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Wells and Illfare

An Overview of Groundwater Use and Abuse in Tamil Nadu, South India

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WELLS AND ILLFARE: AN OVERVIEW OF GROUNDWATER USE AND ABUSE IN TAMIL NADU, SOUTH INDIA

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Section -1 Introduction

India's food production in the early 1950s was around 50 million tons and it rose to around only 85 million tons in the early 1960s. Since then, food grain production has started rising quite steadily, thanks to `green revolution'. It was 100 million tons in 1971, 130 million tonnes in 1981, 176 million tons in 1991 and 200 million tons in 2000. Per capita availability of food grains also have gone up steadily over a period time from 141 kilograms per year in 1951 to 200 kilograms in the year 2000. Nevertheless, it is still a question mark whether it has resulted in the availability of food for all. The bumper crop harvests and a huge buffer stock of food grains (to the extent of about 60 million tons) appear to be promising and reassuring at the macro level; but viewing from the angle of mass poverty, growing malnutrition and hunger on the one hand, and food non-availability, lack of purchasing power and frequent occurrence of drought on the other, the piling up of food grains buffer stock decipher into nothing for those of marginalized and defenceless section of population. This calls for a critical review of Government's policy on agriculture and irrigation.

Four major interventions were made by the Government during the 1950s and the 1960s, which were instrumental in achieving self-sufficiency in the food grain production in the country. They were, (a) building up of large multi-purpose dams with a view to facilitate irrigated agriculture, (b) massive rural electrification programme by way of building up rural infrastructure, (c) introduction of high yielding varieties (HYV) technology and (d) massive rural credit programmes for capital investments such as for well digging and so on. The construction of a series of large and medium dams has certainly contributed to increase in irrigated agriculture and therefore to food production. But the HYV technology has enabled farmers to grow three short duration crops in an agricultural year. The available surface water sources were not enough for such intensive cultivation. Further, surface irrigation was found to be irregular, in adequate and at times uncontrollable. But the success of the high yielding variety seeds depended upon the availability of more assured, controlled and timely application of water. This has been an instrumental factor in the massive spread of groundwater irrigation, not only in Tamilnadu State but also elsewhere in India. The massive rural electrification programme provided a cheap energy to farmers for installing water-lifting devices. Numbers of wells and net area irrigated by wells have shot up tremendously over time in Tamilnadu, as it has happened in many other parts of the country too. However, what is interesting also is that while the number of wells have gone up over three times during the last four decades, the net area irrigated per well has come down over time. (See Table-1) This opens up an important issue of sustainability of groundwater irrigation. Several questions emerge from this information: Is it that quantity of water pumped has declined over time? Is it due to bad management of water or due to less availability of groundwater? Does it also signal competitive deepening of wells?

Table-1 Net area irrigated by sources in Tamilnadu and India, 1950-2000

Year	Total number of wells (in '000)	Net irrigated area by wells (in '000 of hectares)	Net Area Irrigated per well (in hectares)
1953-54	524	499	0.95
1963-64	674	597	0.89
1965-66	692	654	0.95
1970-71	920	755	0.82
1974-75	1134	857	0.76
1979-80	1282	1013	0.79
1984-85	1330	904	0.68
1990-91	1407	889	0.63
1992-93	1452	1027	0.71
1995-96	1485	1127	0.76
1996-97	1445	1155	0.80

Source: Season Crop Reports, Government of Tamilnadu (various years)

Additionally, the State has been instrumental in providing subsidies to groundwater irrigation in several ways, which also has contributed to the sharp growth of well irrigation in the country. The most important of them has been subsidised supply of power to agricultural pump sets, which costs the exchequer to the tune of about Rs.20 billion in the year 1999. Other subsidy schemes have been by way of cheap medium and long term loans for well digging, well deepening and for laying pipe- line connections and so on.

In the process, very little attention was devoted to revamping of and maintenance of traditional irrigation sources such as tanks and spring channels. These age-old sources played a key role not only in providing irrigation water for several centuries, but also in recharging groundwater and, thereby help preserving local ecology. At the moment, in the absence proper maintenance work, many tanks and spring channel sources have dried up and silted. In fact, many tanks and spring channels in the State have been encroached for construction work or cultivation, and in some other parts of the State (such as in the Palar basin), several of these channels are being used to let-off industrial effluent.

Therefore, while a good deal of attention was devoted in promoting groundwater irrigation, inadequate or no attention was paid to sustain this precious resource. The space constraint imposed by the lending institutions / Government has been grossly violated. A study undertaken in the Vaigai basin of Tamilnadu, indicates that there are at least three wells located within the prohibited distance from every sample well selected for the survey (Janakarajan, 1997a). Further, all the pollution abatement laws hitherto enacted, have in no way prevented pollution of water bodies – both surface and sub-surface – contributing to permanent damage to our ecology and environment.

The unregulated and over-use of groundwater has raised a fundamental question of its sustainability and the availability of this resource to our future generation. Therefore, the main motivation of this paper is to bring to light how well irrigation, instead of contributing to farmers' welfare, brings them down; in this context, the paper discusses the issues of competitive deepening of wells and over-draft of groundwater, political economy of groundwater regime and, its socio-economic and policy implications. In other words, the main focus of the paper is to analyse competitive deepening, secular lowering of water table and raising costs on the one hand and, the process of consolidation and exclusion or, to comprehend how the development of well irrigation has been instrumental in differentiating farming community and contributes to the misery of a vast majority.

There is one other dimension to groundwater development which deserves attention. Groundwater as a crucial productive resource, has almost replaced land in determining one's socio-economic and political status. The growing inequity in the availability of these resource results in deprivation and, the process of exclusion and consolidation results in poverty and hunger. In the context where, marginal and small farmers own 60% of the wells (Janakarajan, 1997a), and where, more and more wells are abandoned due to pollution and over-use, the issue of exclusion (from ownership and use of groundwater) and deprivation gains significance. A mere ownership of wells means nothing unless one strikes a good aquifer. Therefore, a mere ownership of 60% of wells by small and marginal farmers does not mean greater access to this resource. In this context, the present paper also discusses the usefulness of social dialogue towards arriving at some innovative solutions and result oriented policy interventions.

The paper organisation is as follows: Section-2 following introduction enters into a discussion on characteristics of groundwater irrigation and use; Section-3 elaborately discusses the core issue of decline in groundwater table and the issue of competitive deepening (present difference between CD and OD), estimated decline in the water table over time and per year, typologies of wells, water extracting mechanisms used, number of hours pumped, estimated quantity of water pumped in relation to estimated recharge in the region and compare the information with the official estimates; Costs of well irrigation and its relationship with the costs of surface irrigation is discussed in Section-4; While Section–5 enters into a discussion on how well irrigation is instrumental in accelerating the differentiation process in a village society, the last section provides an analytical summing up and possible policy options. This paper is based upon the data collected by the author in several river basins of the Tamilnadu State at various points of time. Particular mention needs to be made with regard to the survey conducted by the author in the Palar and Noyyal river basins of the State during the years 1997-1999 supported by the International Development Research Centre, Canada. As a part of this research, meso level surveys were conducted in 51 and 41 villages of the Palar and Noyyal river basins and detailed surveys were conducted in the 8 and 4 villages each in these two river basins respectively.

Section-2 Characteristics of Groundwater Irrigation

An analysis of characteristics of groundwater irrigation is necessary mainly because of its nature, complexity and the type of ownership rights enjoyed, which are quite contrast to traditional community managed or State managed surface irrigation systems. Therefore it is imperative that we get into some of the intricacies of groundwater irrigation, which manifests itself in social relations of production as well as property ownership. In the past, when surface water was the only source of irrigation, the single most important productive resource was land, access to which determined one's power as well as socio-economic status in a village society. The rapid growth of groundwater irrigation and declining status of traditional surface sources has resulted in emergence of groundwater as a crucial productive resource (see Graph). Therefore, in a changing context, it is the ownership of wells along with land, which determines one's status. Some of the characteristics, which we shall discuss in this section, are well density, sole and joint ownership of wells, ownership of wells across different categories of landowners, area irrigated by wells in relation to area irrigated by surface sources; crop pattern and yield performance.

2.1 Ownership of wells – Sole and Joint – across size categories of farmers

2.1.1 Sole and Joint ownership of wells

Wells in Tamilnadu are increasingly getting fragmented from sole-well ownership to joint-well ownership (many farmers sharing a well). This is of fundamental importance for understanding emerging groundwater problems and potential solutions because it has become a central point of conflict within communities and even families. It is increasing the rate of differentiation between the "haves" and "have-nots." Sometimes this is extreme – individuals often deepen their own portion of a dug well and effectively exclude other shareholders in the well from access to water. These types of conflicts complicate decision making and appear to be undermining the possibilities for consensus for sustainable use of the resource base.

Incidence of joint well ownership

As it has been indicated above, the property rights claimed over groundwater and the operation of the law of inheritance have perpetuated the problem of sub-division and fragmentation of wells into many shares along with land. As opposed to sole ownership of wells, virtually there is no database at macro level to appreciate and understand the nature and extent of joint well ownership. However, various village studies conducted in various river basins in Tamilnadu, indicate not only its magnitude, but also throw light on dilemmas and uncertainties associated with management of joint ownership of wells.

The survey conducted in 27 villages of the Vaigai river basin (in southern Tamilnadu) shows that on an average, about one-third of the total of 1100 sample wells are jointly owned (Janakarajan, 1997a). Another survey of 11 villages in the Palar river basin, on the other hand, shows a very high incidence of 47 percent of joint ownership of wells. We were able to ascertain the number of shares (or sub-divisions) in each well for different sections of farmers for 8 out of 11 village surveyed. The results have been discussed in Janakarajan, (1999).

Table 2 incidence of sole and joint wells in the sample villages selected for the meso-level survey - palar basin, 1998-99

Name of the village/ cluster	No. of villages in each cluster	Total no. of wells	Total no. of sole wells	Total no. of joint wells	Sole wells (in percentage)	Joint wells (in percentage)
Cluster-1	2	499	302	197	60.6	39.4
Cluster-2	21	2803	1779	1024	63.5	36.5
Cluster-3	5	476	270	206	56.7	43.3
Cluster-4	8	1666	681	985	40.9	59.1
Cluster-5	13	1006	427	579	42.4	57.6
Cluster-6	2	670	555	115	82.8	17.2
All Clusters	51	7120	4014	3106	56.4	43.6

Notes:

Cluster-1 - Upper reach of the basin, where the tannery effluent has not affected the water - both surface and sub-surface;
Cluster-2 - Another segment of the upper reach of the basin, where a major chunk of tanneries are concentrated;
Cluster-3 - Yet another segment of the upper reach of the basin where a large number of tanneries are concentrated;
Cluster-4 - A segment in the middle reach of the basin where tanneries and other industries are concentrated ;
Cluster-5 - Yet another segment of the middle reach of the basin where a good number of tanneries are concentrated;
Cluster-6 - 2 villages of middle reach of the basin where tanneries are not located.

Source: Meso-level survey, 1997-98

The meso-level survey carried out in the Noyyal and Palar river basins, shows a significantly high incidence of joint well ownership (see Tables 2 and 3). For instance, of the total number of 7120 wells spread over 51 villages covered for the meso-level survey in the Palar basin, percentage of jointly owned wells (for all the survey villages in the basin) works out to 43.6 %. Across clusters (of villages), it varies from 17.2% to 59.1%. Similarly in the Noyyal basin, of the total number of 14,358 wells spread over 41 villages covered for the meso-level survey, 53% of them are jointly owned. Across clusters, extent of joint well ownership varies from 31.3% to as high as 87%. Therefore, the phenomenon of joint well ownership or well fragmentation is a significant issue, which deserves due attention. It is quite striking that the number of shares in a well varies from a minimum of 2 to as many as 29 in the Palar basin and in the Noyyal basin, the number of shares varies from 2 to as many as 30. We attempted to test an hypothesis that wells not-in use are concentrated more in the case of shared wells than solely owned wells. The rationale for this hypothesis rests with the fact that the probability of occurrence of conflicts is more in the shared wells, which could render wells in disuse. Our data does support this view only to some extent. Out of 8 sample villages in the Palar and 4 villages in the Noyyal river basins, only in two villages each in the Palar (Raramanaickenpettai and Solur) and the Noyyal basins (Ugayanur and S.Avinashipalayam), the proportion of joint wells in disuse is relatively higher. However, for the Palar basin as a whole it is indicative that the percentage of joint wells in disuse is 30.4, whereas, it is only 24.7 in the case of sole ownership of wells.

