Chapter 3
Groundwater Depletion in India: Potential of Alternative Approaches and Policy Instruments

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Abstract Since the advent of green revolution in late 1960s, groundwater played an important role in the agricultural and economic development of India. However, large expansion in well irrigation due to policies of promoting private tube well construction, rural electrification programme and subsidies on electricity and diesel for agricultural use resulted in groundwater over-abstraction largely in north-western, western and peninsular India. As most of the measures to regulate groundwater overuse in India have met with little success, this chapter examines the viability of alternative institutional and economic instruments for sustainable groundwater irrigation. Analysis suggests that the enforcement of private and tradable property rights in groundwater can bring about a significant increase in farm outputs, with a reduction in the aggregate demand for water in agriculture. It will also bring about more equitable access to, and control over, the water available from groundwater for food production and thus ensure household-level food security. This has to be complemented by the pro-rata pricing of electricity in the farming sector, with improved quality and reliability of the supplied power.

Keywords India • Groundwater over-exploitation • Groundwater legislations • Water rights • Energy pricing

3.1 Introduction

In India, groundwater has become a mainstay of rural economy supporting agricultural development and providing food security to millions of people. Following diffusion of green revolution technology in late 1960s, the area of irrigated cropland using groundwater has expanded rapidly with farmers making extensive use of

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groundwater in irrigated agriculture. It came as no surprise that between 1993–1994 and 2006–2007, irrigation structures (dug wells and tubewells) pumping groundwater increased from 8.9 to 18.7 million. At present, groundwater nearly sustains 60 % of the net irrigated area and about 2/3rd of irrigated food production depends on irrigation from groundwater wells (Kumar 2007). Almost all major agricultural states in India heavily depend on groundwater for irrigation. In Tamil Nadu, Maharashtra, Madhya Pradesh, Rajasthan, Uttar Pradesh, Punjab, and Gujarat, groundwater caters to more than 60 % of the net irrigated area (CGWB 2006).

It has been estimated that crop yield in groundwater irrigated areas is higher by one third to one half then those irrigated by surface sources (Dhawan 1995). Productivity of groundwater irrigation is more than that of surface water because it is reliable, available at the point of use, requires minimum conveyance infrastructure, and has high application efficiency (Dhawan 1989). Thus in order to optimize crop yields and maximize profits from agriculture, farmers intensively use groundwater. Though it contributed significantly to agricultural and economic development of the country, of late it has thrown many challenges for the management and governance of this resource (Singh and Singh 2002). Overdraft of groundwater beyond the recharge potential resulted in water scarcity across many regions in India. Out of 5842 number of assessed administrative units, nearly 802 are over-exploited, 169 are critical, 523 are semi-critical and 4277 are safe.[1] Further, 71 assessed units are completely Saline.[2] In Delhi, Gujarat, Haryana, Himachal Pradesh, Karnataka, Punjab, Rajasthan and Tamil Nadu, number of over-exploited and critical administrative units are significantly higher (i.e. more than 15 % of the total assessed units) (CGWB 2011).

With this context, this chapter discusses the extent of groundwater overexploitation in India, various existing institutional arrangement for groundwater management and the role of alternative approaches and policy instruments in promoting sustainable use of groundwater for irrigation.

3.2 Extent of Groundwater Overexploitation in India

Groundwater use for irrigation in India has increased steadily and surpassed canal irrigation in the early 1970s (Fig. 3.1). Since mid-1960s, it is actually energized irrigation (through electric and diesel operated pumps) that has increased more. Between 1961 and 2002, number of electric pumps increased from mere 0.2 to 10.3 million, and diesel pumps increased from 0.2 to 6.5 million. The expansion of energised irrigation is attributed to: (1) government programs to promote private tubewells, supported by soft loans to farmers and rural electrification (Scott and Sharma 2009); (2) the general shift to a flat rate electricity tariff for agricultural use in most states (Janakarajan and Moench 2006; Scott and Sharma 2009); and (3) diesel subsidy. Such ambitious interventions led to overdependence and overuse of

[1] An administrative unit is categorized as: overexploited if the stage of groundwater development is more than 100 %; critical if it is between 90 % and 100 %; semi-critical if it is between 70 % and 90 %; and safe if it is below 70 %.

[2] Saline units are those where the entire assessment area is having poor quality groundwater.

