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Costs of Resource Degradation Externalities: A Study of Groundwater Depletion in Andhra Pradesh

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Abstract

This paper looks in to the process of environmental degradation and the resultant externalities in the context of groundwater depletion in drought prone regions. The main objective here is to estimate the costs of groundwater depletion externalities and examine the costs and benefits from groundwater replenishing mechanisms in different ecological contexts. This study shows how groundwater exploitation in India is resulting in economic losses to individual farmers apart from ecological degradation. It is argued that policies towards strengthening the resource base (abatement mechanisms) and equitable distribution of the resource (property rights) would be beneficial, economically as well as ecologically.

The cost-benefit comparison is in favour of investment in replenishment mechanisms such as irrigation tanks and percolation tanks. The situation of over extraction and the resultant environmental degradation is a consequence of lack of appropriate and adequate policies (policy failure) for managing the subsurface water resources. Hither to, groundwater policies (subsidised credit, power, etc) are in the nature of encouraging private initiatives in groundwater development. While these policies helped in promoting groundwater development in the regions where groundwater development was below potential, they have led to over exploitation of the resource in fragile resource regions. On the other hand, no attempts were made (at the policy level) to strengthen the natural resource base in terms of replenishing the water table. On the contrary, groundwater development is seen as a substitute for tanks, which are the main agents of replenishment.

Key words: Environment, Degradation, Groundwater, Externalities, Costs, Andhra Pradesh, South India.

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I Background

Water is among the most ill managed resources in India, which is resulting in severe scarcity, both for drinking and irrigation, as well as environmental problems such as water logging in endowed regions and desertification in fragile regions. Of late there has been great emphasis on judicious management of water at the policy level. Market (pricing) and institutional (user participation) approaches are suggested to overcome the strident problems. However, these policy changes so far have been limited to surface irrigation. An important segment of water resources (groundwater), which covers most of the rain-fed regions (covering 2/3 of the total cropped area) of India are more or less neglected. In the absence of any effective policy measures groundwater regions are plagued with water scarcity, inequitable distribution of water and environmental degradation. The situation seems to have aggravated during the recent years, especially in the arid and semi-arid regions of the country (Reddy, 2001).

Water resources in the form of tanks, groundwater and canal water are among the important CPRs. CPRs are defined as natural or manmade resources with attributes of non-exclusion and substractability (Singh, 1994). It may be noted, however, that all the water resources may not fall strictly under the above definition in all situations. In reality, most of these resources do not represent pure forms of open access, communal or state property, as they are mixtures of these three idealised types (Berkes and Farvar, 1989). A classic example is groundwater in India. A groundwater basin is a common pool resource in the sense that exclusion of multiple users (pumpers) is difficult and costly. Groundwater tables go down, as water is extracted beyond optimum yield level (withdrawals exceed replenishing capacity of the aquifer) and may even lead to drying up of the aquifer in fragile environments. The capital intensity of groundwater extraction makes it easier to exclude rival users especially in fragile resource regions where the high cost of groundwater extraction coupled with low and inequitable asset ownership makes the resource privy to a few well-to-do households. This gives rise to 'free riding' externalities. These externalities differ in nature and intensity depending on biophysical and climatic conditions. These externalities may not be a serious problem in the absence of degradation or unlimited availability of groundwater. For, in the regions with greater groundwater potentials markets help in internalising these externalities to a large extent (Shah, 1993). On the other hand, fragile resource regions need external interventions for internalising these externalities.

This paper is an attempt to estimate the costs environmental degradation in the context of groundwater depletion and the resulting externalities. Important issues in this regard include identifying various externalities associated with groundwater depletion in fragile environments and the costs associated with these externalities. Further, the rationale for external interventions such as environmental investments in abatement mechanisms in terms of private costs and benefits are investigated. That is, costs of groundwater depletion *Vis a Vis* costs of groundwater replenishing mechanisms in fragile resource regions. This study is based on primary data collected at the household level from three villages experiencing groundwater situations. The paper is organised as follows: the following section presents the conceptual framework of the study. Section three discusses the approach of the study along with the profile of the study villages. While section four examines the externalities associated with groundwater degradation / depletion and the costs of such externalities are estimated in section five. And the last section summarises the findings and puts forth some pointers for policy.

II. Conceptual Framework

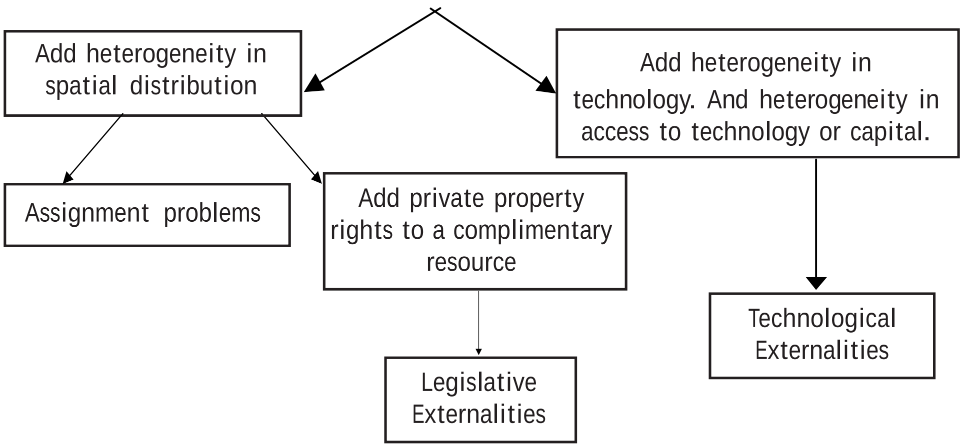
Externalities arising out of groundwater depletion could be stock related, cost related and strategic in nature (Provencher, 1998). Stock externalities arise when all the available resource stocks are exploited. In the case of renewable resources this happens when extraction rates go beyond sustainable yield rates. There is also a danger of loosing the resource permanently if the non-renewable portions of the stocks are exploited. This could result in drying up of the aquifers. Cost related externalities arise when the costs of extraction become uneconomical to exploit the resource or costs go beyond the reach of some individuals. These costs are private as well as social in nature. Private costs arise due to cost related externalities, which are mainly use values or user costs. Where as social costs arise due to stock related externalities that include use and non-use values such as protecting the resource for future generations, existence values, etc.