Table 3 Incidence Of Sole And Joint Wells In The Sample Villages Selected For The Meso-Level Survey - Noyyal Basin, 1996-97

Name of the Village /Clusters	Number of villages in each cluster	Total no. of Wells	Total no. of sole wells	Total no. of joint wells	Sole wells (in percentage)	Joint wells (in percentage)
Cluster-1	4	1819	1250	569	68.7	31.3
Cluster-2	5	1225	781	444	63.8	36.2
Cluster-3	2	438	57	381	13.0	87.0
Cluster-4	2	510	190	320	37.3	62.7
Cluster-5	7	4610	2112	2498	45.8	54.2
Cluster-6	4	1670	325	1345	19.5	80.5
Cluster-7	6	1841	854	987	46.4	53.6
Cluster-8	6	634	335	299	52.8	47.2
Chennimalai	5	1611	829	782	51.5	48.5
All cluster	41	14358	6733	7625	46.9	53.1

Notes:
Cluster 1 : 4 Villages located along the Tiruppur - Avinashi road;
Cluster 2 : 5 Villages located along the Tiruppur - Perumanallur road;
Cluster 3 : 2 Villages located along the Tiruppur -Uthukuli raod;
Cluster 4 : 2 Villages located along the Tiruppur - Kangayam raod;
Cluster 5 : 7 Villages located along the Tiruppur - Dharapuram raod;
Cluster 6 : 4 Villages located along the Tiruppur - Palladam road;
Cluster 7: 6 Villages located along the Tiruppur - Mangalam road;
Cluster 8: 6 Villages located along the Tiruppur - Orathapalayam road;
Cluster 9: 5 Villages located around Chennimalai textile units.

Source: Meso-level survey, 1997-98

Extent of share ownership of wells across different size categories of farmers

In the next few pages let us examine the incidence and size of well fragmentation across size classes of land ownership. The whole idea of analyzing the incidence of share ownership of wells across different size classes of farmers is to understand to what extent the sharing of a well benefits an individual farmer and serves the purpose of equity in the use of groundwater. Let us first see, how the share ownership varies across size classes of farmers in the 8 sample villages of the Palar basin, selected for the main survey. (See Table-4).

Table-4 Extent Of Share Ownership Of Wells In The Palar Basin

Size class (Ac)	No.of HHs reporting	Extent of share ownership of wells							
		<0.1	0.1-0.2	0.21-0.30	0.31-0.50	0.51-0.75	0.76 0.99	1 and more	Total number of wells owned in the size class
Upto 1.0	89	15	25	15	23	0	0	14	31.7
1.01-2.0	124	1	16	17	58	1	0	39	67.8
2.01-4.0	92	7	3	7	35	2	0	53	72.3
4.01-6.0	40	0	2	7	7	1	0	35	41.1
6.01-10.0	37	0	0	5	10	1	1	29	36.4
10.0-15.0	16	0	0	0	3	0	0	19	20.5
+15.0	8	0	0	1	0	1	0	12	1.3

Source: Main survey, 1998-00

The main points emerging from this table are:

- It is striking that the average number of wells owned in each size class increases at an increasing rate as size class increases. This, in other words, conveys the message that the better access to land is associated with the better access to groundwater.
- There is a negative association between extent of land ownership and the incidence of joint well ownership. The larger landowners, along with land holdings, consolidate their shares in a well, by purchasing from other sharers.
- The incidence of ownership of a lesser fraction of a well (of less than 0.1 share in a well to 0.2 share) is quite high among the poor farmers. Therefore, the degree of vulnerability in the well ownership, in particular, those of small and tiny plot holders

Who own unmanageably small fraction in a well is such that they easily succumb to the pressure from the richer landowners. The end result, as one may anticipate, is a distress sale of one's share in a well, very often executed along with land.

In principle, share ownership of wells should augment the use of groundwater to wider sections. But given the fact that initial resource endowment is unequal, several problems crop up in pumping water from a shared well. What complicates the matter more is the social problem such as one's caste status. A large number of conflicts occur in the process of sharing of water from a jointly owned well. The practical difficulties involved in extracting water by a multiple number of sharers from a single well, happens to be the most important source of conflict. We have not gone into documenting the details of the management of jointly owned wells in each and every case in the survey villages. But the overall interviews suggest that the incidence of occurrence of conflicts is quite widespread.

The most general practice of joint well management seems to be to install a single pump set and run the motor in rotation for a fixed number of hours. The cost is shared among the sharers in proportion to number of shares they own. A frequently encountered problem, however, is the lack of cooperation among shareholders in sharing the costs as well as the available water / power supply. Unlike the case of the disintegration of the traditional tank irrigation communities, which is primarily due to the lack of motivation among the users for various reasons (Janakarajan, 1993), the lack of cooperation in the joint well ownership is primarily due to financial constraints. In such cases, those who have `not cooperated' are excluded from the use of a pump set. Even if everyone agrees to share the initial costs of installation of a pump set, many disputes occur in the using / sharing of water, thanks to the erratic power supply. Many of these disputes, though, settled by Village Panchayats (informal village courts), are not sustainable, as they crop up again in the next period of scarcity. The other way of using the water from a jointly owned well is to install individual pump sets (either electric or diesel operated) by each sharer in a same well. The joint well owners land up in serious difficulties in this method of sharing a well, as the available water is drained quite rapidly. The problem is inflamed when a sharer installs a high-powered motor in a competitive manner with a view to extract more supply. The incidence of such disputes is very high if the cultivators of different castes share a well. In many of these cases, one of the sharers, who have a better resource position, buys up the shares of the others. There have been instances in which the poor farmers sold their tiny parcels of land also along with their shares in a well.

In several cases, when shareholders have different land holding status, and if a sharer contemplates that the potential benefit after deepening goes to the others, flatly refuses to cooperate. Conflicts under circumstances are referred to the Village Panchayats again. The often-extended solution by the Village Panchayats is to divide a well in dispute physically into as many shares as needed, leaving it thereby to the individuals concerned to dig and deepen their delineated parts. Such fragmented wells are significant in number in all the villages surveyed. Although this is the widely adopted solution, it is turning out to be a dangerous one as it encourages competitive deepening even within a well and results in the emergence of wells within a dug well. Very soon, in such cases, the sharers whose resource position is weak find it difficult to survive. Eventually, one among the sharers, who is better endowed with resources, dominates the well. On the other hand, the position of the resource-poor farmers is quite vulnerable, as they are excluded from the use of a well. There are also instances in which, the wells were completely abandoned due to the prevalence of too many sharers, resulting in far too many disputes for any solution to be effective.

We have recorded the history of each joint well studied in the basin. As a matter of fact, each well when it was originally dug, was only a sole well. Subsequently, due to many reasons, sole wells have become jointly owned wells. The prime reason for the extensive prevalence of joint well ownership has been the operation of law of inheritance. When land is divided among legal-heirs, wells are also divided. Therefore, most sharers in joint well ownership are brothers and / or close cousins. In due course, however, these shares are sold to others for many socio-economic reasons. In a few cases, sole well owners due to resource constraint, have deliberately approached neighbouring plot holders to share the cost of well deepening and thereby sold a share in their wells.

While sharing of water from a joint well appears quite problematic, one cannot have any dispute with positive features of joint well ownership. The fact that a minimum of one – third of wells are jointly owned (in some villages it is as high as three-fourths), indicates the sustainability of this system. Indeed, in all the villages, there are institutionalized (informal) rules governing sharing of water from a joint well. Joint well system certainly promotes use of groundwater in a more dispersed manner. It helps in particular those who cannot afford a well of their own. Many joint wells however, fail mainly due to two main reasons, namely, declining groundwater table and two, resource constraint for deepening. These are precisely the reasons why many joint well owners became heavily indebted and eventually were forced to sell their shares along with their parcels of land. Therefore, while equity is achieved to some extent in the use of groundwater, inequality is again reinforced in village societies.

2.1.2 Ownership of wells across size categories of farmers

It is generally perceived that since well irrigation requires a big investment, only resource rich farmers could afford it. But our data refutes this belief. According to a survey of 27 villages carried out in the Vaigai basin by the present author in Tamilnadu, nearly three-fourths of wells are owned by farmers whose holding size is less than or equal to 5 acres (Janakarajan, 1997a). The detailed survey carried out in 8 villages of the Palar basin indicates that 54% of sample wells are owned by 65% of sample farmers, whose holding size is less than or equal to 4 acres; but they own together only 29% of the total land owned by all sample farmers. And, average area irrigated per well works out to 1.46 acres by this size class. On the other hand, 3% of sample farmers, whose holding size is more than 15 acres, own 8% of the sample wells; but they own together 19% of total land owned by all sample farmers. And, average area irrigated by per well in this size class works out to 26 acres. These information shows the extent to which polarisation exists among well owners and in the use of groundwater (see Table 5).

One may ask, to what extent it is rational to classify the sample well farmers according to size classes of land ownership. This is important because to get some new insights into the characteristics of well owners and their access to groundwater. For instance, a simple fact of the matter 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 larger land owners compared to smaller ones: For instance, all those respondents who owned wells successfully stayed in the race of competitive deepening or appeared to be sustaining. But it is imperative to ask for how long will they sustain the problem of competitive deepening? In this context it is important to note that while the threat of getting eliminated from the race of competitive deepening is seemingly just around the corner for the resource-poor farmers, the resource rich farmers have the capability of sustaining the adverse of effects of competitive deepening and drought. This is simply because the resource-rich farmers are not constrained in the same degree as resource-poor farmers in mobilizing finance for well digging or well deepening activities. This is one of the main reasons why it is necessary to study the relationship between well and land ownership.

Table-5 Ownership Of Wells Across Size Classes Of Landholding In The Palar Basin

Landholding size (in acres)	Number of well owners	Total number of wells owned	Total extent of land owned / irrigated (acres)	Average extent irrigated per well (acres)
Less than 1.00	26	29	16.7	0.64
1.01-2.00	64	86	101.7	1.59
2.01-4.00	67	100	193.9	2.89
4.01-6.00	28	43	140.8	5.03
6.01-10.00	35	75	257.7	7.36
10.01-15.00	14	35	173.8	12.42
15.01-25.00	5	13	97.0	19.40
25.00+	3	17	111.1	37.04
Total	242	398	1092.7	4.52

Source: Main survey, 1998-00

There is another dimension to look at this issue. Small landowners owning larger number of wells, at the surface appears as though groundwater irrigation is quite diffused across farming community. What is however underneath is the unpopular story of the underprivileged: As it has now been well established, the success of the HYV technology in a great measure attributed to the massive development of well irrigation. In this setting, the large farmers perhaps have struck groundwater quite early, who in the process, have not only exploited groundwater much early on the day, but have done substantial damage by draining aquifers. Therefore, poor farmer – well owning households though appear to own large number of wells, are indeed latecomers. They are trapped in a regime in which water table is retreating progressively. Their position is quite vulnerable for, in order to be able to remain in the race of competitive deepening, they have to keep investing in well deepening activities without any assurance of striking an aquifer. While some are successful in striking groundwater, a large majority fails. In the process they are pushed into a debt trap. We shall get back to this issue in a later section.

2.2 Linkage between surface and groundwater

Inter-relationship between surface and groundwater is yet another important characteristic, which deserves some discussion, more so in the particular context of the Palar basin which is known for its rich river bed aquifer (RBA). It contributes substantially to spring channels and also to thousands of wells located along the riverbed. But pumping of groundwater in the prohibited areas (such as in the riverbeds or in their neighbourhoods) results in, either drying up of the surface water bodies or results in the reduced flow in the down stream or both. Over 200 mld of water is pumped from the Palar riverbed for drinking and industrial purposes. It has resulted in the drying up of thousands of age-old spring channels, which used to originate from the river. These spring channels were a rich a source of irrigation for at least one full crop. While there are clear data on the number of spring channels that existed in the past, there used to be at least one such spring channel for each village located along the riverside. Thousands of such spring channels reported to have existed in the village records. But most of these at present have dried up and encroached upon. As a part of the current research, a meso-level survey was conducted in 51 villages of the Palar basin. We identified 35 villages where the spring channels are practically defunct. While in six villages they are found to be less effective, in three villages they seem to be somewhat effective. In several villages the spring channels have been taken over by the tanneries for discharging industrial effluent. These are the defunct spring channels, which served a very useful purpose in the past by way of contributing towards the prosperity of farmers. It looks catastrophic at present not only for the village but for its neighbourhood too. Since these springs pass through many interior parts of villages, even groundwater is heavily polluted.

