farmers have been striving to give protective irrigation to coconut plantation to alleviate the moisture stress to avoid drastic fall in productivity. However, in HWIA, the method of drip irrigation is not so popular because of food crops which do not really allow drip irrigation. The irrigation method should be flow method because of paddy and other field based crops which require water to be stored to prevent weeds.

Table 16: Expenditure on Drip Irrigation by Farmers

Expenditure on drip irrigation (Rs.)	LWIA				HWIA			
	Marginal Farmers	Small Farmers	Medium Farmers	Large Farmers	Marginal Farmers	Small Farmers	Medium Farmers	Large Farmers
Less than 10000	0 (0.0)	4 (57.1)	3 (50.0)	5 (29.4)	0 (0.0)	1 (10.0)	0 (0.0)	0 (0.0)
10001 to 25000	1 (100)	2 (28.6)	1 (16.7)	3 (17.6)	1 (100)	1 (10.0)	0 (0.0)	0 (0.0)
25001 to 50000	0 (0.0)	1 (14.3)	2 (33.3)	3 (17.6)	0 (0.0)	2 (20.0)	0 (0.0)	1 (100)
More than 50000	0 (0.0)	0 (0.0)	0 (0.0)	6 (35.3)	0 (0.0)	6 (60.0)	0 (0.0)	0 (0.0)
Total no. of farmers	1 (100)	7 (100)	6 (100)	17 (100)	1 (100)	10 (100)	0 (0.0)	1 (100)

Source : Primary survey
Note : Figures in parenthesis indicate percentage to total

6.3 CHANGING CROPPING PATTERN

Nearly one-third of the respondents in HWIA changed cropping pattern as a coping strategy to over come water scarcity problem whereas this proportion is nearly one-fourth in LWIA. The changing cropping pattern is mainly due to inadequate water supply for the crops. The cropping pattern is shifting from high water intensive crops to low water intensive crops such as coconut, ragi, groundnut and sunflower. The degree of shifting cropping pattern is high among small farmers as they are not able to cope with severely declining water table. The difference between LWIA and HWIA is clearly visible in terms of cropping pattern. For instance, initially, paddy was the major water intensive crops both in HWIA and LWIA. However, with increasing problem of water scarcity it has shifted to low water intensive plantation crops, coconut in LWIA and ragi and groundnut in HWIA. The rate at which the fallow land is increasing is also high in HWIA as they cannot cope with increasing water scarcity problem.

Majority of farmers are actively adopting coping strategies. Small farmers adopted less capital intensive coping mechanisms while large farmers adopted capital intensive measures. The results from the studies by Shyamsunder (1997) and Nagaraj and Chandrashekhar (un.d.) show that to cope with well failure farmers change cropping pattern in favour of less water intensive crops, go for deepening of well and drill additional well. Further, the adoption of different conservation practices by different categories of the farmers in the groundwater overexploited area supports the hypothesis that the overexploitation of groundwater has differential impact on different categories of the farmers in terms of the conservation measures.

7. CONCLUSION

The overexploitation of groundwater is evident at different scales in the study area, posing threats to sustainability, equity and efficiency. Given the current rate of groundwater development in the overexploited area of the study, irrigated agriculture can hardly sustain. Added to this, groundwater resource status is also deteriorating leading to bankruptcy of the aquifers. The existing institutional arrangement only promoted overexploitation of aquifers and failed to generate adequate incentives for the adoption of efficient water use technologies. Thus, appropriate policy measures aimed at regulation and control of groundwater for the development of integrated groundwater and surface water system is the need of the hour. Unfortunately, LWIA is also falling into the jar of overexploitation due to mining of aquifers to sustain capital intensive cash crops.

Analytical results of the study clearly suggest the following:

1. inter well distance in relation to groundwater availability should be strictly maintained;
2. wherever cropping pattern is dominated by perennial plantation cash crops groundwater exploitation is minimum, which has dampened negative externalities of overexploitation to a large extent. For instance, cultivation of low water intensive crops itself is a coping mechanism in LWIA. Therefore, there is scope to educate farmers to adopt light water crops and irrigation literacy;
3. traditional water bodies such as tanks and streams should be efficiently managed hence, groundwater recharge can be done while extracting required quantity of groundwater for sustaining crops. Therefore, there is a need to integrate institutional and technical aspects of surface and groundwater sources that can alleviate overdraft problem;
4. water saving technologies can be promoted for high water intensive crops to increase water use efficiency and to arrest overexploitation of aquifers; and
5. the problem of inequity existing in well irrigation could possibly be addressed by promoting group investments in well irrigation where sharing the cost and benefits among the farmers are crucial. The group investment on well irrigation could possibly solve the problem of over extraction of groundwater that would encourage the principle of *more crops per drop*!

ACKNOWLEDGEMENT

This paper forms part of first author's Ph D work carried out at the Institute for Social and Economic Change, Bangalore. The authors would like to thank Prof. M. G. Chandrakanth for helping in finalizing the methodology.

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