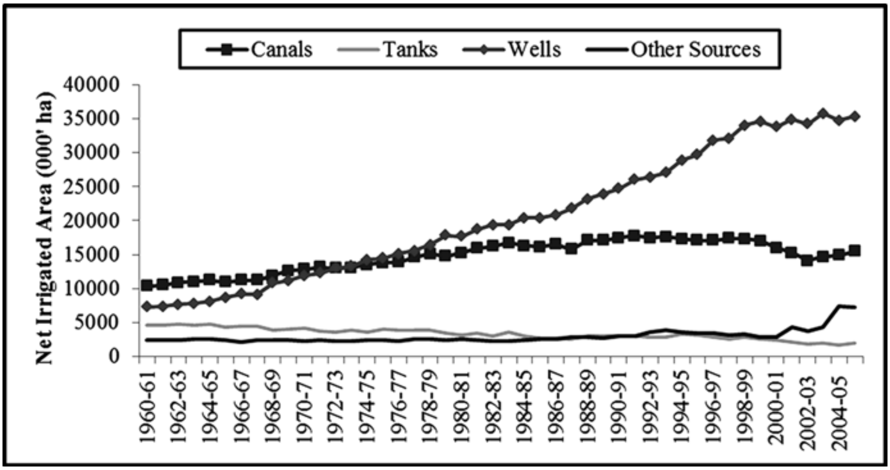

Fig. 3.1 Source wise net irrigated area (Source: Author's own analysis using data tables from Indiastat)

groundwater for irrigation in many parts of the country. This resulted in declining groundwater level, reduction in supply, saline water encroachment (Singh and Singh 2002; Narayanamoorthy 2010), drying of the springs and shallow aquifers, increased cost of lifting, reduction in free flow and even local subsidence at some places (Singh and Singh 2002). Lack of well-defined ownership rights in groundwater too contributed to its unsustainable use.

As a consequence of overuse of groundwater for irrigation, 37 % of the total assessed administrative units in Karnataka, 37 % of the total units in Tamil nadu, 49 % of total units in Haryana, 59 % of the total units in Rajasthan and 75 % of the total units in Punjab were found to be overexploited (CGWB 2006). These figures are much above the average figure (which is 15 %) of the country's total overexploited administrative units. However, it is argued that the current assessment of groundwater over-exploitation did not provide a clear picture of the actual extent of over-exploitation in both absolute and relative terms. It tends to underestimate the magnitude of groundwater overexploitation in India, which can be assessed from the negative social, economic and ecological consequences of over-development (Kumar and Singh 2008). From that perspective, many districts in Madhya Pradesh, Andhra Pradesh and Tamil Nadu could be actually over-exploited, though the official figures show that they fall under "safe", "semi-critical" or "critical" categories. The regions which have serious problems are alluvial Punjab, both the hard and alluvial areas of Gujarat, and the hard rock areas of Maharashtra, Tamil Nadu, Karnataka, and Andhra Pradesh.

Nonetheless, large-scale overexploitation of the groundwater resource has serious consequences for the Indian subcontinent where hard rock (consolidated) formations cover almost 70 % of the total area. In these hard rock areas, mainly in water scarce Western and Peninsular India, recharge of aquifers is comparatively low and often occurs at places having fissure or cracks or weathering in the rock formations. In general groundwater potential of hard rock areas is poor (Fig. 3.2), though relatively high yields may be obtained in restricted locations under favorable