The most glaring illustration, however, is the unregulated pumping of groundwater in the tank commands. Evidently, since the wells located in the tank commands are quite significant in number and since these wells derive most of their supplies through seepage from the tanks, the tank as an important source of irrigation is losing its place. (Vaidyanathan and Janakarajan, 1989). The rapid spread of well irrigation, accompanied by the large scale rural electrification and the introduction of the high yielding bio-chemical technology, have contributed in a great measure, for the rise of the conflicting interests in the use of ground and surface waters. Since the high yielding varieties required more assured, controlled and timely application of water and since the available tank water was inadequate to raise three short duration - HYV - crops, the growth of well irrigation in the tank commands became inevitable. Furthermore, some studies indicate a positive correlation between the rapid growth of well irrigation and the decay of traditional tank irrigation systems such as tanks (Janakarajan, 1993). Lindberg (1996) in his paper shows, how an individual rationality conflicts with collective rationality, which eventually results in the erosion of common property resources. An individual rationalizes his disassociation from the collective action of tank / canal maintenance and resorts to indiscriminate pumping of groundwater, resulting in the progressive lowering of the water table. The government's policy of supplying free electricity to the agricultural needs has aggravated this problem. The net result is the general environmental degradation in which not only that the water table has been progressively declining, the wells are not adequately recharged due to the drying up of the surface water bodies such as tanks. The traditional irrigation institution was found to be defunct in 6 out of the 17 tanks studied in the Palar Anicut System. These were also the tank commands in which well density was quite high. In one of the tanks, the tank sluices were kept closed permanently with a view to facilitate recharge into the wells located in the tank commands. On the contrary, in the rest of the tanks, the traditional irrigation system was reasonably unimpaired but these were also the tank commands in which the well density was very low (Vaidyanathan and Janakarajan, 1989, Janakarajan, 1993). A similar result was obtained in a large scale study, undertaken in the Tamilnadu Agricultural University (Palanisamy, Balasubramanian and Mohamed Ali, 1996). The close association between a high well density and the disintegration of the tank system has also been in conformity with several other village studies carried out in Tamilnadu (Harriss, 1982, Janakarajan, 1986, Chinnappa, B.Nanjamma, 1977, Janakarajan, 1997b). However, another study on tanks in the Periyar-Vaigai system does not confirm this point of view. (Vaidyanathan and Sivasubramaniyan, 1998). This study shows that the spread of well irrigation in the tank commands does not lead to a total collapse of the tank institution although its degree of effectiveness varies according to well density.

The meso-level survey conducted in 51 villages of the Palar basin indicates that there exists a close association between well density in the command area of tanks and springs (traditional irrigation sources) and their declining role. Information provided in Table 6 shows that in almost all the villages surveyed, the well density is found to be much higher than expected even in the villages where tank irrigation institution is reported to be somewhat alive. This is because dependability of tank water is quite low and the degree of risk and uncertainty were high. Therefore, with a view to get access to more assured irrigation, many farmers have invested on wells. The tanks, if at all, serve the purpose of percolation ponds in most of these villages. Indeed, access to private source of irrigation (wells) has provided generous disincentive to farmers for non-cooperation in the collective action of tank and spring channel maintenance. At one level, one might argue that pumping of recharged groundwater is a more efficient way of using water. In fact, in several villages, the better off farmers (multiple well owners) find it convenient and useful to close down the sluices of tanks so that the impounded tank water provides constant recharge to their wells. But, in many cases, since there is absolutely no maintenance of inlet channels, tanks and springs remain virtually silted and abandoned and stores very little water. Such a state of condition is not only distressing but contributes to the misery of non-well owners who were solely dependent upon tank water.

Table 6 Well Density In The 51 Villages Of The Palar Basin

Cluster	No. of villages	Total extent of land in the villages (hectares)			Total number of wells in the villages			Well density (well per hectare)		
		Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total
1	2	230	779	1009	153	346	499	0.67	0.44	0.49
2	21	902	4589	5491	596	1808	2404	0.66	0.39	0.44
3	5	262	494	756	170	306	476	0.65	0.62	0.63
4	8	887	1719	2606	784	1013	1717	0.79	0.59	0.66
5	13	2037	2567	4604	668	767	1435	0.33	0.30	0.31
6	2	1290	562	1771	475	238	713	0.39	0.42	0.40
All	51	5526	10710	16236	2766	4478	7244	050	0.42	0.45

Source: Meso-level Survey, 1997-99

Section 3 - Area Irrigated, Crop Pattern And Yield

First of all, it is necessary to underline the fact that the Palar and Noyyal river basins are under severe stress not only due to over-use but also due to pollution. Therefore, it is necessary to view the issues of area irrigated, crop pattern and crop yields in this context. Water yielding characteristics and area irrigated by the wells varies between those villages, which are affected by industrial effluent and those, which are not. For instance, average net irrigated area (NIA) and gross irrigated area (GIA) per well in the non-affected villages are 4.16 acres and 5.94 acres per well respectively; whereas, in the affected villages, this average works out to 2.72 and 5.50 acres per acre (See Table 7). It is more striking when we compare the area irrigated under paddy in both sets of the villages: Total area irrigated by all crops by the sample wells in the selected villages works out to 903 acres of which 505 acres (56%) contributes to paddy. Over 90% (456 out of 595 acres) of it is grown only in the unaffected villages. It works out to 2.9 acres of area irrigated per sample well under paddy in the unaffected villages in contrast to only 0.50 acre per sample well in the affected villages. As may be seen from the table, the area under sugarcane and coconut (which tolerate reasonably the polluted water) are more compared to paddy in the affected villages. However, in the case the Noyyal river basin, one hardly finds any difference between the affected and unaffected villages (Table 8). Since paddy is cultivated only in a restricted area in both the sets of villages and since all other crops cultivated in this area such as coconut, cotton and pulses tolerate salts and other pollutants to some extent, there is no big difference in the area irrigated per well as well as in crop pattern.

Table 7 Area Irrigated By Sample Wells By Crops In The Palar Basin

Village	No of sample wells Wet + Dry	Net area irrigated by the sample wells by crops (acres)							
		Paddy	Sugar Cane	Coco-nut	Oil seeds	Others	Total	NIA / well	GIA/ well
Kathia-vadi	40	86	8	12	14	12	131	3.28	4.50
Damal	49	324	14	0	13	2	353	7.20	7.78
Ramanaic-Kenpettai	42	5	1	48	0	2	56	1.33	3.71
Nariam-pattu	26	41	1	43	0	28	113	4.35	8.27
Sub-total	157	456	24	103	27	44	653	4.16	5.94
Peria-varigam	30	4	7	54	0	10	75	2.5	6.67
Solur	21	2	0	23	0	15	40	1.9	5.14
Poondi	22	37	22	0	7	0	66	3.0	4.91
Gudimallur	19	7	45	8	4	5	69	3.63	4.74
Sub-total	92	49	74	85	11	30	250	2.72	5.50
Grand total	249	505	98	188	38	74	903	3.63	5.78

Source: main Survey, 1998-00

Table 8 Area Irrigated By Sample Wells By Crops In The Noyyal Basin

Village	No of sample wells	Net area irrigated by the sample wells by crops (acres)							
	Wet + Dry	Paddy	Sugar Cane	Co-conut	Cott-on	Others	Total	NIA / well	GIA/ well
SA Palayam	54	1	0	47	11	112	171	3.15	5.00
Ugaya-nur	59	20	0	28	9	106	163	2.76	4.25
Sub-total	113	21	0	75	20	218	334	2.96	4.61
Orathu-palayam	20	0	0	16	25	33	74	3.70	5.30
Karai-pudur	48	13	0	34	15	55	117	2.44	2.84
Sub-total	68	13	0	50	40	88	191	2.81	4.40
Grand total	181	34	0	125	60	306	525	2.90	4.53

Source: Main Survey, 1998-00

The scarcity induced due to over-use of groundwater and pollution, come out clearly from Tables 9 to 12. For instance, area irrigated per well is nil in about 33% (in 80 out of 253 sample wells) and 28% (80 out of 253) of the sample wells in the Palar and the Noyyal river basins respectively. The difference is quite sharp between affected and unaffected villages - 26% (41 out of 159 sample wells) in the unaffected and 41% (39 out of 94) in the affected villages of the Palar basin, and 25% in the unaffected (i.e., 28 out of 112 sample wells) and 34% in the affected villages (i.e., 23 out of 68 sample well) of the Noyyal river basin report zero area irrigated (Tables 9 and 10).

Table 9 Gross Irrigated Area By The Sample Wells In The Selected Villages Of The Palar Basin

GIA by the sample wells (acres) Frequency	**Number of wells reporting in various frequencies of GIA in various villages**										
	KYD	DML	RNP	NMP	Sub Total	PVG	SLR	PND	GDR	Sub total	TOTAL
Nil	8	13	17	3	41 (25.8)	17	13	2	7	39 (41.4)	80 (32.6)
0.01-1.00	2	0	2	0	4 (2.5)	0	0	1	0	1 (1.1)	5 (2.0)
1.01-5.00	17	9	12	8	46 (28.9)	4	2	11	7	24 (25.5)	70 (27.7)
5.01-10.00	11	13	8	8	40 (25.2)	2	0	5	3	10 (10.6)	50 (19.8)
10.01-20.00	2	11	4	4	21 (13.2)	5	4	3	2	14 (14.9)	35 (13.8)
20.00+	1	3	0	3	7 (4.4)	4	2	0	0	6 (6.4)	13 (5.1)
Total	41	49	43	26	159 (100)	32	21	22	19	94 (100)	253 (100)

Notes:
Un-affected villages: KYD - Kathiyavadi; DML - Damal ; RNP - Ramanaickenpatti; NMP - Nariampattu
Affected villages: PVG - Periavarigam; SLR - Solur; PND - Poondi; GDR - Gudimallur;
(Source : Main survey, 1998-00)

Table 10 Gross Irrigated Area By The Sample Wells In The Selected Villages Of The Noyyal Basin

GIA by the sample wells (acres) Frequency	**Number of wells reporting in various frequencies of GIA in various villages**						
	SAP	UGR	Sub total	OPM	KPR	Sub total	Grand Total
Nil	14	14	28 (25.0)	7	16	23 (33.8)	51 (28.3)
0.01-1.00	2	5	7 (6.3)	0	5	5 (7.4)	12 (6.7)
1.01-5.00	22	19	41 (36.6)	6	15	21 (30.9)	62 (34.4)
5.01-10.00	6	13	19 (17.0)	3	6	9 (13.2)	28 (15.6)
10.01-20.00	9	5	14 (12.5)	4	4	8 (11.8)	22 (12.2)
20.00+	1	2	3 (2.7)	0	2	2 (2.9)	5 (2.8)
Total	54	58	112 (100.0)	20	48	68 (100.0)	180 (100.0)

Notes:
Un-affected villages: SAP: South Avinashipalayam; UGR: Ugayanur
Affected villages: OPM: Orathapalayam; KPR: Karaipudur
(Source: Main survey, 1998-00)

Such difference in the area irrigated by wells between affected and unaffected villages reflects very much on the crop yields (Tables 11 and 12). About one-third of the sample well farmers in both the river basins reported zero crop yield. Again this difference is quite high between the affected and unaffected villages. While in the affected villages, 43% of the sample well farmers reported zero crop yield, it is 28% in the unaffected villages. But in both types of villages, incidence of sample well farmers reporting zero yield is quite significant; While in the case of unaffected villages, zero yield is because over-use, in the affected villages it is primarily due to severe water contamination. Similarly, the incidence of wells (sample well farmers) reporting higher crop yields is quite high in the unaffected villages (in both the basins) compared to the wells in the affected villages due to pollution. For instance, 79 out of 159 sample wells (50%) and 60 out of 112 sample wells (54%) in the unaffected villages of the Palar and Noyyal river basins respectively reported more than Rs.5000 value of crop yield per acre; whereas in the affected villages, only 16 out of 94 sample wells (17%) and 11 out of 68 sample wells (16%) respectively in the Palar and Noyyal river basins reported more than Rs.5000 as the value of crop yields per acre. The most important fact that needs to be underlined is that small operators of land who own wells, operate their wells with either poor water yields or pump a bad quality of water; whereas, the large farmers manage to sustain better by digging new wells or deepening the existing wells or both.