Externalities could take place at the intermediary level in the event of market imperfections, especially credit market. That is, in the event of inequity in access to capital across sections of the community, those who do not have access to capital will be left out of resource extraction activity due to increasing costs. These distortions in capital markets in turn give rise to strategic externalities where a few individuals with access to capital strategically capture all the available resources. This creates monopoly power in the water markets. This may be termed as technological externalities also, as the technology used to extract water is costly (Fig.1). Added to this heterogeneity in spatial distribution of groundwater creates the problem of assignment. The problem assignment is further complicated, as land (under which groundwater lies) rights are privately owned. The intertwining of private and common resources results in further externalities, which can be termed as *legislative externalities* (Fig. 1). Legislative externalities arise when there is no clear-cut legislation demarcating and protecting different property regimes. For instance, in India property rights in land may be purely individual (highly concentrated), or purely collective (attenuated) though there exist many intermediate forms between these two extremes (Bell, 1990). Legislative externalities reinforce technological externalities.

On the other hand, while groundwater is a common pool resource in which rights are limited to use and income deriving, it is also sold and transferred along with land due to its link with land. But, legislation is not clear in specifying how groundwater should be managed judiciously and distributed equitably. As a result, farmers make private investment assuming that they have absolute rights to the groundwater aquifer beneath their land. These situations arise not only due to the nature of the resource but also due to the existing institutional arrangements. For, in other situations (California, USA) a groundwater basin is treated and used as a CPR in the pure sense of the term (Ostrom, Gardner and Walker, 1994; Chapter. 13).

While negative externalities are associated with the extraction of the resource positive externalities are associated with resource investments in abatement or mitigation measures for replenishing groundwater. The positive externalities associated with resource investments are in the nature of reviving or creating water bodies such as percolation tanks / replenishment mechanisms. The positive externalities are seen in terms of recharge of groundwater through these systems. It was estimated that the recharging capacity of a normal percolation tank is about 7.87 mm/day while a de-silted percolation tank can recharge up to 20.40 mm/day (Patel, 2002). And the radius of this impact ranges from 1.1 km to 0.72 km depending on the type of soil.

Figure 1: APPROPRIATION EXTERNALITIES



Source: Adopted with modification from Ostrom, Gardner and Walker (1994).

In the context of agrarian economies these externalities affect the household utility through changes in net returns to farming. For water is the main source of irrigation and the productivity of irrigated agriculture is substantially higher than that of un-irrigated agriculture. Therefore, we conceptualise the household profit maximisation behaviour as the basis for our analysis. In the normal resource conditions household's profit function can be expressed as:

$$P_{it} = \{[P_{yt} * Y_{it}(X_{it}, D_{it-1})] - [PC_t(X_{it}, D_{it-1}) - (Z_{ct})]\} \text{——} 1$$

Where:

P_{it} = Net income or profit to HH in ith household in year t

P_y = Price of Output in year t

Y_i = Output of the ith HH

X_i= Vector of inputs

D_{t-1}= Resource degradation in the year t-1

PC_t= Production Costs

Z_t= Vector of environmental / resource investments by community / public

Objective is to maximise P_{it}, fulfilling the following conditions:

$$dP_{it}/dy > 0$$

$$d^2P_{it}/dy < 0$$

In the event of resource degradation different households face different profit functions with profit maximisation objective. These households can be grouped as resource rich and resource poor. The profit function faced by each group can be written as:

$$P_{rr} = \{[P_{yt} * Y_{rrt}(X_{rrt}, D_{rrt-1})] - [PC_t(X_{rrt}, D_{rrt-1}) - (Z_{ct})]\} \text{——} 2$$

$$P_{rp} = \{[P_{yt} * Y_{rpjt}(X_{rpt}, D_{rpt-1})] - [PC_t(X_{rpt}, D_{rpt-1} - Z_{ct})]\} \text{——} 3$$

Where, rr represents resource rich and rp represents resource poor farmers.

In the event of negative externalities:

P rr # P rp in the short run due to technological or strategic externalities, as resource rich farmers tend to appropriate more resources using their resource position while resource poor find it difficult to invest in the absence of access to credit. It may be noted that here physical degradation may be same in both the cases but only resource rich have the capacity to invest and attract extract.

P rr $\Longrightarrow$ P rp in the long run due to stock externalities. Exploitation rates exceeding sustainable yields as the resource is exhausted. Over extraction may even result in use of non-renewable part of the resource. Ultimately this would result in the tragedy of commons in the absence of cooperative strategies.

III Approach

Three villages facing groundwater degradation and water scarcity were selected from Warangal district of the Telangana region of the state[1]. These villages represent different levels of groundwater situation and reflect the overall situation in the district as well as the state. The three villages - Vanaparthy, Teegaram and Vaddicherla - represent no-scarcity (good), average and scanty (scarce) groundwater status respectively. Thus, the sample villages range from reasonably good availability of groundwater to acute shortages (including drinking water). There are no alternative sources of supply in two of the villages, while in one village an existing tank has been converted in to a percolation tank, where the water situation is much better (Vanaparthy). This village provides an opportunity to explore the linkages between surface and groundwater bodies.

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1. *This region is reported to have serious groundwater problems in the recent years.*

Table 1
Details of Sample Selection

Village	Total Area (acres)	Percentage area Irrigated	Number of Wells			Sample Size	
			Open	Bore	Total	Well-owners	Inten-sive
1. Vanaparti	3791	25	50	105	155	Census	25
2. Teegaram	2124	19	104	61	165	Census	25
3. Vaddicherla	2970	15	30	145	175	Census	25

The analysis was carried out at two levels. At the first level, well census was carried out in all the villages in order to get a complete picture of well irrigation and its status. Basic information on well irrigation was collected using a small questionnaire from all the well owners in the sample villages. At the second level, detailed information regarding various socio-economic aspects was collected using a detailed questionnaire from a sample of 25 households owning the wells. These sample households were selected using the probability proportionate (to size) sampling. Details of the sampling are presented in Table 1. The method of before and after scenarios was used in order to understand the impact of the changes in recent years. Care was taken to minimise the problems relating to memory lapse[2]. This was done through the method of cross checking at different points of interview as well as with the information collected from well census. Moreover, memory lapse was not very serious, as the collection of data is restricted to the last five years. That is, households were asked to narrate the changes in groundwater situation during the last five years.

Basic features of these villages (Vanaparthy, Teegaram and Vaddicherla) 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 except in Teegaram where the proportion of medium

2. Though using panel data over a period of time is the best to address this problem, it is beyond the scope of the study due to the time constraint.

size farmers is quite high (Table 2). There are no landless households in Teegaram village. Despite this Teegaram has the lowest average annual household income. Of the three sample villages, Vanaparthy has the highest average household income followed by Vaddicherla and Teegaram. This is mainly due to the reason that the main livelihood activity in these villages is cultivation and the main source of irrigation is well. That is, household income is dependent on the status of groundwater. And Vanaparthy has the highest proportion of its area under irrigation. Besides, the cropping pattern, which influences average household income, in these villages differs substantially.