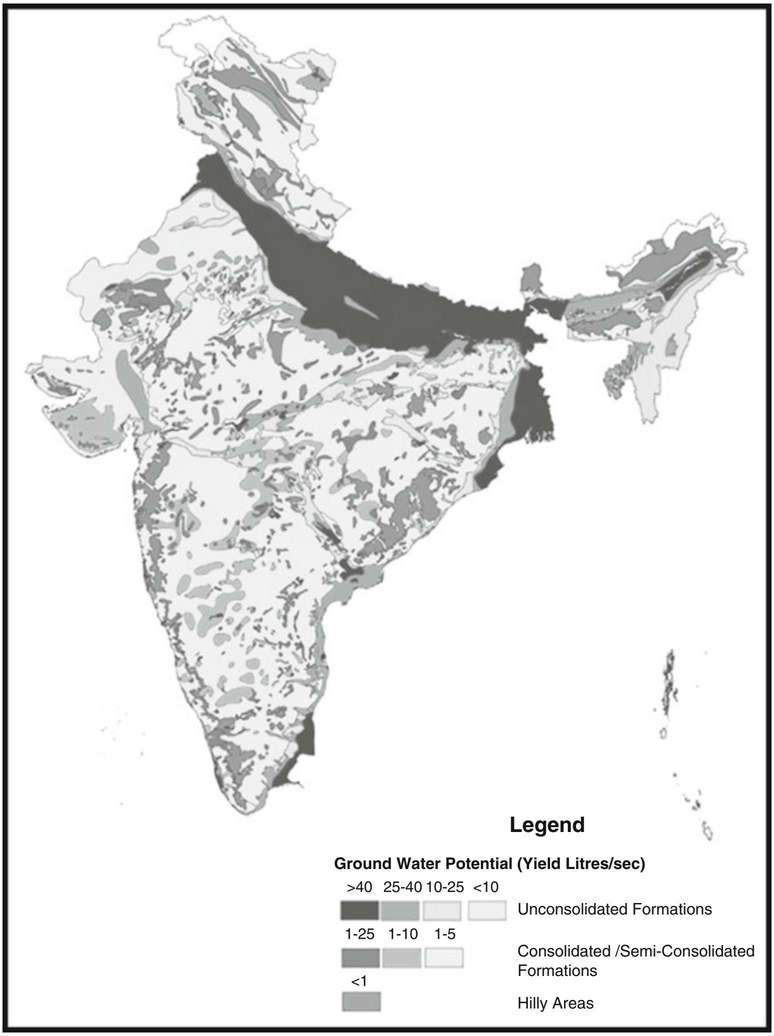

Fig. 3.2 Ground water potential in different hydro-geological settings, India (Source: CGWB 2006)

circumstances of topography and rainfall (NIH 1999). Therefore any form of over-exploitation seriously affects the groundwater availability and contributes to well failures in these regions (Bassi 2011).

Over the years, though the total number of irrigation wells in the hard rock regions has increased, there is a simultaneous increase in abandoned or failed wells (Fig. 3.3). Further, in some states, increase in number of wells has not contributed to corresponding increase in groundwater irrigated area. For example in Tamil Nadu, it was found that with the increase in number of wells there is no major increase in groundwater irrigated area after 1980s (Janakarajan and Moench 2006). Similarly,

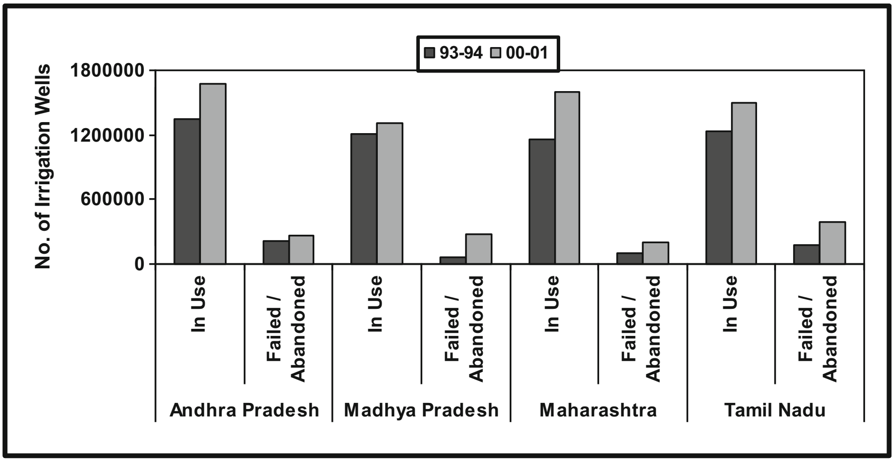

Fig. 3.3 Well failures in hard rock regions, India (Source: Author's own analysis using data from minor irrigation census and Indiastat)

in five districts of Madhya Pradesh namely Balghat, Chhindwara, Shahdol, Jhabua and Betul, the average command area of energized wells was observed to be declining almost consistently after mid 1970s (Kumar 2007). On the other side there are areas in the Gangetic river basin, mostly comprising alluvial aquifers in Bihar and West Bengal, with comparatively less development of groundwater resources (39 % and 42 % respectively). The reasons are: (1) small and fragmented land holdings; (2) low number of water extraction mechanisms; (3) high cost of energy; and (4) low investment capacity of small and marginal farmers (Sharma et al. 2008). Along with economic water scarcity, these are the areas which also face scarcity of arable land. As a result, development of groundwater for irrigation and overall agricultural growth is very low in this water rich eastern part of India (Kumar et al. 2011).