Table 11 Crop Yields Per Acre Of Area Irrigated By The Sample Wells In The Selected Villages Of The Palar Basin

Yield per acre of GIA (Rs) Frequency	**Number of wells reporting in various frequencies of crop yields in the selected villages**										
	KYD	DML	RNP	NMP	Sub Total	PVG	SLR	PND	GDR	Sub total	TOTAL
Nil	8	13	19	4	44 (27.7)	18	13	2	7	40 (42.6)	84 (33.2)
<500	0	0	0	0	0 (0.0)	0	0	0	0	0 (0.0)	0 (0.0)
501-1000	1	0	0	0	1 (0.05)	2	0	0	1	3 (3.2)	4 (1.6)
1001-2500	2	0	3	0	5 (3.1)	5	5	0	2	12 (12.8)	17 (6.7)
2501-5000	5	0	14	11	30 (18.9)	6	3	10	4	23 (24.5)	53 (20.9)
5001-10000	21	15	6	11	53 (33.3)	1	0	9	5	15 (16.0)	68 (26.9)
10000+	4	21	1	0	26 (16.4)	0	0	1	0	1 (1.1)	27 (10.70)
Total	41	49	43	26	159 (100)	32	21	22	19	94 (100.0)	253 (100)

Notes:
Un-affected villages: KYD - Kathiyavadi; PND - Poondi; GDR - Gudimallur; DML - Damal
Affected villages: PVG - Periavarigam; SLR - Solur; RNP - Ramanaickenpatti; NMP - Nariampattu
(Source: Main survey, 1998-00)

Table 12 Crop Yields Per Acre Of Area Irrigated By The Sample Wells In The Selected Villages Of The Noyyal Basin

Yield per acre of GIA (Rs)	Number of wells reporting in various frequencies of crop yields in the selected villages						
Frequency	SAP	UGR	Sub total	OPM	KPR	Sub total	Grand total
Nil	18	15	33 (29.5)	7	17	24 (35.3)	57 (31.7)
<500	1	0	1 (0.9)	0	3	3 (4.4)	4 (2.2)
501-1000	2	2	4 (3.6)	0	1	1 (1.5)	5 (2.8)
1001-2500	2	5	7 (6.3)	3	8	11 (16.2)	18 (10.0)
2501-5000	7	0	7 (6.3)	7	11	18 (11.8)	25 (13.9)
5001-10000	11	14	25 (22.3)	3	6	9 (13.2)	34 (18.9)
10000+	13	22	35 (31.2)	0	2	2 (2.9)	37 (20.6)
Total	54	58	112 (100)	20	48	68 (100)	180 (100)

Notes:
Un-affected villages: SAP: South Avinashipalayam; UGR: Ugayanur
Affected villages: OPM: Orathapalayam; KPR: Karaipudur
(Source: Main Survey, 1998-00)

Section 4 - Progressive Lowering Of Water Table, Cmpetitive Deepening And Its Socio-Economic Implications

Rapid expansion of groundwater irrigation has resulted in the steady decline of water table in several parts of the country. It is cautioned that the pumping rates exceed the recharge and that the secular lowering of water table has resulted in the mining of water (see for instance, Bhatia, 1992, Rao 1993, Moench 1992, Vaidyanathan 1996, Janakarajan 1997a). Competitive deepening and emerging conflicting interests among well owners surface precisely in this context. Since the conflicts among well owners manifest in the progressive lowering of the water table, it is necessary in the first instant, to ascertain the extent to which groundwater table has declined over a period of time in the selected river basins.

A more appropriate way of ascertaining the secular lowering of water table is to measure over a period of time the actual the depth of wells, depth to water table and volume of water extracted. But this kind of information is not available from any published source nor is it possible to capture through any survey. Therefore, an attempt was made in the selected river basins to get an idea on the extent of decline in the water table through an indirect method. The methodology adopted was quite simple. Two important information were sought from each sample well owner, namely, (a) what was the depth of the well when it was originally dug? Or what is referred to as the `original depth' (OD) and (b) what was the depth of the well at the time of the survey? Or what is referred to as the `current depth' (CD). The difference between the OD and CD for any given well, illustrates the extent to which water table has declined over a period of time. Indeed, this study indicates that in the case of the sample wells located outside the canal and tank commands, the decline of water table is even more rapid. A careful analysis of this data conveys one crucial point: the OD of the sample wells dug at different points of time increase over time, which implies that a `new comer ' has to have a well deeper well than what his predecessor had, say, 10 years ago (see Janakarajan 1997a).

Tables 13 and 14 illustrate this point respectively for the Palar and the Noyyal river basins as a whole. It is seen from these tables that in both the river basins, there exists a vast gap between original and the current depths. For instance, in the Palar basin, 141 wells (or 59.5% of sample wells) reported <30 feet as their original depth. But as per the current depth, only 85 wells (or 36%) reported it as their current depth. In other words, 56 wells (or 24% of the sample wells), which reported < 30 feet as their current depth, have moved on to a higher depth range at the time of the survey. Similarly, only 6 wells (or 2.5% of the sample wells) fell in the depth range of 61-80 feet as per the original depth, but as per the current depth, the number of wells reporting in this depth range moved up to 29 (12.4%). This difference between the original and the current depths is much more significant in the case of the Noyyal basin.

*Table-13 Depth-Wise Distribution Of Sample Wells As Per Their Original And Current Depths In The Palar BasIN (Excluding The Depth Of The Vertical Bores)***

Depth Range (in feet)	Original Depth		Current Depth		(4) - (2)	%age variation
	No of wells	Per cent	No of wells	Per cent		
1	2	3	4	5	6	7
<30	141	59.5	85	35.9	-56	-23.6
31-40	53	22.4	51	21.5	-2	-0.8
41-50	23	9.7	35	14.8	12	5.1
51-60	13	5.5	31	13.1	18	7.6
61-80	6	2.5	29	12.2	23	9.7
81-100	1	0.4	4	1.7	3	1.3
101+	0	0.0	2	0.8	2	0.8
Total	237	100.0	237	100.0		

*** Information presented in this table is the summary data for 8 sample villages in the basin; it includes wells located both in the wet and dry lands.*
Source: Main survey 1998-00

*Table-14 Depth-Wise Distribution Of Sample Wells As Per Their Original And Current Depths In The Noyyal Basin (excluding the depth of the vertical bores)***

Depth Range (in feet)	Original Depth		Current Depth		(4) - (2)	%age variation
	No of wells	Per cent	No of wells	Per cent		
1	2	3	4	5	6	7
<30	46	26.9	12	7.0	-34	-19.9
31-40	55	32.2	21	12.3	-34	-19.9
41-50	45	26.3	38	22.2	-7	-4.1
51-60	18	10.5	51	29.8	33	19.3
61-80	6	3.5	41	24.0	35	20.5
81-100	1	0.6	4	2.3	3	1.8
101+	0	0	4	2.3	4	2.3
Total	171	100.0	171	100.0		

*Note: **Information presented in this table is the summary data for 4 sample villages in the basin. (Source: Main survey 1998-00)*

Moreover, if the depth of the vertical bores installed beneath the dug wells are included into this calculation, the scenario one gets is more drastic (see Tables 15 and 16 respectively for the Palar and the Noyyal basins). For instance, the number of sample wells fell in the highest depth range of 101+ feet as per the original depth, were 4 wells (or 1.6 % of the total number of sample wells) in the Palar basin and 10 wells (or 5.5 of the total number of sample wells) in the Noyyal basin. But as per the current depth, this number has dramatically moved up to 35 (14.3 % of the total) and 57 (31.5% of the total) in the Palar and Noyyal basin respectively. The data presented in the Tables 13 to 16 besides reconfirming the fact of drastic drop in the groundwater table testifies also that wells have been deepened in a competitive manner over a period of time.

*Table-15 Depth-Wise Distribution Of Sample Wells As Per Their Original And Current Depths In The Palar Basin (including the depth of the vertical bores)***

Depth Range (in feet)	Original Depth		Current Depth		(4) - (2)	%age variation
	No of wells	Per cent	No of wells	Per cent		
1	2	3	4	5	6	7
<30	142	58.2	70	28.7	-72	-29.5
31-40	53	21.7	37	15.2	-16	-6.6
41-50	23	9.4	27	11.1	4	1.6
51-60	13	5.3	15	6.2	2	0.8
61-80	7	2.9	30	12.3	23	9.4
81-100	2	0.8	30	12.3	28	11.5
101+	4	1.6	35	14.3	31	12.7
Total	244	100.0	244	100.0		

*** Information presented in this table is the summary data for 8 sample villages in the basin; it includes wells located both in the wet and dry lands.*
Source: Main survey 1998-00

*Table-16 Depth-Wise Distribution Of Sample Wells As Per Their Original And Current Depths In The Noyyal Basin (including the depth of the vertical bores)***

Depth Range (in feet)	Original Depth		Current Depth		(4) - (2)	%age variation
	No of wells	Per cent	No of wells	Per cent		
1	2	3	4	5	6	7
<30	46	25.4	11	6.1	-35	-19.4
31-40	54	29.8	19	10.5	-35	-19.4
41-50	45	24.9	28	15.5	-17	-9.4
51-60	18	9.9	37	20.4	19	10.5
61-80	7	3.9	25	13.8	18	9.9
81-100	1	0.6	4	2.2	3	1.7
101+	10	5.5	57	31.5	47	26.0
Total	181	100.0	181	100.0		

*Note: ** Information presented in this table is the summary data for 4 sample villages in the basin.(Source: Main survey 1998-00)*

As indicated earlier, the original and current depths of the wells dug at different points of time indicate that the new comers have to invest in deeper wells compared to those who dug say a decade ago. The aggregate information for the Palar basin as a whole on the basis of 238 sample wells (for which we have obtained information) spread over 8 sample villages in both wet and dry lands indicates that there has been a secular lowering of water table and that newcomers have to dig deeper wells. For instance, the average original depth of the sample wells dug before 1960 was 30.2 feet. It rose to 35.8 feet for those wells, which were dug during 1961-1970; It further went up to 41 feet for those which were dug during 1971-1985. And finally, the original depth of those wells, which were dug after 1985, has moved further to 69 feet. Similarly, in the case of the Noyyal basin, we have information for 101 sample wells spread over four villages. The average original depth of the sample wells dug before 1960 was 42.6 feet. It rose to 48 feet for those wells, which were dug during 1961-70; It further rose to 59 feet for those wells which were dug during 1971-85; And finally, the average original depth of those wells, which were dug after 1985 has moved upward to 66 feet. In the Noyyal basin, the depths of the vertical bores are more prominent unlike the case of the Palar basin. The average original depth up to which vertical bores were installed in the basin were zero, 100 feet, 170 feet and 260 feet respectively by the sample wells dug during the periods before 1960, 1961-70, 1971-85 and after 1985. Roughly, annual decline of the water table works out to 1.5 feet in the Palar basin, whereas it works out to about one foot in the Noyyal basin. In the Noyyal basin, (since installation of vertical bores are more prominent), if the annual decline in the water table is calculated on the basis of the depth up to which bores were installed, then the annual decline in the water table works out to about 10 feet.

The original and the current water lifting devices (WLD) used in the sample wells also indicate the competitive nature of well digging in the river basins under study. For instance, in the Palar basin, of the 253 sample wells surveyed, 191 reported *kavalai* (bullock bailing lift) as the original WLD, which has been reduced to one as per the current WLD reported at the time of the survey (that too not in use) . Similarly, out of 181 sample wells in the Noyyal basin, while 121 wells reported to have used k*avalai* as the original WLD, only one well reported to be using still *kavalai* as the WLD. In other words, all the sample wells had to shift to mechanized pumping technology over a period of time, as manual or animal lift proved to be virtually impossible beyond around 30 feet depth. It is also interesting to note that the number of wells with no WLD has gone up considerably over time, from 3 (as per the original WLD) to 71 (as per the current WLD) in the Palar basin and nil to 19 in the Noyyal basin. These are the wells, which are deepened but abandoned either due to lack of water supply or due to bad quality of water.

The significant issue that needs to be noted in the present context is the extent to which the deepening of one well affects the other and the ensuing stress and tension among the well owners in exploiting groundwater. There is virtually a cut-throat competition as deepening of one well affects adjacent wells directly in particular, since most of these wells are installed with vertical and horizontal bores. If one looks at the history of the sample wells, a vast majority of them have deepened their wells several times. However, it is interesting that no dispute seems to have occurred due to side-bore installations even when such side-bores reaches the sub-soil structure of the adjacent lands and sucks water from beneath the adjacent lands. The manner in which wells are deepened in a competitive manner eventually results in secular lowering of water table. This is, however, a peculiar situation in which although an aggrieved party, whose well is dried due to the deepening activity of his neighbour, would not seek justice through the court of law, as it is also a common knowledge that the property rights in groundwater is ambiguous and indeterminate. This is a fragile situation, which poses a heavy negative externality on the future users and adds tremendously to the costs on the current users (see also, Janakarajan 1997b).

Before concluding this section, however, one point needs to be mentioned. The competitive deepening of the sort that we discussed takes place on the unaffected villages; in the pollution affected villages, competitive deepening is virtually absent since farmers do not have incentive even to use groundwater for irrigation.

The following are a few case studies of sample wells by way of illustrating what have been discussed in this section with more qualitative information on how competitive deepening results in prosperity for a few and deprivation for many.