Table 2
Socio-economic Characteristics of the Sample Villages

	Vanaparthy	Teegaram	Vaddicherla
1. No.of Households	700	350	800
2. AverageHouse-hold size	5.5	6.1	38
3. Average Farm Size	4.78	5.15	5.52
4. % area Irrigated	56	41	38
Economic Categories (% Households)			
Large Farmers	11	07	09
Medium Farmers	25	43	19
Small Farmers	29	34	25
Marginal Farmers	32	16	41
Land Less	03	0.0	06
Social categories(% Households)			
OC	29	26	25
BC	53	36	50
SC / ST	18	38	25
8. Main Occupation	Cultivation	Cultivation	Cultivation
9. Average Income (Rs./HH/year)	21900	12500	16600

Note: OC= other castes; BC= Backward castes; SC/ST= Scheduled castes and tribes.

Figures in brackets are sample size.

Status of Groundwater

Dependence on groundwater is total in all the sample villages. There are no alternative sources of water supply in two of the villages, while in one village an existing tank was converted in to a percolation tank, where the water situation is much better. In the other villages also there are tanks but fallen to disuse due to various reasons. Concentration of wells, open as well as bore, is quite high in all the villages. Proportion of households owning wells ranges from 17 per cent (Vaddicherla) to 37 per cent (Teegaram) in the sample villages (Table 3). Distribution of wells is in favour of large and medium farmers in Vanaparthy, while it is in favour of small and marginal farmers in

Table 3
Distribution of Well Owners by Economic Class and Well Type.

Land Category	Number of Households Having				
	Open Wells	Bore wells	Both	Total	% of Wells dried up
Vanaparthy [700]	43	100	9	152 (22)	45
Large Farmers [77]	13	37	7	57 (74)	48
Medium Farmers [175]	5	42	1	48 (27)	71
Small Farmers [203]	13	17	1	31 (15)	28
Marginal Farmers [224]	12	4	0	16 (07)	15
Teegaram [350]	69	40	21	130 (37)	52
Large Farmers [25]	2	1	4	07 (28)	33
Medium Farmers [50]	27	14	15	56 (37)	26
Small Farmers [119]	21	12	2	35 (29)	59
Marginal Farmers [56]	19	13	0	32 (57)	90
Vaddicherla [800]	19	108	8	135 (17)	85
Large Farmers [72]	2	11	3	16 (22)	69
Medium Farmers [152]	7	28	1	36 (24)	84
Small Farmers [200]	6	41	4	51 (25)	86
Marginal Farmers [328]	4	28	0	32 (10)	90

Note : Figures in [] indicate the total number of households. Figures in ( ) indicate the respective percentages to total number of households.

Source: Village Well Census survey.

Teegaram and Vaddicherla (only small farmers). The higher proportion of ownership among small and marginal farmers in these villages may be due to large-scale well failures / drying up among small and marginal farmers. Of late most of the open wells are converted in to bore wells by putting in-well bores, as most of the open wells have dried up and water tables have gone down substantially during the last 5 years.

During the last five years 85 per cent of the wells, mostly open wells have dried-up in Vaddicherla while 45 and 52 per cent of the wells dried-up in Vanaparthy and Teegaram respectively. Interestingly, in all the villages, except Vanaparthy, the burden of well failure was borne mainly by small and marginal farmers. In Vanaparthy where groundwater situation is reasonably good, well failure among small and marginal farmers is substantially lower when compared to large and medium farmers. That is, small and marginal farmers become the first victims of the onset of environmental degradation. This is mainly due to the location disadvantages apart from the poor quality of soils they own. For, small and marginal farmers operate on small stretches of aquifers due to their small size of holdings. In most of the regions small and marginal farmers are endowed with rocky and poor quality soils located on the ridges, where groundwater resources are limited and also difficult to extract.

The average depth of bore wells is higher in the scarcity villages. Across the size classes the variations in depth are more in the scarcity village. Bore wells owned by large farmers in Vaddicherla are deeper than that of marginal and small farmers (Table 4). These differences tend to dilute as we move to less scarcity village (Vanaparthy). However, bore wells owned by small and marginal farmers seem to irrigate less area per well is all situations. This reflects the disadvantages faced by small and marginal farmers in terms of access to the common pool resources. This is a clear case of negative externalities resulting from over extraction of groundwater.

Table 4

Depth of Wells and Area Irrigated by Wells across Size Classes

Land Category	Average Depth (in feet)		Avg. Horse - power of bore wells	Area Irrigated per bore well (acres)	
	Bore wells	Open wells		Kharif	Rabi
Vanaparthy	87 (110-200)	36 (30-50)	3.97	1.87	1.11
Large Farmers	118 (130-200)	34 (30-50)	3.00	2.50	1.24
Medium Farmers	81 (110-180)	32 (30-50)	4.28	1.87	1.03
Small Farmers	106 (110-180)	39 (30-50)	4.20	2.00	1.13
Marginal Farmers	127 (110-150)	39 (30-50)	3.67	1.11	1.04
Teegaram	116 (110-150)	45 (25-50)	3.53	1.37	0.55
Large Farmers	116 (110-130)	48 (42-50)	3.00	1.72	1.00
Medium Farmers	116 (120-130)	45 (25-50)	3.85	1.46	0.58
Small Farmers	129 (120-150)	47 (30-50)	3.92	1.32	0.37
Marginal Farmers	123 (150-150)	42 (30-50)	3.00	0.98	0.25
Vaddicherla	131 (60-300)	39 (24-60)	3.63	1.05	0.53
Large Farmers	163 (90-300)	31 (30-50)	2.89	1.23	0.87
Medium Farmers	125 (90-220)	48 (35-60)	4.57	1.23	0.51
Small Farmers	129 (60-200)	40 (30-50)	4.88	0.99	0.46
Marginal Farmers	108 (150-170)	30 (24-40)	3.00	0.76	0.28

Source: Village Well Census survey. Figures in brackets indicate range.

Besides, small and marginal farmers seem to face market disadvantages as well. Despite little variations in the depth and horse power used in the bore wells these farmers tend to spend more money per well in terms of capital costs as well as running costs towards maintenance, etc (Table 5). Running costs mainly include maintenance (repairs) costs and electricity charges. Electricity is charged flat rate per year. These annual rates are Rs. 1080 per 3-horse power motor and Rs.1320 per 5-horse power motor[3]. Variations in costs across size classes would be much higher in terms of per unit of area irrigated, as the area irrigated per well is lower on small andmarginal farms. Across the villages the capital costs range from about Rs. 26 thousand in Vaddicherla to Rs. 31 thousand in Teegaram while the

3. In April 2002 these rates were increased to Rs. 1800 and Rs. 2640 respectively.

working costs range between Rs. 2803 (Vanaparthy) and Rs. 2959. Interestingly, the per acre costs reflect the status of groundwater in the sample villages. On per acre basis both capital and running costs are the lowest in Vanaparthy (no-scarcity village) and highest in Vaddicherla (scarcity village). Perhaps the high per unit costs may be responsible for driving the farmers in to debt trap.