3.3 Institutional Arrangements for Groundwater Management in India

In context of groundwater management, institutional arrangements include formal laws dealing with groundwater, irrigation laws and their regulations, and informal norms regarding groundwater development and use (Kemper 2007). Some past legal attempts include Bombay Irrigation (Gujarat Amendment) Act of 1976 (on well depth restriction), Pondicherry Groundwater (Control and Regulation) Act of 2002 (on well spacing restriction) and Andhra Pradesh Water, Land, and Trees Act of 2002 (dealing with well registration and ban on well construction in notified villages). More recent is the Maharashtra Groundwater (Management and Development) Act 2009 which envisages several restrictions such as, ban on the construction of wells; prohibition on groundwater pumping from the existing deep-wells (more than 60 m deep); stipulation on deep-wells users to follow the groundwater use plan and crop plan.

In pursuance of these legislations, many direct and indirect measures were adopted for groundwater management in India. These include: artificial recharge in areas facing problems of overdraft; direct regulation of groundwater abstraction; indirect regulations through well financing and other leverages; local management of groundwater by user groups; and establishment of cooperative property rights in groundwater. However, most of these measures have met with little success and have been ineffective in arresting groundwater depletion (Janakarajan 2002; Kumar 2005). Moreover, the 1992 Model Groundwater Bill which advocates well permits, water metering, and withdrawal limits has not been properly adopted by any state so far (Saleth and Dinar 2000). But of late, direct institutional instruments; such as establishment of water rights and effective enforcement of legislations, and indirect economic instruments; such as power rationing (Scott and Shah 2004; Shah et al. 2008) and pro rata electricity pricing (Gupta 2002; Kumar 2005; Kumar et al. 2011), for managing groundwater demand are being increasingly advocated.

3.4 Can Water Rights and Energy Pricing Emerge as Better Options?

The spatial and temporal variation in both water availability and demand is very high in India. In eastern regions, such as states of Bihar, Eastern Uttar Pradesh and West Bengal, though water resources are abundant, irrigation demand is very low. Further, problems of water logging due to rising groundwater levels caused by flooding and excessive irrigation from canals are encountered (Shah 2001). On the other hand, demand for water is extremely high in water scarce arid and semi-arid regions of Gujarat, Rajasthan, Tamil Nadu, and Maharashtra, where groundwater is the major source of water for all purposes. Pumping regulations in these areas facing overdevelopment problems through groundwater legislation, control of institutional financing for well development, and restrictions on power connections for pumps have been ineffective (Janakarajan 2002; Kumar 2000).

It is argued that even an imperfect system of groundwater rights will have more sustainable benefits than a most perfectly designed power tariff structure (Saleth 1997). Many other scholars in the past have also suggested establishment of property rights as a means to build institutional capability to ensure equity in allocation and efficiency in use of water across sectors (Saleth 1994; Narain 1998; Kumar 2000). Other institutional mechanisms, such as groundwater legislations, to check and control overdraft have fallen flat due to their social and political implications. The issue of effective water rights is particularly important for irrigation water which has significant implication for agricultural sustainability (Saleth 1994).

Scott and Shah (2004) claimed that strict rationing of power supply to agriculture in India is having an unintended consequence of limiting the rate of groundwater exploitation. Further based on power reforms in Gujarat, Shah et al. (2008) argued that metering electricity use by tubewells and charging farmers at rates based on power consumption is detrimental to the marginal and landless farmers who largely depend on groundwater markets and hence, unlikely to happen in near future. Therefore best intermediate strategy is to provide good quality rationed power but at a common flat rate tariff to all tubewells regardless of whether metered or not metered. Citing example from water rich eastern state of West Bengal, Mukherji (2007) supported the view that high flat-rate electricity tariff encourages development of water markets whereby the water buyers, mostly small and marginal farmers, benefit from access to irrigation. But these views do not hold true in case of western and peninsular India which are water scarce and already facing increased problem of groundwater depletion due to continuing subsidized energy regimes for groundwater pumping. Researchers have indicated that energy rationing but without metering and unit pricing have failed to motivate farmers to use water and electricity efficiently (IRAP 2010). For instance, in Gujarat where *Jyotigram* scheme of rationalized power supply to farm sector was launched during 2003–2006, agricultural power consumption has actually increased from 9,571 million units in 2002–2003 to 11,009 million units in 2006–2007 (Data Source: Gujarat Electricity Board). Whereas, Kumar (2005) showed that unit pricing of electricity influences groundwater use efficiency and productivity positively. In fact, Kumar et al. (2011) has provided empirical evidence that raising power tariffs in the farm sector to achieve efficiency and sustainability of groundwater use is both socially and economically viable.