Illustration: 1 Basin: Palar: Village: Nariampattu; Sample well code No: NMP14

This sample well was originally dug in the year 1975 to a depth of 30 feet and the total land owned by this well owner was 3.77 acres. The depth of the nearest well (to the sample well) was also 30 feet, which is located at a distance of 600 feet. The initial water-lifting device used in both the wells was *kavalai* (bullock bailing). In a few years, both of them replaced it with electrical pump. The sample well was deepened for the first time in the year 1985 to a depth of 16 feet, which apparently reduced the water yield of the nearest well. Therefore, in the year 1987, the nearest well was also deepened to a depth of 12 feet. In the very next year (1988), the sample well was deepened for the second time to a depth of 12 feet. Therefore, the sample well was deepened to a total depth of 28 feet during 13 years period (the total of depth of the sample well was 58 feet in 1988). Since this has drastically reduced the water yield of the nearest well (whose depth in 1988 was only 42 feet) it was also deepened to a depth of 18 feet in 1991 taking the total depth of this well to 60 feet. This in turn has reduced the water yield of the sample well considerably. But he could not deepen further due to financial constraints. He had already borrowed heavily at a high rate of interest (ranging from 36% to 60% per annum) from his friends and relatives. In order to return them he had to sell 1.50 acres of land in the year 1997. Therefore, total land owned by him has come down from 3.77 to 2.27 acres. Earlier his well used to supply at least 8 to 10 hours of water supply per day, which was abundant enough to raise a minimum of two crops in his four-acre plot. But at present, the sample well yields only 2 hours in the first season, 1 hour in the second season and hardly one-half hour of water supply in the third season. In the process of competitive deepening, the sample farmer, having got into the debt trap, has lost a part of his land. Moreover, since the area cropped as well as water supply from the well is substantially reduced, he was struggling to cope up with the pressure. He was also operating in a situation where there is an imminent danger of permanent cessation of water supply from his well if not deepened further at least to the extent of his neighbour's well. He has started seeking more casual labour work to supplement his income.

Illustration: 2 Basin: Palar: Village: Kathiavadi; Sample Well Code No: KYD3

Our respondent originally purchased the sample well under study in the 1940s when its depth was only 12 feet. The original water extracting mechanism was Kavalai (bullock bailing). The well was first deepened in the year 1967 by 5 feet and subsequently in 1973 by another 10 feet. Electric pump has replaced the traditional bullock water-lift in the same year. During the 1982-83 drought, it was again deepened to an extent of another 15 feet. Therefore, in 1983, the total depth of the well was 42 feet. There were four adjacent wells, all located within a radius of about 100 feet; their depths were in the range of 30 to 40 feet. During the continuous drought conditions of the 1980s, all these wells were deepened one after another with an additional installation of vertical and horizontal bores beneath the dug wells. This has considerably reduced the water supply of the sample well. Therefore he was again forced to deepen the well by 6 feet in 1987 and by another 6 feet in 1989. The total depth of the sample well in 1989 has touched 54 feet. This has again prompted the adjacent well owners to deepen their wells. Of the four, two have given up their deepening effort and so; their wells have been in disuse since then. Other two have deepened their wells to the extent of another 10 feet with additional installation of bores. This has prompted the sample well to deepen further by 6 feet in the year 1991. Water supply in the sample well is just adequate to irrigate 3 acres of paddy crop in each season (for two seasons) supplemented by tank water in one season, but it is doubtful whether it would sustain any drought conditions. The sample well farmer is not really fortunate, even though he seems to be sustaining at the moment. He has already accumulated a huge debt from various sources to the extent of Rs.28,000 (at usurious rate) that he cannot afford any more deepening of his well, leave alone sustaining a drought condition. His net worth is fast diminishing, thanks to the competitive deepening.

Illustration: 3 Basin: Palar; Village: Kathiavadi; Sample Well Code No: KYD 40

This sample well was dug in the year 1938 with a depth of 15 feet. During the year 1950 - 1985, this well was deepened six times to a total depth of 24 feet, taking the total depth of the well to 39 feet. The electric pump replaced the manual lift during the mid 1960s. There are three adjacent wells located within a radius of 150 feet, whose depths were around 30 feet. The series of droughts that struck this region in the late 1980s have made every one to invest in the deepening of their wells. Therefore, all the adjacent well owners had to deepen their wells. This has prompted the sample well also to deepen his well in order to cope up with the drought condition. In 1992, the depth of the sample well was 50 feet with vertical and horizontal bores installed beneath the dug well. This has virtually dried two of the adjacent wells and the other one was yielding very little water. They have given up the idea of deepening their wells due to severe financial constraint. On the other hand, the sample well was irrigating about 5 acres of own land and supplying (selling) water to another two acres (owned by the adjacent well owner) in each season at the rate of one-third crop share. This is the clear case of competitive deepening resulting in prosperity; this case also brings to light how well owners are reduced to a position of water purchaser due to competitive deepening.

Illustration: 4 Basin: Palar: Village: RN Patti; Sample Well Code No: RNP 3

This sample well was dug before 1950 with the original depth of 15 feet and operated with bullock-bailing lift. The present owner of this well purchased it in the year 1975 for Rs.5000. Subsequently, the well was deepened twice: Once in 1978 by 15 feet and the other in 1983 by 20 feet. He installed electric pump set in 1978. In the last one decade, supply of water was not adequate in his well to grow paddy. Therefore, he shifted to coconut cultivation in his 1.40 acres of land. The current value of this well including water lifting devices amounts to Rs.120,000. There were two wells located very close to this sample well within 200 feet radius. One well was not in use with the depth was 25 feet. The owner of this well was already indebted to an extent of Rs.50,000 and so decided to abandon it even though it was possible to extract water by deepening it. The other adjacent well was a joint well, which was 40 feet depth with very low water yield. With great difficulty this well was already deepened twice. The well needed to be deepened again in order to cope up with the depth of the sample well (the depth of which was 50 feet). Since the other sharers of this well did not cooperate, the well was not deepened any further and so the water supply was quite low. At the moment even the sample well owner (whose well is better performing compared to the two other adjacent wells) is struggling with an accumulated debt; just an episode of drought is enough to make their living virtually difficult.

Illustration: 5 Basin: Noyyal: Village: SA Palayam; Sample Well Code No: SAP 2

This well owner initially had an open well and kept sustaining on it until 1980. The depth of that well was 70 feet with 6 vertical and 6 side bore. Still that well stopped yielding water during the drought of 1980s. By then he had already spent over 3 lakes on the well. Ultimately he had to abandon that well in 1990 because all his neighbours have started installing deep bores right from the surface up to 250 feet. Finally, he also decided to install deep bores. In the last 10 years, he has installed 10 bores in different part of his land to depths varying between 300 to 700 feet. Out of 10 bore, only two supply water at the moment. At present, more than 25 bore wells around his well have dried because of the 700 feet deep bore installed by him. He has spent Rs.5 lakhs on all these bores during this period. He is able to sustain with these two bores and cultivates in 8 acres (coconut and tobacco) out of his total land holding 20 acres. He has no debts. He is one of the rich farmers in this village, who also owns a tobacco processing company in his farm. He stated that his survival is possible not because of income from his farm but because of his tobacco company in which 100 women are working. He proudly informed us that his neighbouring farmers decided to sell their land because of drying up of their bores.

Illustration: 6 Basin: Noyyal: Village: Ugayanur; Sample Well Code No: UGR 54

This sample well owner was happy until 1990. He has 10 acres of land in which he was growing coconut. Since the late 1980s, many agricultural wells around his farm started selling water in the dyeing and bleaching units located in he Tiruppur town. Every day, more than 100 tanker loads (12000 litres each) were supplied for these industries from this area. This has considerably reduced the water yields in his well. The depth of his well was only 70 feet with 5 vertical bores of 100 feet each. As a result, he had to install a new deep bore in his farm to a depth of 400 feet. He spent Rs.80,000 towards new bore, a new motor and compressor, air-pipes and other accessories. But, this bore supplied water only for 10 months. By then he has accumulated a debt of Rs.1.5 lakhs at 36% per annum. By borrowing another Rs.2 lakhs, he installed three other bores in his farm with depths, 500 feet, 630 feet and 700 feet during the period 1992-94. Of the three bore, at present only one supplies water. But he has sold 6 acres in order to repay the loan with interest in 1996. At present his total holding is reduced from 10 to 4 acres in which he is growing coconut. He was looking quite uncertain and looked literally threatened because water supply from his bore may cease yielding at any time.

Illustration: 6 Basin: Noyyal: Village: Orathapalayam; Sample Well Code No: OPM

This sample well owner has 5 wells and 18 acres of land. All the wells are inter-connected with pipelines. The idea was to pump water from all the wells, channel them together for irrigation. This arrangement was done basically because of low yield of water from his wells. The depths of the wells are in the range of 50 to 70 feet. Total amount spent on all these wells, including 5 motors and pump sets, pump sheds, pipelines and all other accessories amounts to Rs.13 lakhs. He was doing a profitable agriculture until late 1980s. In 1990, a dam was constructed in this village, across the river Noyyal, with a view to provide irrigation to 11000 acres. The sample well owner's destiny has changed since then. This dam collects all the effluent water discharged by 750 dyeing and bleaching units located in and around Tiruppur town. The dam water was not opened for irrigation even once because of very high TDS and other chemicals and salts contained in the water. Unfortunately, all the wells belonging to the sample well owner, although got copious supply to his wells by way of recharge from the dam, he could not use the water for irrigation. This farmer at present is managing with coconut crop, which tolerates salinity to some extent. Even then, his income has annual has come down drastically from about Rs.3 lakhs to less than Rs.50,000. He has accumulated debts to the extent of Rs.4 lakhs. The condition of many small well-farmers is much worse; they have given up their cultivation in this village and have sought employment in the Tiruppur knit-wear and dyeing and bleaching industries.

Section 5 The typologies of wells and the technology of water extracting mechanism in the Noyyal basin

Unlike the Palar basin, groundwater is extracted from deep bores in the Noyyal basin, where the current depth goes up to 1200 feet in some parts of the basin. The yield of water in most of the bores is quite meager, which makes continuous pumping hard and very often virtually impossible. Therefore, to pump again, one has to allow for the recuperation to take place. With a view to avoid this, farmers use the compressor technology, which allows them to run their motors (which are fitted with compressors) even when there is very low yield of water. In other words, what may be normally pumped with full supply in one hour, takes about six or seven hours. About 95% of bore wells in this basin are fitted with compressors. However, since the yield of water from the bores is quite low, farmers cannot use the water for irrigation or for sale directly from the bore well. Therefore, they adopt the technique of storing the pumped water either into a well or in a big concrete tank (the capacity of which goes up to 100, 000 liters), which is again pumped either for irrigation or for sale, as the case may be. Please note that electricity consumption in these bore wells are double or even triple due to (a) the use of compressors to run the motors, (b) the running of the motors for abnormally longer hours to pump a meager quantity of water and (c) twice pumping of the same water (once from bore and secondly from either open well or concrete tank where the pumped water is stored).

Based on data collected through the sample survey conducted in the four villages of this basin, we have identified several typologies of bore wells operating with different water extracting mechanisms (see Tables 17 to 20). It may be seen from these tables that in each village, there are many typologies of bore wells with varying types / capacities of water extracting mechanisms, and which pump water for different purposes. Moreover, in many cases, same water is pumped twice either for irrigation or for sale. In South Avinashipalayam village (see Table 17), in 19 out of 54 sample wells, in Ugayanur (Table 18), in 27 out of 59 sample wells, in Orathapalayam (Table 19), in 2 out of 20 sample wells and in Karaipudur (Table 20), in 19 out of 48 wells, same water is pumped twice. In essence, the characteristics such as very low yield of groundwater, extensive use of high power motors and compressors, the prevalence of multiple bores (both vertical and horizontal) beneath the dug wells and twice pumping of the same water are all the clear manifestations of water scarcity and emerging competitiveness among well owners.