Table 5
Costs of Bore Well Irrigation (in rupees)

Land Category	Costs per well		Costs per acre irrigated	
	Capital	Running	Capital	Running
Vanaparthy	29073 (16000-65000)	2803 (300-500)	9756	941
Large Farmers	27787 (20000-65000)	2711 (300-5000)	7430	725
Medium Farmers	29522 (16000-60000)	2920 (600-5000)	10180	1007
Small Farmers	32555 (22000-60000)	2695 (1200-4000)	10401	861
Marginal Farmers	25500 (18000-30000)	3150 (1200-1200)	11860	1465
Teegaram	31230 (15000-65000)	2941 (1200-3000)	16266	1532
Large Farmers	24000 (20000-25000)	2060 (1200-2400)	8824	757
Medium Farmers	23694 (15000-30000)	2196 (1200-2400)	11615	1076
Small Farmers	34785 (18000-60000)	3070 (1200-5000)	20583	1817
Marginal Farmers	48153 (15000-65000)	3769(2500-5000)	39149	3064
Vaddicherla	26753 (15000-60000)	2959 (1000-10000)	16932	1873
Large Farmers	26821 (20000-40000)	2796 (1000-10000)	12772	1331
Medium Farmers	25027 (15000-40000)	2760 (1200-6000)	14383	1586
Small Farmers	28094 (17000-35000)	3015 (1500-10000)	19375	2079
Marginal Farmers	26429 (20000-60000)	3278 (1500-5000)	25413	3152

Source: Village Well Census survey. Figures in brackets indicate range.

III Resource Degradation and Externalities

Groundwater situation in the region is changing by year due to the ever-increasing pressure on the resource. In majority of the locations groundwater extraction has crossed the threshold level of maximum sustainable yield leading to drying up of swallow wells and bore well failures. This is mainly due to the mining of groundwater aquifers without improving the replenishing mechanisms. Distribution and access to groundwater is uneven and varies within a microenvironment (village). Access problems or externalities get aggravated in the light of deteriorating groundwater resources. Our sample villages provide an opportunity to understand the dynamics in terms of the impact of such degradation in diverse ecological situations. Here we examine the externalities due to groundwater depletion.

Prior to getting in to details of the cost of degradation, a household income function is estimated in order to establish the impact of groundwater degradation on agriculture production. Agriculture production is converted in to value terms due to measurement problems across crops. Ordinary least squares (OLS) estimates were carried out using the data from 426 well owners in all the 3 sample villages[4]. The estimated specification is as follows:

$$\underset{}{Yht} = \underset{(2.45)}{3682.27^*} + \underset{(10.36)}{763.88\ TLNDht^*} + \underset{(2.37)}{19.64\ DEPT^*} - 0.03\ DEPT^2 + \underset{(1.19)}{68.33\ \%AIRIht^*} + \underset{(5.19)}{}$$

$$\underset{(2.31)}{174.01\ EDUHHht^*} - \underset{(1.04)}{187.49\ HHSZEht} - \underset{(0.74)}{651.55\ VDTRM} - \underset{(1.62)}{1448\ VDVDC^{***}}$$

$R^2 = 0.34$; N= 426

Note: Figures in brackets are t values. * and *** indicate levels of significance at 1 and 10 per cent respectively.

4. Though we estimated a profit function at the crop level using the sample households the results were not significant due to the small sample.

Where,

Yht = Income in rupees of the household 'h' in time 't'.

TLAND = Total land owned by the household in acres.

DEPT = Depth in feet of the well owned by the household.

$DEPT^2$ = Squared value of the DEPT.

%AIRI = percentage of area irrigated of the household.

EDUHH = Education of the head of the household in years.

HHSZE = Size of the household in numbers.

VDTRM = Village dummy of Teegaram (average village)

VDVDC = Village dummy of Vaddicherla (scarcity village)

The estimates indicate a positive relation between groundwater depth (DEPT) and household income (Yht). Though not significant the positive sign of the square of depth ($DEPT^2$) indicates that the income is rising at a declining rate. This indicates that there is economic rationale for well deepening. But, all the farmers can't afford it due to resource constraints. Proportion of area irrigated (%AIRI) and total land (TLND) of the household has a positive impact on household income, which needs no explanation given the importance of irrigation and size of the holding. Education of the head of the household (EDUHH) has a positive impact on income indicating that better education means better use of inputs and production. As expected income levels are lower in the Teegaram (average) and Vaddicherla (scarcity) villages when compared to Vanaparthy (no scarcity) village.

Over the last five years well population (total wells) in the sample villages has gone up in all the villages though the composition of wells has changed. The extent of growth ranges from 39 percent in Vanaparthy to 68 percent in Vaddicherla (Table 6). The growth in well population does not seem to have any relation either with the status of groundwater or the rate of well failure. In all the villages the expansion of well irrigation (number of all wells) is mostly on large and medium farmers though small farmers have recorded higher rate of expansion in Vaddicherla. In all the villages there is significant decline (about 60 percent) in the number of open wells. On the other hand, number of bore wells has increased many folds in all the villages. In majority of the cases small and marginal farmers have resorted to bore wells consequent to the decline in open wells. In other words, the cost of resource degradation is mainly born by the small and marginal farmers. This coupled with their fragile resource base could explain the indebtedness in this region to some extent.

Table 6
Changes in Number of Wells, Depth and the Reasons for Change During the Last Five Years

Village/size class	% Change in number of Wells and Depth					Reasons for change (% of farmers)			
	Open wells		Bore wells		Total	1	2	3	4
	No.	Depth	No.	Depth	wells				
Vanaparthy	-61	67	400	13	39	44	44	08	28
Large Farmers	00	67	00	50	00	67	67	0	67
Medium Farmers	-80	33	@	100	100	17	17	17	0
Small Farmers	-75	87	450	11	30	30	30	10	20
Marginal Farmers	-33	80	100	00	20	83	83	0	0
Teegaram	-58	75	200	36	52	48	0	16	16
Large Farmers	00	108	75	56	75	33	0	0	0
Medium Farmers	00	108	150	36	75	43	0	14	28
Small Farmers	-83	67	450	20	50	70	0	20	10
Marginal Farmers	-50	36	300	33	20	20	0	20	20
Vaddicherla	-67	31	2700	56	68	56	0	0	28
Large Farmers	-58	36	700	41	15	44	0	11	44
Medium Farmers	-67	25	@	67	167	100	0	0	0
Small Farmers	-100	50	@	50	200	71	0	0	29
Marginal Farmers	-67	11	@	64	67	20	0	0	20

Note: Positive change in depth indicates declining groundwater table. Depth is measured in terms of availability of sufficient water below the ground level, as perceived by the farmers. However, some farmers may go deeper than this keeping long-term interests and affordability.