Table 17: Village: South Avinashipalayam: Basin: Noyyal Showing Typologies Of Wells With Different Water Extracting Mechanisms In Use

Sl. No	Typology of sample wells, the type of water extracting mechanism used and the number of times same water is pumped either for sale or for own agricultural use	No. of wells
1	Deep bore well from which water is pumped with one motor and a compressor in order to store water in an independent well - only to pump again for irrigation (twice pumped)	16
2	Deep multiple bores (up to 3) simultaneously operated with one high power motor (10 HP) along with one compressor in order to store water in a deep open well - only to pump again for irrigation (twice pumped).	3
3	Deep multiple bores (>3) simultaneously operated with 2 high power motors (of up to 10 HP each) along with two compressors in order to store water in a open well - only to pump again for irrigation (twice pumped)	0
4	Shallow well which is operated (with up to 5.00 HP motor) for direct irrigation - own use (once pumped)	6
5	Deep well which is operated (with up to 7.5 HP motor) for direct irrigation - own use (once pumped)	18
6	Deep multiple - vertical bores installed within a dug well - operated with a high power motors - used for own agriculture - (once pumped)	2
7	Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (of up to 10 HP) with one compressor in order to store water in a concrete tank (capacity is 100,000 litres) both to sell water for urban industrial use as well as to pump for own agricultural use (twice pumped)	0
8	Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (of up to 10 HP) with one compressor in order to store water in a concrete tank (capacity is 100,000 litres) but used for own industries - D/B) (twice pumped)	0
9	Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (of up to 10 HP) with one compressor in order to store water in a concrete tank (capacity is 100,000 litres)- but water is used for own agricultural use by letting water through gravity flow. (once pumped)	0
10	Shallow wells not - in –use	9
	Total of all typologies	54

Notes: Deep well: More than 50 feet; Shallow well: Less than or equal to 70 feet
Deep bore well: 350 to 700 feet (Source: Main survey, 1998-00)

Table 18 Village: Ugayanur: Basin: Noyyal Showing Typologies Of Wells With Different Water Extracting Mechanisms In Use

Sl. No	Typology of sample wells, the type of water extracting mechanism used and the number of times same water is pumped either for sale or for own agricultural use	No. of wells
1	Deep bore well from which water is pumped with one motor and a compressor in order to store water in an independent well - only to pump again for irrigation (twice pumped)	15
2	Deep bore well from which water is pumped with one motor and a compressor in order to store water in an independent well - only to pump again for water sale for industries (twice pumped)	3
3	Deep multiple bores (up to 3) simultaneously operated with one high power motor (10 HP) along with one compressor in order to store water in a deep open well – only to pump again for irrigation (twice pumped).	8
4	Deep multiple bores (>3) simultaneously operated with 2 high power motors (of up to 10 HP each) along with two compressors in order to store water in a open well - only to pump again for irrigation (twice pumped)	0
5	Shallow well which is operated (with up to 5.00 HP motor) for direct irrigation - own use (once pumped)	7
6	Shallow well which is operated (with up to 5.00 HP motor) for water sale to industries and irrigation (once pumped)	2
7	Deep well which is operated (with up to 7.5 HP motor) for direct irrigation - own use (once pumped)	10
8	Deep multiple - vertical bores installed within a dug well - operated with a high power motors - used for own agriculture - (once pumped)	4
9	Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (of up to 10 HP) with one compressor in order to store water in a concrete tank (capacity is 100,000 litres) both to sell water for urban industrial use as well as to pump for own agricultural use (twice pumped)	1
10	Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (of up to 10 HP) with one compressor in order to store water in a concrete tank (capacity is 100,000 litres) but used for own industries - D/B) (twice pumped)	0
11	Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (of up to 10 HP) with one compressor in order to store water in a concrete tank (capacity is 100,000 litres)- but water is used for own agricultural use by letting water through gravity flow. (once pumped)	1
12	Shallow wells not - in –use	8
	Total of all typologies	59

Notes: Deep well: More than 50 feet; Shallow well: Less than or equal to 70 feet
Deep bore well: 350 to 700 feet (Source: Main survey, 1998-00)

Table 19 Village: Orathapalayam: Basin: Noyyal Showing Typologies Of Wells With Different Water Extracting Mechanisms In Use

Sl. No	Typology of sample wells, the type of water extracting mechanism used and the number of times same water is pumped either for sale or for own agricultural use	No. of wells
1	Deep bore well from which water is pumped with one motor and a compressor in order to store water in an independent well - only to pump again for irrigation (twice pumped)	2
2	Deep multiple bores (up to 3) simultaneously operated with one high power motor (10 HP) along with one compressor in order to store water in a deep open well - only to pump again for irrigation (twice pumped).	0
3	Deep multiple bores (>3) simultaneously operated with 2 high power motors (of up to 10 HP each) along with two compressors in order to store water in a open well - only to pump again for irrigation (twice pumped)	0
4	Shallow well which is operated (with up to 5.00 HP motor) for direct irrigation - own use (once pumped)	5
5	Deep well which is operated (with up to 7.5 HP motor) for direct irrigation - own use (once pumped)	7
6	Deep multiple - vertical bores installed within a dug well - operated with a high power motors - used for own agriculture - (once pumped)	0
7	Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (of up to 10 HP) with one compressor in order to store water in a concrete tank (capacity is 100,000 litres) both to sell water for urban industrial use as well as to pump for own agricultural use (twice pumped)	0
8	Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (of up to 10 HP) with one compressor in order to store water in a concrete tank (capacity is 100,000 litres) but used for own industries - D/B) (twice pumped)	0
9	Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (of up to 10 HP) with one compressor in order to store water in a concrete tank (capacity is 100,000 litres)- but water is used for own agricultural use by letting water through gravity flow. (once pumped)	0
10	Shallow wells not - in –use	6
	Total of all typologies	20

Notes: Deep well: More than 50 feet; Shallow well: Less than or equal to 70 feet
Deep bore well: 350 to 700 feet (Source: Main survey, 1998-00)

Table 20 Village: Karaipudur: Basin: Noyyal Showing Typologies Of Wells With Different Water Extracting Mechanisms In Use

Sl. No	Typology of sample wells, the type of water extracting mechanism used and the number of times same water is pumped either for sale or for own agricultural use	No. of wells
1	Deep bore well from which water is pumped with one motor and a compressor in order to store water in an independent well - only to pump again for irrigation (twice pumped)	8
2	Deep multiple bores (up to 3) simultaneously operated with one high power motor (10 HP) along with one compressor in order to store water in a deep open well - only to pump again for irrigation (twice pumped).	5
3	Deep multiple bores (>3) simultaneously operated with 2 high power motors (of up to 10 HP each) along with two compressors in order to store water in a open well - only to pump again for irrigation (twice pumped)	1
4	Shallow well which is operated (with up to 5.00 HP motor) for direct irrigation - own use (once pumped)	6
5	Deep well which is operated (with up to 7.5o HP motor) for direct irrigation - own use (once pumped)	5
6	Deep multiple - vertical bores installed within a dug well - operated with a high power motors - used for own agriculture - (once pumped)	5
7	Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (of up to 10 HP) with one compressor in order to store water in a concrete tank (capacity is 100,000 litres) both to sell water for urban industrial use as well as to pump for own agricultural use (twice pumped)	2
8	Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (of up to 10 HP) with one compressor in order to store water in a concrete tank (capacity is 100,000 litres) but used for own industries - D/B) (twice pumped)	3
9	Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (of up to 10 HP) with one compressor in order to store water in a concrete tank (capacity is 100,000 litres)- but water is used for own agricultural use by letting water through gravity flow. (once pumped)	1
10	Shallow wells not - in –use	12
	Total of all typologies	48

Notes: Deep well : More than 50 feet; Shallow well : Less than or equal to 70 feet
Deep bore well : 350 to 700 feet (Source : Main survey, 1998-00)

The various modern techniques, twice pumping of the same water through multiple pump-sets and the use of high power compressors and motors reflect in the cost incurred in the water extracting mechanisms (WEM) used by the farmers. The cost of WEM is relatively less in the Palar basin compared to Noyyal basin. For instance, in the Palar basin, the average cost of WEM works out to Rs.14600 per well (which includes motor and pumps and other related accessories); whereas, in the Noyyal basin, the average cost of WEM per well works out to Rs.31,000. The most important cost however, is the cost of pumping. Since the electricity for agricultural pump-sets is absolutely free in Tamilnadu State, farmers do not hesitate to pump water even if the delivery of water is quite low. This is one of the main reasons why same water is pumped twice or thrice in the Noyyal basin. This means also that electricity consumption is twice or thrice in the wells where the same water is pumped twice or thrice.

In our sample survey in the Noyyal river basin, we tried to get the farmers' perceptions on competitive deepening and the reasons for the lowering of water table in their villages. The information given by them have been tabulated: In as many as 50% of the sample wells, water levels has been dropping progressively due to the prevalence of multiple bores beneath dug wells (both vertical and side bores) and due to the installation of bores in a competitive spirit. Each farmer, before having a successful bore-well, has got to spend in at least five or six trial-bores. Furthermore, around each bore or open well, there are several closed bore points, which have stopped yielding water. These again demonstrate competitiveness in the installation of bore wells. What is also imperative is that in many villages the depth of the bore wells are somewhat uniform, which underlies the point that farmers do keep up with the general water level in the village.

5.1 What does secular lowering of water table and competitive deepening convey?

Groundwater table is one of the main factors, which determines the economics of well irrigation. Its decline, in particular when it is secular as we have noticed in the Palar and the Noyyal river basins, has manifold implications. Though it is not possible to go into all the technicalities, it is worth discussing some salient points.

First of all, there has been a change in the design and type of wells dug. The conventional, large diameter round or square wells are found to be inadequate to cope with the continuous falling of water table. The way the well digging technology has transformed over a period of time is clearly emerging from our survey in both the river basins. We found basically, five types of wells, viz., dug wells, dug plus vertical bores, dug plus horizontal bores, dug plus vertical plus horizontal bores and deep bores right from the surface. The technology of multiple bores and deep bores has emerged into picture only in the last couple of decades. While a large majority of wells in the Palar river basin are fitted with both vertical and horizontal bores, in the case of Noyyal basin, a majority resort to installing deep bores from the surface. The hydraulic drilling machine hiring companies have spread in large number in this region. Their profits have gone up because of continuous business, in particular in the Noyyal river basin. This kind of well digging technology has substantially contributed to competitiveness and over-pumping of groundwater.

Secondly, the indiscriminate deepening of wells has resulted in the employment of high power motors and compressors, which to a great is facilitated by the supply of free electricity by the State. As we have discussed, until the past three decades, bullock bailing was the main method of water extraction. That practice is almost extinguished. Until the mid 1980s, 3.5 HP motor was used most widely in the State for agricultural pump sets. But the series of droughts that have struck many parts of India have resulted in the deepening of wells more rapidly, which warranted for the use of high power motors. At present, a 10 HP motor is quite commonly seen for instance in the Noyyal river basin. Further, in many cases, farmers use more than one motor in a same well, which we have already indicated while discussing different typologies of water extraction.

Thirdly, the progressive lowering of water table also reflects upon the manner in which water is conveyed from the delivery point to the plots of land, which need to be irrigated. Until the late 1980s, open cur channels were used for conveying water. At present, farmers use more frugal ways of water conveyance such as underground pipelines and hose pipes.

Fourthly, every additional cost on the wells falls disproportionately on the small farmers who own about 60% of wells in the State. This is because, while the large farmers and multiple well owners have the incentive to irrigate a larger area, small farmers can irrigate only a limited extent. Furthermore, while a large operator can sustain events of unsuccessful investment in well digging and well deepening or persistent drought conditions (as occurred in the 1980s), for a small operator it poses a heavy burden and will be an unsustainable blow.

Finally, all the improvements in well irrigation technology, secular lowering of water table and competitive deepening of wells have got direct relationship with enhanced investments / costs attached to groundwater. Let us turn to this issue in the next section.

Section- 6 Costs and investments on wells

One of the most important implications of competitive deepening of wells is ever-increasing cost. Farmers keep investing on their wells without calculating their expected rate of returns on their investment. The alternate livelihood strategy is not something, which gets into the psychology of farmers, but instead think about only the survival strategy given their skills in agriculture. In the process, many wells go dry after yielding water for a few years (or few months as it has happened in many cases). Indeed, as per the latest available statistics for Tamilnadu (Government of Tamilnadu, Season and Crop Report, 1997-98), the wells not-in-use constitute about 10% of the total number of wells in the State. This is primarily due to low recharge, hard rock formations and due to groundwater contamination. Many wells have been abandoned after investing over Rs.100,000. (Janakarajan, 1997a). Eventually, all the investments that have gone into wells accumulate to pose a heavy burden on the community as a whole as well as on an individual farmer.

As a part of the present survey in the Palar and Noyyal river basins we attempted to gather data with a view to examine the extent to which farmers have invested in well irrigation. The types of questions that we tried in the survey are the following: What was the investment made on the wells when it was first dug? What was the cost incurred in further well deepening, bore installations, pipe lines and other well improvement? What is the amount spent on water extracting mechanisms, compressors and other associated structures? And finally, what would be value of all the components specified at current prices at the time of survey? In other words, with a view to ascertain the current value / costs / investments on existing wells, we asked each sample well owners, how much he would have to invest on his well (sample well) and other associated components in current prices? In a majority of the cases, sample well owners were giving understated value at current prices. Therefore, the current value may be more than what has been specified. Nevertheless. These data were pooled for each villages –separately for wells located in the wet and dry land. We had lots of difficulties in gathering this information primarily because of problems of memory lapses, due to transfer or sale of wells to others etc. With the result we had to delete some sample wells from our analysis, which we found unreliable.