Source: Intensive sample survey.

Reasons: 1= Groundwater level decreased, Open wells dried-up; 2= Tank converted in to Percolation tank; 3= Neighbour farmers installed bore wells, 4= No other sources are available. Change is due to bore wells only, as the number of open wells declined over the years.

Source: Intensive sample survey.

Apart from the changing composition of wells depth of wells has increased considerably over the period of five years. Increased depth of wells means higher capital and running costs. Capital costs increase due to deepening of open wells, conversion of open wells in to in-well bores and replacement of open wells with bore wells. All the open wells have motors with 3 HP while most of the bore wells have 5 HP motors. All the sample villages experienced substantial decline in water levels in open wells during the last five years (Table 6). Since open wells usually do not cross 40-50 feet the average depth has saturated at 50 feet in all the villages. The differences in the depth during the base year have resulted in marginal changes in depth in Vaddicherla. On an average open wells have recorded about 4 feet decline in water table per year in Vanaparthy and Teegaram while it is more than 2 feet in Vaddicherla. The decline is much sharper in the case of bore wells. Depth of bore wells increased by 35 feet (7 feet per year) in Teegaram and 55 feet in Vaddicherla (11 feet per year) during the last 5 years. Where as, the increase was only 13 feet (2.5 feet per year) in Vanaparthy. This is mainly attributed to the percolation tank, as most of the bore wells have come up in the vicinity of the tank. It may be noted that as the water stress increases small and marginal farmers tend to go deeper in search of water. For, large farmers could invest in deeper wells even before the scarcity sets in. In the event of scarcity small and marginal farmers are forced to go deeper. Besides, location disadvantage of these farmers adds to their owes. However, this is not true in the case of open wells, which are labour intensive and hence small and marginal farmers are at an advantageous position due to their family labour.

The most important reason, according to the farmers, for the increase in bore wells is the declining water table and drying up of open wells (Table 6). In Vanaparthy the expansion is attributed to the conversion of an irrigation tank in to percolation tank in the recent years. The second important factor is the natural expansion, as there is no other source of irrigation. While the first reason stems out of the externality problems, trigger mechanism does not seem to be an important reason (3) for the expansion. Impact of declining water table and the drying up of open wells is reflected in the changes in the composition of wells over the period.

While declining water tables and well failure is the first and second casualties of groundwater degradation, decline in irrigated area, cropped area, shifts in cropping pattern and declining yield rates are the externalities of degradation. Despite the increase in number of bore wells and depth of the wells the area under well irrigation declined in all the sample villages (Table 7). The decline is more in terms of gross area irrigated than net area irrigated indicating that rabi (January-April) crops were affected more. Decline in net area irrigated ranged from 10 percent in Vanaparthy to 24

Table 7
Changes in Area Under Irrigation and Cropping Pattern

Village/ Size class	% change area irrigated		% change in area under crops					
	Net Area	Gross Area	Paddy		Cotton	Gingelly	All Crops	
			Kharif	Rabi			Kharif	Rabi
Vanaparthy	-10	-14	-17	-17	163	86	11	-17
Large Farmers	00	-10	-20	-28	@	@	74	-28
Medium Farmers	-18	-19	-18	-21	100	-27	-06	-21
Small Farmers	-12	-13	-20	-13	00	550	00	-13
Marginal Farmers	-03	-02	-2	00	00	00	05	00
Teegaram	-24	-24	-30	-43	37	@	-01	-43
Large Farmers	-13	-21	-33	-38	38	00	00	-38
Medium Farmers	-44	-15	-44	20	17	@	-08	20
Small Farmers	-18	-29	-18	-48	73	00	10	-48
Marginal Farmers	-20	-37	-26	-75	33	00	-11	-75
Vaddicherla	-18	-30	-22	-50	27	138	-05	-50
Large Farmers	-12	-24	-15	-52	83	100	-02	-52
Medium Farmers	-15	-31	-32	-50	00	@	-07	-50
Small Farmers	-20	-26	-20	-35	-67	00	-05	-35
Marginal Farmers	-39	-47	-39	-77	00	75	-35	-77

percent in Teegaram. Where as, the decline in gross area irrigated ranged from 14 percent in Vanaparthy to 30 percent in Vaddicherla. Size class wise variations indicate that the loss of area under irrigation is more on marginal holdings in the scarcity villages. This supports our earlier observation that small and marginal farmers suffer more as the water stress increases. It may be noted that rabi crops (gross area irrigated) are affected more in the scarcity village (Vaddicherla) when compared to kharif crops (net area irrigated). Thus, the huge costs incurred on bore wells by farmers failed to keep the area under irrigation in tact. This is mainly due to the appropriation externalities coupled with the degradation of the resource.

Paddy is the main and most preferred crop despite poor groundwater conditions in the region. Despite the adoption of high value crops like cotton, chillies, groundnut, etc., farmers still prefer paddy. Farmers are not willing to shift away from paddy (not yet) even after the recent glut in the paddy market. The reasons could be that paddy continues to be more profitable than other crops in these villages and the efforts (supervision) involved in paddy crop are much less compared to commercial crops like cotton or chillies. In fact, paddy is known as lazy man's crop. Despite high preference as well as profits farmers are forced to shift away from paddy due to water scarcity during the recent years. Farmers are shifting towards irrigated dry crops in the place of paddy. In some of the villages farmers more or less stopped growing rabi paddy. The actual shifts in cropping pattern in the sample villages are presented in Table 7. Paddy is the only rabi crop grown in the sample villages. All the villages recorded a decline in the area under rabi crop. The decline ranges from 17 per cent in Vanaparthy to 50 per cent in Vaddicherla. Even the area under kharif crops has declined in two of the villages while it has gone up in Vanaparthy. This indicates that water stress has adversely affected the net sown area. The decline is more in the scarcity village (Vaddicherla) when compared to the moderate village (Teegaram).

Paddy, kharif as well as rabi, is the main loser while dry and irrigated dry crops like gingelly, cotton, etc., have gained in terms of area allocations. Area under kharif paddy declined by 17 per cent in Vanaparthy followed by 22 per cent in Vaddicherla and 30 per cent in Teegaram. Water stress will be severe during the rabi season, which is more prominent in the moderate (Teegaram) and scarcity (Vaddicherla) villages. However, variations in water stress between kharif and rabi seasons are not much in Vanaparthy due to the presence of the percolation tank. The decline in area under paddy, especially rabi paddy, is the highest among marginal and small farmers in scarcity and moderate villages. Apart from the changes in the cropping pattern yield rates, especially paddy, have declined over the period of five years. Changes in the yield rates are attributed mainly to water scarcity in the recent years. Depending on the water stress paddy yields have declined by 4 to 16 per cent during kharif season and by 7 to 10 per cent during rabi season. Vanaparthy has recorded the lowest decline in paddy yields (Table 8).