It is evident from our data that cost incurred on well irrigation by individual farmers is quite high. In particular, cost incurred on well irrigation looks quite disproportionate to level of farm income generated. For instance, amount spent per well located in the wet and dry lands land of the Palar basin (aggregate for 8 sample villages) at current prices, works out to Rs.76000 and Rs.80000 respectively. The current average cost calculated per hectare of area irrigated by the sample wells works out to Rs.38000 and Rs.87500 respectively in the wet and dry lands. And, the average for the wells located in both wet and dry lands put together, it works out to Rs.83000 per well and Rs.59000 per hectare of net irrigated by the sample wells. Evidently, costs incurred in the dry land wells are much higher compared to those located in the wetlands simply because of water table variations. In the dry lands water table has declined much more steeply than in the wetlands. Similarly, in the Noyyal river basin, average cost incurred per well works out to Rs.223,000. And, cost incurred per hectare of net area irrigated by the sample wells amounts to Rs.190,000. Tables-21, 22 and 23 give data pertaining to costs incurred on well irrigation separately for wet and dry lands in the Palar and Noyyal river basins for each sample village.

Table-21 Costs of well irrigation in the wetland wells of the Palar basin

Village	No. of sample wells	Original costs incurred in '000 of Rupees	Current costs (in '000 of Rs.)	Average current cost per well in '000s of Rs.	NIA by sample wells (Ha.)	Current average cost per Ha. of NIA in '000s of Rs.
Kathiavadi	13	34	1179	91	17.57	67
Poondi	15	131	1178	79	20.19	58
Gudimallur	7	6	603	86	11.23	54
Periavarigam	5	44	290	58	4.78	61
Solur	5	9	257	51	1.62	159
Damal	38	505	2845	75	117.53	24
RN Pettai	8	39	521	65	5.00	104
NM Pattu	8	50	698	87	21.58	32
Total	99	816	7571	76	199.50	38

Note: Solur, Periavarigam, Gudimallur and Poondi are affected villages due to discharge tannery effluent, where groundwater is badly contaminated; Among other villages, while Kathiavadi is partially affected, Damal, NM Pattu and RN Pettai are not affected(Source: Main survey, 1998-00)

Table-22 Costs of well irrigation in the dry land wells of the Palar basin

Village	No.of sample wells	Original costs incurred in '000 of Rupees	Current costs (in '000 of Rupees)	Average current cost per well in '000s of Rs.	NIA by sample wells (Ha.)	Current average cost per hectare of NIA in '000s of Rs.
Kathiavadi	27	299	3137	116	35.54	88
Poondi	7	118	587	84	6.13	96
Gudimallur	12	67	944	79	7.21	131
Periavarigam	25	135	2316	93	21.99	105
Solur	16	113	1494	93	14.55	103
Damal	11	176	896	81	25.96	35
RN Pettai	34	356	2583	76	18.04	143
NM Pattu	18	188	1230	68	21.28	58
Total	150	1451	13187	88	150.70	88

Note: Solur, Periavarigam, Gudimallur and Poondi are affected villages due to discharge tannery effluent, where groundwater is badly contaminated; Among other villages, while Kathiavadi is partially affected, Damal, NM Pattu and RN Pettai are not affected

Source: Main survey, 1998-00

Table-23 Costs of well irrigation in the Noyyal basin

Village	No.of sample wells	Original costs incurred in '000 of Rupees	Current costs (in '000 of Rupees)	Average current cost per well in '000s of Rs.	NIA by sample wells (Ha.)	Current average cost per hectare of NIA in '000s of Rs.
SA Palayam	54	535	12438	230	68.78	181
Ugayanur	59	1345	11774	200	66.11	178
O Palayam	20	180	4049	202	29.90	135
K Pudur	48	1008	12121	253	47.37	256
Total	181	3067	40381	223	212.17	190

Note: O.Palayam and K Pudur villages are affected due to discharge of effluent from the dyeing and bleaching industries, where groundwater is badly contaminated; Other two villages, namely, SA Palayam and Ugayanur are not affected.

Source: Main survey, 1998-00

Two points are worth noting from Tables 25, 26 and 27:

- First of all, it is evident that costs incurred per well and per hectare of area irrigated are no mean figures. As per the data published by the Ninth Five year Plan Document (1997-2202), cost incurred to create one hectare of major and medium irrigation potential by the Government works out to Rs.40166 at current prices. (Government of India, undated). But as per our survey, an individual farmer has spent Rs.38000 and Rs.88000 to get one hectare of net area irrigated by wells in the wet and dry lands respectively in the Palar basin. In the Noyyal basin it is much worse. A farmer had to spend Rs.190,000 to get one hectare of area irrigated by wells, which is little less than four times what the Government has spent to create one hectare irrigation potential under major and medium irrigation projects. In other words, this is the amount that a newcomer – farmer would have to spend to get one hectare of net area irrigated by well. Further, there is always the danger of one's well going dry due to several reasons such as drought conditions, competitive deepening, resource constraint and above all if one's well gets polluted, all the investment that have gone into a well will become an absolute waste. This is indeed the case of many 1000s of wells spread over hundreds of villages in the Palar and Noyyal river basin.

- Secondly, it is evident from these tables that there exists a big difference between those villages, which are affected by industrial pollution and those which are not. Cost incurred per hectare of NIA by well is much higher in the affected villages compared to unaffected villages. This is primarily because, in the affected villages, net area irrigated by wells is quite low because of unsuitability of groundwater for irrigation. Therefore, given the low area under irrigation by wells, total investment incurred on wells really boosts up the figure when calculated per hectare of area irrigated.

Our discussion on costs incurred on well irrigation makes one other point clear. After all, well irrigation has become a gamble. Not all those who invest on wells are successful. Many fail and lose in the race of competitive deepening. Or as is the case in the Palar and Noyyal river basins, wells go into disuse due to pollution. In which case, they either sell their land or get themselves locked-up in debt trap. Its direct consequence is the emergence of a new dimension of inequality of those who have sustained the race of competitive deepening and those who have not. While the former has emerged as the potential water sellers, the latter are reduced to the status of water purchasers. It is indeed the case of those of successful ones and those of a deprived and an excluded lot (Janakarajan, 1997b, Vaidyanathan, 1996).

Section-7 Water Markets – Conflicts and Contradictions

The sale of groundwater in the rural areas has come to be a common phenomenon. Like joint well ownership, emergence of water market in rural areas is yet another spontaneous institution, which facilitates an opening for sharing of this scarce resource. Its magnitude and terms and conditions vary from place to place, depending upon availability of groundwater, quality, soil conditions, need / purpose for which water sale is effected and conventions. Further, price paid for water is often dictated by type of water supplier / seller. For instance, if the State plays the role of a water seller, the price the individual seller would want to pay is far less or insignificant in India compared to what is paid to a private seller. Thus the Committee on Pricing of Irrigation Water reports, "At present, the actual gross receipts per hectare of area irrigated by major and medium projects is barely 2 per cent of the estimated gross output per hectare of irrigated area…"(Planning Commission, Government of India, 1992). On the other hand, farmers pay up to one-third of their gross produce or up to Rs.40 per hour towards water when supplied by a private well owner (Janakarajan, 1992, and Janakarajan, 1997a).

Moreover, the private water seller pays very little or nothing by way of electricity tariff to the State while pumping waters for instance in the States such as Tamilnadu and Haryana. Subsidy on water or electricity or for that matter any other services or good should be motivated, targeted and be sufficiently justified. But in the present context, neither subsidies are motivated or targeted nor do they make any attempt to justify. Most of these measures are inspired by the myopic policy of competitive populism. For example, in principle, water tariffs should be charged not only to the extent of recovering costs (both fixed and recurring / maintenance), but should also aim to encourage water conservation. But in the Indian context, water tariffs charged do not even cover annual maintenance costs, not to mention the zero recovery towards fixed costs. Further, if at all, the prevailing water tariff system, rather than encouraging water conservation, promotes misuse or over-use of water for any given purpose. In the process, a few benefit more, get access to more water and many suffer without even a pot of safe drinking water. Therefore, the present situation is neither efficient nor equitable nor sustainable.

The exclusion of a majority of the agricultural population from having access to own well irrigation and the clear polarization in the resource position of water sellers and water purchasers are the principal sources of conflict between these two agents. The Vaigai basin study (Janakarajan, 1997a) indicates that a little more than three-fourths of the water purchasers are poor farmers whose holding size is less than one hectare. Yet another study carried out in the Palar basin indicates that the extent of inequality in the distribution of land across all the cultivators (excluding landless population) was found to be extraordinarily high, as reflected in a Gini coefficient of concentration of O.88. What is interesting is that the Gini coefficients calculated separately for the water purchasers and the water sellers, are relatively small - at 0.34 and 0.40. These figures indicate that the `between-group' component of inequality (viz., between water sellers and water purchasers) is far greater than the `within-group' component (Janakarajan, 1992). Furthermore, a vast majority of the water purchasers belong to the socially deprived castes; In fact, the Scheduled castes, the most deprived in the social hierarchy in India, constitute 27.3% of the water purchasers (Janakarajan 1997a). Therefore, it is intelligible that the agents involved in the water deals are sharply polarized socially as well as economically with unequal bargaining capacity.

Let me discuss briefly, the manifestations of the conflicts between these agents. There are two forms in which conflicts unveil: First is the prevalence of an informal rule that a water purchaser should purchase water only from a nearest well owner. However, if a concerned well owner agrees, water can be purchased from the next nearest well owner. This rule is enforced, basically with a view to avoid conflicts, which may otherwise arise, as water may have to pass through the field channels of the others. There are instances of conflicts between water sellers and water purchasers due to the violation of this rule (Janakarajaan, 1992). Even if all those concerned agree, the distant water seller would insist that the water purchaser should have a hose pipe of the necessary length, with a view to conserve water from seepage. A water purchaser, however, is reluctant since there is no guarantee that a water seller would sell water regularly (Janakarajan, 1997a).

Secondly, the unequal trading relationship results in the exploitation of the weaker agent, not only through the mechanism of price (paid for water purchased) but through several non-price measures. One of the most usual non-price mechanisms used by the water sellers is to exploit the free or under-paid labour services of the water purchasers. The water purchasers cannot refuse as they are constrained by the retaliatory act of the cessation of water supply in the middle of a season by the water sellers (Janakarajan, 1992). In several cases, as we found in our survey in the Vaigai basin, the payments for water were required to be made through labour compensation and in several other cases through output (grains). In the process, water market gets interlocked with the other agrarian markets such as labour, credit and product (Janakarajan, 1992 and 1997a). In addition, there are instances in which the water purchasers were forced to lease-out their parcels of land in favour of the water sellers, at the terms dictated by the latter. This is nothing but the case of reverse tenancy in which a lessee is seemingly more powerful than a lessor.

Although, instances of open conflicts between such aggrieved peasants / water purchasers and water sellers are sporadic and infrequent, by and large, the former are quite resentful with the latter, the fact which they disgorge while narrating the water supply conditions. Moreover, as it has been observed in some villages, the water sellers are in collusion in fixing the price for water, which again annoys the water purchasers (Folke, Steen, 1996, Janakarajan, 1992).

7.1 Decline in the Water Market

Nevertheless, incidence of water sale for agricultural purposes, seems to have declined significantly in the recent times. While in the Noyyal river basin, water sale for agriculture never took place, in the Palar basin, water market was a flourishing business until last decade as explained in the previous paragraphs. In the last one decade or so, there has been a significant drop in the extent of water sale primarily for two reasons: One, progressive decline in the groundwater table has made it hard to irrigate even one's own crop; Two, a high level of groundwater pollution caused due to the discharge of effluent from tanneries, dyeing, bleaching and other chemical industries reduced the agricultural activities quite significantly.

Table-24 gives information on number of sample wells reporting water sales in the Palar river basin and the gross area to which water was sold. Roughly about 10% of the sample wells in these three villages reported water sales, supplying water to about 35 acres of land in an agricultural year. But, the information provided in this table pertains to only three of the 8 sample wells selected in the Palar river basin. In the rest of the five sample villages, absolutely no water sale has been reported. These are the villages, which are affected due to tannery pollution.

Table 24 Extent Of Water Sale In The Sample Villages As Reported By The Sample Wells In The Palar Basin

Village	Total number of sample wells	Number of sample wells reporting water sale	Gross area to which water was sold in 1998-99 (acres)
Damal	49	7	20.50
Kathiavadi	41	1	2.50
Ramanaicken Pettai	43	5	11.70
Total	133	13	34.70

(Source: Main survey, 1998-00)

In the Noyyal river, on the other hand, absolutely no water sale takes place within rural areas for agricultural purposes. But there is a roaring water trade taking between rich well owning farmers and urban industries (mainly dyeing and bleaching units). From two of the sample villages, viz., SA Palayam and Ugayanur, from 21 deep bores (depths of which go up to 1400 feet) water is old for urban industries. According to our estimate, easily 80 mld of water is transported. The rate per load of 12000 liters varies from Rs.75 to Rs.400, depending upon season. These are the agricultural wells transformed into commercial wells selling water. All these are rich farmers, who also irrigate a part of their holdings. Besides, several industrial owners also own their own deep bore wells in this area. According to our calculation, in both these villages, there were 15 such deep bores and their depths go up to 1400 feet. But, its effect is disastrous. All the neighbouring wells / and bores have stopped yielding water or supplies very poorly. Family members from such farming households, which failed in the race of competition in well deepening, have almost stopped cultivation, and are seeking jobs in the urban industries.