Table 8
Changes in Yield Rates of Paddy (quintals / acre)

Village/ Size class	% changes in yields		Net Returns per acre of (in Rs.)			
	Kharif paddy	Rabi paddy	Kharif paddy	Rabi paddy	Cotton	Gingelly
Vanaparthy	-04	-07	8848 (2.6)	8797 (1.9)	—	—
Large Farmers	-00	-07	8111 (2.8)	8625 (1.5)	4812 (1.1)	3270 (4.8)
Medium Farmers	-08	-04	10186 (3.4)	9410 (2.0)	4767 (1.3)	4120 (4.7)
Small Farmers	-08	-07	7046 (2.0)	8490 (2.0)	10889 (3.5)	3110 (2.5)
Marginal Farmers	00	-17	10148 (2.5)	8660 (1.9)	—	3320 (2.0)
Teegaram	-16	-10	9577 (2.6)	7672 (2.4)	3754 (0.6)	—
Large Farmers	-14	-13	12812 (4.4)	7160 (2.1)	7688 (1.5)	—
Medium Farmers	-14	-06	9205 (2.8)	8480 (2.5)	1938 (0.3)	—
Small Farmers	-27	-17	6536 (1.4)	7975 (2.5)	-668 (-0.08)	—
Marginal Farmers	-07	-04	9755 (2.6)	7080 (2.6)	6060 (1.4)	—
Vaddicherla	-14	-08	8851 (2.7)	7755 (2.0)	4257 (0.9)	2902 (2.5)
Large Farmers	-12	-15	8698 (3.1)	5970 (1.3)	3898 (0.6)	3595 (2.6)
Medium Farmers	-10	-04	11161 (3.7)	7845 (2.5)	5842 (1.4)	3640 (2.7)
Small Farmers	-17	00	9128 (2.2)	7380 (2.0)	3031 (1.0)	2650 (2.4)
Marginal Farmers	-14	-14	6417 (2.2)	7110 (2.0)	—	1725 (2.2)

Note: Figures in brackets indicate cost-return ratios.

However, changes in cropping pattern and yield rates need not necessarily result in loss of income to the farmers. For, they may shift to more remunerative high value and low water intensive crops. But, the changes in the sample villages do not indicate any such shift, as paddy happens to be the most remunerative crop in these villages. Relative crop economics are highly favourable to paddy both in kharif and rabi seasons (Table 8). In most of the cases paddy has net returns that are double that of next most remunerative crop i.e., cotton. More importantly returns on per rupee investment (cost) are quite high for paddy when compared to cotton. This reflects the risk involved in growing these crops due to high investments. As a result, marginal farmers do not grow cotton in two of the villages. Gingelly is the second most preferred crop, which has comparable cost-return ratios with paddy. But gingelly is not as remunerative (net returns) as paddy or cotton. Therefore, shift away from paddy is a net loss to the household farm income. Resource degradation in terms of groundwater table thus adversely affects household income through shrinking of area under irrigation as well as shifts in cropping pattern.

Thus, the externalities arising from groundwater depletion can be viewed from two angles i.e., horizontal and vertical in nature. Though the type and impact of these externalities does not differ, the victims differ. Impact of resource degradation externalities that are borne by the entire community (farmers) can be termed as horizontal in nature. On the other hand, the impact seems to be disproportionately borne by the marginal and small farmers, which can be termed as vertical in nature. While mitigation measures would help solving the problem of horizontal externalities, internalising or removing technical and legislative distortions is necessary to address the vertical externalities. The crux of the problem is to understand the magnitude of the costs of externalities and whether mitigation measures are cost effective. The following section estimates the costs of groundwater degradation and compares with mitigation costs.

IV. Costs of Degradation Externalities

There are number of appropriation (negative) externalities associated with groundwater depletion. These externalities range from decline in area irrigated to drying of trees and desertification. While all these impacts are not observed in the study region, a few of the negative impacts can be quantified in monetary terms. The actual costs of externalities can be compared with the abatement costs (assuming that the impacts are not irreversible yet) for policy action. Abatement costs are the costs of converting the existing tanks in to percolation tanks that would replenish the groundwater. The positive externalities of percolation tanks are evident from one of the study villages (Vanaparthy). The difference in losses between Vanaparthy and the other two villages can be attributed to the percolation tank. This implies that there are some savings or benefits in Vanaparthy due to the positive externalities of the percolation tank. These benefits can be compared with the costs of restoring percolation tank. A part of these costs could be internalised (depending on the benefits) and a part can be borne by the state in the public interest.

Despite large private investment in groundwater exploitation the area under irrigation declined over the period of five years. Besides, the cropping pattern has shifted away from the more remunerative water intensive paddy crop to other less remunerative dry crops. As a result farmers have incurred net losses, direct and indirect costs. Direct costs include the investments made in bore wells and loss of capital due to drying up of open wells. These costs may be termed as 'sunk costs' in the case of drying up of open wells and 'replacement costs' in the case of new bore wells that have replaced the old open wells. Direct costs are one time costs and are likely to increase over time along with the drying up of open wells and increase in the number of bore wells. These costs cumulate till groundwater tables totally dry-up or go down beyond reach (too expensive). Indirect costs are those costs that are incurred due to decline in the area under irrigation (paddy) and the changes in cropping pattern. Indirect costs are recurring costs that may grow at an increasing rate as the water table goes down. Since all the irrigated area is devoted to paddy crop, indirect costs are estimated at two levels. Firstly, the loss in net returns per acre due to the decline in net sown area under irrigation. Here net returns are taken from the paddy crop, as paddy is the only crop grown under irrigated conditions. Secondly, losses due to cropping pattern changes are estimated by taking the net return differential between paddy and other crops (weighted average)[5] that replaced paddy and the decline in area under paddy are used to estimate the losses due to shifts in cropping pattern. It may be noted here that we are not estimating all the indirect costs of groundwater degradation due to lack of full information and measurement problems. Therefore, we limit our estimates to some of the prominent costs like area and crop changes, which are more relevant for private investment decisions.

The direct (sunk + replacement) costs range from Rs. 2744 per acre in Vanaparthy to Rs. 13159 per acre in Vaddicherla (Table 9). At the household level these costs are substantial ranging from Rs. 18 to 42 thousand among the sample villages. Though there is no clear pattern in these costs across size classes at the household level, on per acre basis the burden seems to be much higher on small and marginal farmers in all the sample villages. These high costs destabilise the household economy, as the withstanding capacity of these farmers is low. This is more so in the scarcity villages where burden is more coupled with the instability in crop production. Compared to direct costs the burden of indirect costs is much less, per household as well as per acre. Indirect costs range from Rs. 605 per acre in Vanaparthy to Rs. 1910 per acre in Vaddicherla (Table 10). In the case of indirect costs also the burden is disproportionately born by small and marginal farmers in most of the cases on per acre basis though the reverse is true if we look at per household losses. On per household basis these costs range from Rs. 4990 in Vanaparthy to Rs. 8173 in Teegaram.

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5. Weighted average is calculated based on the proportion of area under the crop.

Table 9
Direct (Sunk + Replacement) Costs of Groundwater Degradation (in Rs)

Village/ Size class	Open wells			Bore wells			Total Direct costs	Direct cost per house-hold	Direct cost per acre
	No.of open wells Dried up	Cost of wells	Total cost (sunk)	No.of new bores	Cost of a bore	Total cost (replace-ment)			
Vanaparthy	44	17429	766876	92	29073	2674716	3441592	22642	2744
Large	20	16739	334780	41	27787	1139267	1474047	25860	1782
Medium	17	17000	289000	37	29522	1092314	1381314	28777	4667
Small	05	18071	90355	14	32555	455770	546125	17617	5354
Marginal	02	18250	36500	0	25500	0	36500	2281	1259
Teegaram	56	19134	1071504	42	31230	1311660	2383164	18332	3831
Large	02	21667	43334	1	24000	24000	67334	9619	732
Medium	12	17278	207336	19	23694	450186	657522	11741	1889
Small	16	19696	315136	11	34785	382635	697771	19936	5673
Marginal	26	22053	573378	11	48153	529683	1103061	34471	11031
Vaddicherla	101	19725	1992225	140	26753	3745420	5737645	42501	13159
Large	11	15742	173162	25	26821	670525	843687	52730	6158
Medium	26	23752	617552	36	25027	900972	1518524	42181	10694
Small	38	19300	733400	52	28094	1460888	2194288	43025	17696
Marginal	26	20750	539500	27	26429	713583	1253083	37909	36855

Table 10
Indirect Costs of Groundwater Degradation (in Rs)

Village/ Size class	Decline in paddy area (acres)		Differen-tial Net returns* (Rs.)	Total loss (Rs.)		Total loss (Rs.)	Loss per house-hold	Loss per Acre
	Kharif	Rabi		Kharif	Rabi			
Vanaparthy	69.25	39	7007	485235	273273	758508	4990	605
Large Farmers	41	37	6154	252314	227698	480012	8421	580
Medium Farmers	22	15	8464	186208	126960	313168	6524	1056
Small Farmers	14.5	5.5	5177	75067	28473	103540	3340	1020
Marginal Farmers	.35	0	10015	3509	0	3509	219	120
Teegaram	89.75	51	7549	677523	384999	1062522	8173	1708
Large Farmers	9	7	8323	74907	58261	133168	19024	1455
Medium Farmers	86.5	10	8062	697363	80620	777983	13892	2236
Small Farmers	10.75	11.25	6761	72681	76061	148742	4250	1209
Marginal Farmers	11.5	9.75	9095	104593	88676	193269	6040	3248
Vaddicherla	21.25	92.43	7327	155691	677235	832926	6170	1910
Large Farmers	7.75	31.36	6998	54234	219457	273691	17106	2001
Medium Farmers	18.35	25.65	8798	161443	225669	387112	10753	2733
Small Farmers	13.15	16.13	8825	116049	142347	258396	5067	2091
Marginal Farmers	15	28.5	6055	90825	172567	263392	8231	7747

Note: Differential net return is arrived at by subtracting the net returns of the crops that replaced paddy from the net returns of paddy.

On the whole the total per acre costs (direct and indirect) of degradation range from Rs. 3349 in Vanaparthy to Rs. 15069 in Vaddicherla (Table 11)[6]. On both the accounts the costs are substantially lower in Vanaparthy. This is mainly due to the presence of percolation tank in this village. For, in all the villages more than 80 per cent of the respondents felt lack of proper maintenance of the tank or its low capacity as the reasons for the present status of groundwater. And the next important reason is the increased

Table 11
Total Costs (direct and indirect) of Groundwater Degradation (Rs./acre)

Village/ Size class	Costs due to groundwater degradation		Total costs (Rupees per acre)
	Direct	Indirect	
Vanaparthy	2744	605	3349
Large Farmers	1782	580	2362
Medium Farmers	4667	1056	5723
Small Farmers	5354	1020	6374
Marginal Farmers	1259	120	1379
Teegaram	3831	1708	5539
Large Farmers	732	1455	2187
Medium Farmers	1889	2236	4125
Small Farmers	5673	1209	6882
Marginal Farmers	11031	3248	14279
Vaddicherla	13159	1910	15069
Large Farmers	6158	2001	8159
Medium Farmers	10694	2733	13427
Small Farmers	17696	2091	19787
Marginal Farmers	36855	7747	44602

number of bore wells. The differential loss per acre between Vanaparthy and the other two sample villages is Rs. 2190 in Teegaram and Rs. 11720 in Vaddicherla. The magnitude of losses increases, as the farm size declines. On the other hand, the losses in scarcity and moderate villages could have

6. This methodology can be used to estimate the costs of degradation at the district level based on the changes in number of wells, open as well as bore. However, estimating the indirect costs is somewhat difficult.

been averted if there were percolation tanks in these villages. That is the differential loss is totally attributed to the absence of percolation tank. Though this seems to be a strong assumption one of the recent studies dealing with the ecological impact of tank restoration programme in drought prone areas strongly supports this view (Reddy, et. al., 2001). These differential losses or benefits are likely to increase at an increasing rate over time. However, we assume that these losses would be constant over the period of five years mainly to avoid estimation problems. These losses are comparable with the costs of renovating an existing or converting it in to a percolation tank, which ranges between Rs. 4000 to Rs. 6000 per acre depending on the size with a life of 10-15 years[7]. As it is, the incremental losses are above Rs. 1000 per acre per year in Teegaram and Vaddicherla villages. In fact, conversion of old tanks into percolation tanks is more effective as far as the impact on groundwater is concerned. Though watershed development also helps in improving groundwater table, it is long term in nature and also depends on the soil and climatic conditions. Watershed development does not necessarily generate irrigation facilities in all climatic situations especially in arid regions where average annual rainfall is below 700 mm.