An important issue, which deserves attention in this context, is to what extent water market is a solution to the growing unequal access to groundwater? At least from what we have observed from the two river basins in Tamilnadu, the water market does not seem to be a solution for the growing water scarcity; it only aggravates the problem of inequity since the resource rich farmers / industrialists chase the water table better and faster than the others. Nor could this be a mechanism for influencing the demand management. In other words, water market in the context of the two river basins studied seems to aggravate the problem of inequality and provides a mechanism to reinforce backward relations.

Section 8: Analytical summary and conclusion:

That groundwater can act, as a buffer during acute drought conditions needs no elaboration. It is also now well established that area irrigated by groundwater produced much better yield compared those irrigated by surface sources. In changing agro-climatic and environmental conditions, the necessity to protect groundwater gains more significance. Further, ever raising demand for food grains, increasing urbanisation, rapid industrial expansion and acute dependence upon groundwater for drinking purposes adds stress on the existing stock of groundwater. The stress on groundwater is due not only because of over-use and retreating water table but also due to its deteriorating quality. How the civil society is going to respond to this kind of escalating and competing demand for groundwater?

In the Noyyal basin, we encounter two situations: The first is the case of (e.g., Orathapalayam and Karaipudur sample villages) in which well owning farmers (in particular small farmers), who are badly affected due to water pollution; they have lost their cultivation, income and amount invested in wells, bores etc. They have become job seekers in the urban areas. The second is the case (e.g., Ugayanur and SA Palayam sample villages), in which farmers have lost due to competitive deepening. These issues become more important particularly because, as we found in our survey, over 60% of the well farmers are small and marginal, whose land size is less than 5 acres. Under these stress conditions, their survival is a big question mark.

In this particular scenario, it is crucial to address the question, what will happen if electricity tariff is introduced to agricultural pump sets? Since 1989 electricity tariff for agricultural sector has been supplied free. This myopic policy of the State government has induced the farmers to go in for indiscriminate deepening and pumping of groundwater. Indeed, many small farmers have reported that they dug their own wells only because of free electricity supplied by the State. In fact, time series data of electricity tariff and consumption in the State of Tamilnadu clearly indicates that there is big jump in the per pump set power consumption from the year free electricity was introduced in the year 1989 (See Table-25). It is evident from the table annual electricity consumption per pump set goes up steeply since 1989. During the 20 years period from 1970-71 to 1990-91, the per pump set consumption has gone up from 2342 units to 3014 units. That is, over a period two decades, annual per pump set consumption has gone by about 650 units. This may be due to long term decline in the water table or low delivery of water from the wells. As a consequence, farmers may be running their pump sets for longer hours to irrigate a given lot of land. But from 1991-92 to 1996-97, the increase has been rapid. During this 5 years period, it has gone up 1136 units (from 3273 units to 4409 units per pump set). This clearly indicates that farmers have the tendency to operate their motors even under uneconomical conditions mainly because of zero operating cost.

In SA Palayam village for instance (in the Noyyal basin), we found 16 out of 54 sample wells in disuse due to non-availability of water in the wells. These are the farmers who are indebted heavily and who have lost in the race of competitive deepening. Of the remaining 38 well owners, 23 pumped water only once and the remaining pumped the same water twice. We calculated the electricity consumption per pump set in both these sets of wells separately. In the case of those wells, which pumped water only once, power consumption per pump set works out to 2370 units per year. By multiplying 2478 units three times (assuming generation cost is Rs.3 per kwh), we get the total subsidy enjoyed by these farmers, which is Rs.7110. On the other hand, 15 well owners who pump the same water twice consume 17825 units per year or its equivalent in value Rs.53,478. These are the rich and successful farmers who have gained in the race.

At present, even if Rs.0.50 is charged per unit of electricity consumption, many small farmers will have to close down their wells because of uneconomical conditions (Janakarajan,S, forthcoming). This will have a multiplier effect in the village economies.

On the whole, indiscriminate and unregulated pumping, competitive deepening, rural – urban water trade and pollution of groundwater have become the typical characteristics of groundwater irrigation in Tamilnadu and in other hard rock regions of India as well. In addition, the State’s myopic subsidy populist policies aggravates all these problems; Indeed, the free electricity supplied to agricultural pump sets have complicated the matter. All these signal not only depletion of this precious resource, but also will intensify poverty conditions.

Table-25 Electricity tariff and Consumption of Electricity per Pump Set inTamilnadu 1970-71 to 1996-97

Year	Total energy consumed for ag. Pump sets (mu)	Number of electric pump sets	Energy consumed /pump set (units)	Tariff charged for agricultural pump sets
1970-71	1,241 (100)	5,29,932 (100)	2,342	8 paise / unit
1971-72	1,269 (102)	5,94,169 (112)	2,136	9 paise / unit
1972-73	1,430 (115)	6,49,241 (122)	2,203	11 paise / unit
1973-74	1,576 (127)	6,81,205 (128)	2,314	11 paise / unit
1974-75	1,847 (149)	7,06,914 (133)	2,613	11 paise / unit
1975-76	1,675 (135)	7,42,745 (140)	2,255	16 paise / unit
1976-77	1,697 (137)	7,73,702 (146)	2,193	16 paise / unit
1977-78	1,786 (144)	8,09,606 (153)	2,206	Big farmers - 16 paise / unit Small ----- - 14 paise / unit
1978-79	2,104 (170)	8,40,557 (159)	2,503	Big farmers - 14 paise / unit Small ----- - 12 paise / unit
1979-80	2,186 (176)	8,87,227 (167)	2,464	Big farmers - 14 paise / unit Small ----- - 12 paise / unit
1980-81	2,299 (185)	9,19,162 (173)	2,501	Big farmers - 14 paise / unit Small ----- - 12 paise / unit
1981-82	2,354 (190)	9,45,520 (178)	2,490	Big farmers - 15 paise / unit Small ---- - 12 paise / unit
1982-83	2,230 (180)	9,65,017 (182)	2,311	Big farmers - 15 paise / unit Small ---- - 12 paise / unit
1983-84	2,200 (177)	9,82,606 (185)	2,239	Big farmers - 15 paise / unit Small ---- - 12 paise / unit
1984-85	2,415 (195)	9,82,606 (185)	2,458	Big Farmers:Rs.75/HP/year Small …… :Rs.50/HP/year
1985-86	2,840 (229)	10,33,533(198)	2,748	Big Farmers:Rs.75/HP/year Small …… :Rs.50/HP/year
1986-87	3,114 (251)	10,74,184 (203)	2,899	Big Farmers:Rs.75/HP/year Small …… :Rs.50/HP/year
1987-88	3,136 (253)	11,16,177 (211)	2,810	Big Farmers:Rs.75/HP/year Small …… :Rs.50/HP/year
1988-89	3,524 (284)	11,84,450 (223)	2,975	Big Farmers:Rs.75/HP/year Small …… :Rs.50/HP/year
1989-90	3,740 (301)	12,35,941 (233)	3,026	Big Farmers:Rs.75/HP/year Small …… :Rs.50/HP/year
1990-91	3,974 (320)	13,18,671 (249)	3,014	Rs.50 / HP / annum for ≤ 10 HP and Rs.75 / HP/ per annum for >10 HP
1991-92	4,451 (359)	13,59,748 (257)	3,273	Since 1991 free supply for all
1992-93	5,160 (416)	14,03,673 (265)	3,676	
1993-94	5,618 (453)	14,45,951 (273)	3,885	
1994-95	6,228 (502)	14,88,469 (281)	4,184	
1995-96	6,626 (534)	15,28,807 (288)	4,334	
1996-97	6,910 (557)	15,67,317 (296)	4,409	

Source: Compiled from various issues of Tamilnadu Electricity Board – A Glance.

This is the context in which we need to review all the State regulations and laws concerning water, environment and electricity supply. The series of laws relating to water and environment enacted after the 1972 Stockholm agreement have provided enough teeth to book all those who contribute to water pollution. Similarly, the draft Groundwater Bill and Electricity Regulation Bill have all been pending awaiting State Governments' will to enact them as laws. Therefore, we are not lack of laws but what we lack is political will and corruption free governance: we are badly in need of will to implement and enforce these laws effectively with a monitoring mechanism.

There is also an urgent need for water conservation measures both in quantitative and qualitative terms. This means prevention of wastage, over-use and pollution and promotion of recycling of treated waste-water at least for industrial uses. This also calls for social awakening and a continued social dialogue of all stakeholders with a view to discuss and find solutions.

References

Bhatia, Bela, 1992. “Lush Fields and Parched Throats: Political Economy of Groundwater in Gujarat”, *Economic and Political Weekly*, Vol.27, Nos 51 and 52, December, 19-26.

Folke, Steen, 1996. *Cauvery Delta: Canal and Well Irrigationand Conflicts over land and Water,* unpublished.

Government of Tamilnadu, 1998, *Season and Crop Report for the year 1997-98*, Chennai.

Government of India, undated, Planning Commission, *Ninth Five year Plan 1997-2002, Vol-II, Thematic Issues and Sectoral Programmes*.

Harriss, john, 1982, *Capitalism and Peasant Farming: Agrarian Structure and and Ideology in Northern Tamilnadu*, OUP, Bombay.

Janakarajan, 1986. *Aspects of Market Inter-relationships in a Changing Agrarian Economy,* Thesis submitted for the award of the Doctor of Philosophy, University of Madras.

Janakarajan, 1992. `Interlinked Transactiond and the Market for Water in the Agrarian Economy of a Tamilnadu Village’, in S.Subramanian (ed) *Themes in Development Economics: Essays in Honour of Malcolm Adiseshiah,* OUP, Delhi.

Janakarajan,S. 1993. `In Search of Tanks’, *Economic and Political Weekly*, Vol.28, No.6.

Janakarajan,S. 1997a. *Conditions and Characteristics of Groundwater Irrigation: A Study of Vaigai basin in Tamilnadu*, Report of a research project sponsored by the Planning Commission, Government of India, MIDS, Chennai.

Janakarajan,S. 1997b. `Consequences of Aquifer Over-Exploitation: Prosperity and Deprivation’, *Review of Development and Change*, Vol.II No.1.

Janakarajan,S. 1999. `Conflicts over the Invisible Resourcein Tamilnadu: Is there a way out?’, in Marcus Moench, Elizabeth Caspari and Ajaya Dixit (eds), *Rethinking the Mosaic: Investigations into Local Water Management,* NWCF, Kathmandu and ISET, Boulder, U.S.A.

Janakarajan, forthcoming, `Populism, Myopia and Crisis’, *Water Nepal*.

Lindberg, Staffan, 1996. *While the Wells Went Dry - Tragedy of Collective Action among Farmers in South India,* a chapter for the anthology: “From Wild Pigs to Foreign Trees”, mimeo.

Moench, Marcus, 1992. `Chasing the Water Table: Equity and Sustainability in Groundwater Management’, *Economic and Political Weekly*, Vol.27, December.

Nanjamma, C. 1977. `Adoption of the New Technology in North Arcot District’, in. Farmer,B.H. (ed) *Green Revolution? Technology and Change in Rice Growing Areas of Tamilnadu and Sri Lanka*, New York, Macmillan.

Palanisamy,K, R.Balasubramanian and Mohamed Ali, 1996. *Management of Tank Irrigation by Government and Community: An Economic Analysis of Tank Performance in Tamilnadu,* Water Technology Center, TNAU, Coimbatore.

Rao,D.S.K, 1993. `Groundwater Over-Exploitation Through Bore holes Technology’, *Economic and Political Weekly,* Vol.38, December 25th.

Vaidyanathan,A, 1996. `Depletion of Groundwater: Some Issues’, *Indian Journal of Agricultural Economics,* Vol51, Nos 1 and 2, Jan-June.

Vaidyanathan,A and Janakarajan,S, 1989. *`Management of Irrigation and Its Effect on Productivity Under Different Environmental and Technical Conditions’*, research report submitted to the Planning Commission, Government of India, MIDS, Chennai.

Vaidyanathan,A (ed.) *Tanks of South India,* Center for Science and Environment, New Delhi, 2001

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