Though the cost-benefit comparison of groundwater depletion vis-à-vis its abatement (replenishment) costs makes economic as well as ecological sense to invest in the replenishment mechanisms, there are no private initiatives in this direction. For, these initiatives involve collective action strategies rather than individual strategies due to the lumpy ness of the investment. Besides, collective action is a pre requisite in tank restoration and management. Such an approach calls for state intervention in order to revive and restore the traditional systems. The intervention should be more in terms of a facilitator or catalyst for collective action at the community level. Participation of local NGOs would facilitate such policy. While communities expect financial support from the state, a part of the investment can be generated at the community level through user contribution and

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7. Smaller the size higher the per acre costs. But 90 per cent of the tanks in Andhra Pradesh are smaller in size i.e., less than 100 acres of command area (Reddy, et. al., 2001).

charges. This enhances the communities stake and responsibility in managing the systems. Though this is a difficult task requiring proper institutional arrangements, it may not be an impossible task given the costs and benefits from such a programme. In fact, some NGOs have demonstrated the feasibility of high user contribution (Reddy, et. al., 2001). Such investments, private or public, would benefit the poor farmers more.

V. Public Policy and Environment

To recapitulate, exploitation and degradation of groundwater resources is progressing at an alarming rate. Small and marginal farmers, who are not in a position to access the resource, are the first victims of the externalities arising in the process of resource degradation. Even when they have the financial capability they are not in a position to compete with the large farmers in deepening their wells. As a result, the costs of groundwater degradation are disproportionately born by these farmers (vertical externalities). The impact of resource degradation on these farmers is in two ways. Firstly, while small and marginal farmers dominate the ownership of wells in general and open wells in particular, medium and large farmers dominate the ownership of bore wells. As a result of degradation majority of these farmers loose access to water. That is they are denied of their genuine share in the common pool resources. Secondly, one of the interesting observations of our study is that of late bore well technology is becoming cheaper making it size (owned land) neutral, though the process may be slow. As a result these farmers are also investing substantial amounts of money on bore wells. Such investments become unviable in the event of well failure. Besides, the poor quality of technology at lower costs is resulting in high maintenance costs and uncertainty in water supply. It is observed that groundwater markets will take care of vertical externalities (equity problems) to a large extent (Shah, 1993). But, evolution of water markets is possible only in the regions where groundwater is available in sufficient quantities. Markets do not evolve when there is not enough water to share or sell (Reddy, 2001). This is true of our study region where groundwater markets do not operate, as the available water is not even enough to irrigate the well owner’s land.

This is a clear case of appropriation externalities resulting from technological and legislative externalities. For, groundwater extraction technologies are presently expensive and beyond the reach of the small and marginal farmers. This externality is adversely affecting them in accessing groundwater. Added to this are the legislative externalities, which fail to specify the property rights in groundwater in an equitable fashion. At present, legislation does not guarantee equity in access to groundwater resources to all sections of the community irrespective of their land ownership. Moreover, there is no legislation that supports sharing of groundwater equitably. Therefore, there is strong case for internalising these externalities in a systematic fashion. One way of doing it is, to minimise the externalities (mainly horizontal) by strengthening the resource base i.e., improving the replenishing of groundwater through rainwater harvesting. Technological externalities can be addressed through making technology neutral to economic position of the farmers. This calls for policy changes towards prioritisation of surface minor irrigation (irrigation and percolation tanks) in the fragile regions as well as supporting cheaper access to technology.

The cost-benefit comparison is in favour of investment in replenishment mechanisms such as irrigation tanks and percolation tanks. The situation of over extraction and the resultant environmental externalities is a consequence of lack of appropriate and adequate policies (policy failure) for managing the groundwater resources. Hither to, policies such as subsidised credit / power / diesel are in the nature of encouraging private initiatives for groundwater development. While these policies helped in promoting groundwater development in the regions where groundwater development was below potential, they have led to over exploitation of the resource in fragile resource regions. On the other hand, no attempts were made (at the policy level) to strengthen the natural resource base in terms of replenishing the water table. On the contrary, groundwater development is seen as a substitute for tanks, which are the main agents of replenishment. In this regard State has become a mere spectator, as this process conveniently shifted the financial burden to private people.

The policy bias against the fragile resource regions is resulting in widening not only the economic inequalities but also the ecological divide between endowed and fragile resource regions. For, the neglect of resource poor regions in the provision of protective irrigation is further weakening their fragility. Even the recent policies in water management fail to take the needs of these regions in to account. Groundwater, the single most important source of irrigation, is totally left out of the purview of the water user association legislation in Andhra Pradesh. There are no efforts to integrate well and tank irrigation. While water user associations are found to be effective in the canal commands they are not serving the purpose in the case of tank irrigation (Raju, 2000 and Reddy, et. al, 2001). Unless the needs are identified and addressed effectively, fragile resource regions will face irreversible ecological problems like desertification.

Unfortunately, there are no policies so far that address the equity and management aspects of groundwater. Though there are regulations on groundwater exploitation they are inadequate and ineffective. Even the proposed new policies are in the lines of regulation[8] rather than designing innovative policies that would integrate market and institutional dimensions of resource management. Water policies should aim at integrating all sources of water in the regional context rather than treating them in isolation. Demand management is equally, if not more, important especially in the context of scarce resources, as the supplies are limited. Demand management helps in efficient and sustainable use of the resources when compared to supply regulation.

In order to internalise and minimise the impact of externalities arising in the context of groundwater depletion the following issues need immediate policy attention:

1. Integrated approach of groundwater development / exploitation with surface water bodies like tanks. These two sources of water should be treated as complements rather than substitutes. As a first step all traditional

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8. Based on the recent legislation on "Land, water and Trees" of Andhra Pradesh.

tank systems should be revived and converted in to percolation tanks wherever necessary. The benefits from such a programme would be enormous when compared to the losses due to degradation and hence it makes economic and ecological sense. Such investments would minimise the externalities, especially horizontal.

2. So far, groundwater is regulated through supply regulation of electricity rather than fixing the electricity charges appropriately. That is only 9 hours of power supply is being provided in a day in rural areas due to power shortages. Though this has helped in checking the degradation in short run it is not an efficient solution in the long run. The future prospect of surplus power coupled with subsidised power prices would aggravate the process of environmental degradation and the resulting externalities. Therefore, economic pricing of electricity with proper monitoring facilities would be more appropriate in order to internalise these externalities.

3. Institutional arrangements are required to make groundwater a common pool resource in the true sense of the term. In this regard de-linking of water rights from land rights would help addressing the equity issues effectively (vertical externalities). However, the transactions costs for enforcing such a system would be enormous. In this context the experience of some NGO (*Pani Panchayat*) experiments in the country where water rights are given even to land less households would be helpful. Similarly the experiences of countries like South Africa where attempts are being made to effectively abolish the riparian rights on water would shed some light in this regard.

4. In the event of high transaction costs involved with enforcing the separation of water rights from land rights, adding the scarcity price of water to the electricity would be appropriate. This amounts to discriminatory pricing of power depending on the status of water resources in the region. Resources generated from such scarcity rent can be diverted towards the development of the sections of the local community that are unable to have access to water for various reasons. This would not only internalise the externalities at the regional level but also minimise the adverse impacts.

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