3.5 Water Rights as an Instrument to Manage Groundwater

In India, groundwater property structure has remained relatively unchanged since colonial era (Aguilar 2011). Based on the 'dominant heritage' principle implied in the Transfer of Property Act IV of 1882, the Easement Act of 1882 deems groundwater to be an easement connected to the land and grants landowners an unrestricted right to use the groundwater below the land (Saleth 2010). Since the land and well ownership is heavily skewed, there is an inherent inequality in access to groundwater (Kumar 2007). A formal system of water rights can mitigate this inequity in groundwater access and can also promote its sustainable use (Rosegrant and Binswanger 1994; Saleth 1994).

Over-exploitation occurs when users ignore the effects of their actions on the resource and other users when pursuing their own self interests (Johansson et al. 2002). For instance, in Gujarat, where there are well developed informal groundwater markets, water is sold without considering the limits of the resource. Though the allocation of purchased water may be more efficient than in absence of such markets, the groundwater level is nevertheless being drawn down (Kemper 2007). Under such scenario, absence of well-defined private property rights can be a major source of uncertainty about the negative environmental impacts of resource use, leading to its unsustainable use (Pearce and Warford 1993; Kay et al. 1997; Kumar 2003). Once the resource becomes scarce, well defined groundwater use rights can become a key mechanism to control over-abstraction (Kemper 2007). Saleth (1994) notes that the more robust, though politically and administratively harder, options such as the institution of a water rights regime could effectively limit and regulate both individual and collective water withdrawal and use from sub-surface sources. Well-defined groundwater use rights entitle individual users to an abstraction allocation at a certain point in time (Kemper 2007). However, the water rights administrative agency has to ensure that water rights granted will not result in annual pumping quantities that exceed safe yield (Peck 2003).

If the rights are allocated only to use water, it can create incentives to use it even when there is no good use of it. Therefore, water rights have to be tradable (Frederick 1993). Also, transferability and exchangeability of water rights are crucial to capture and reflect the scarcity value of water through price signal and guide water allocation accordingly (Saleth 1994). Well-defined tradable rights (especially in context of developing countries) formalize and secure the existing water rights enjoyed by water users; economize on transactions costs; induce water users to consider the full opportunity cost of water; and provide incentives for water users to internalize and reduce many of the negative externalities inherent in irrigation (Rosegrant and Binswanger 1994). Thus, the highest value of water use is taken into account and provides an incentive to users for more efficient use and reallocation of surplus water to a higher valued use (Kumar 2003; Kemper 2007). Empirical evidences from the functioning of groundwater irrigation institutions in north Gujarat show that under a system of fixed volumetric water use rights, farmers prefer to grow mustard, which is less water intensive, in larger area as compared to wheat, though the earlier one has much lower land use productivity than wheat, but getting same water use productivity (Kumar 2000, 2005). Further, volumetric pricing of water and its rationing as found in the shareholders of tube-well partnerships, farmers allocate their entitlements for growing crops that give higher economic returns from every unit of water used for crop production (Kumar 2005). But for a tradable groundwater use right to resolve overexploitation of groundwater aquifers, a definite proportion of the aquifer volume needs to be reserved to achieve a certain stabilization (Kemper 2007) on sustainable yield considerations (Kumar 2005).

Further, there is a need to separate rights to groundwater from right to land as it has constrained the potential for inter-sectoral allocation. Considering that agricultural use accounts for more than 80 % of water use, the modest transfer of water from agriculture could meet growing urban and industrial demands. As evident from other parts of the world, the infrastructure required for such inter-sectoral water transfers would cost much less than the large hydraulic infrastructures planned to meet growing water demand for domestic and industrial uses (Mohanty and Gupta 2002).

3.6 Pricing Energy for Limiting Groundwater Use

It is a common knowledge that users have an incentive to use a resource more efficiently when it is priced appropriately (Kemper 2007). In case of groundwater, energy pricing is important in developing economies like India where energy subsidies to agriculture are estimated between USD 1.9 billion and USD 6.5 billion per year. Further, the electricity subsidies to agriculture in India are estimated to be 26

% of the gross fiscal deficit. These range from 80 % in Madhya Pradesh and Haryana to 50 % in Andhra Pradesh, Gujarat and Karnataka, and to about 40 % in Rajasthan, Punjab and Tamil Nadu (Bhatia 2005). These are also the states which are experiencing tremendous groundwater over-abstraction for irrigation. Hence, the 'pro poor' subsidies regime has affected both groundwater situation and the state finances alike; and has already turned 'anti-poor' in several regions of Peninsular and Western India where the aquifers are already over-exploited and only the rich and large farm owners can afford to abstract water.

Earlier, many researchers have suggested rational pricing of electricity as a potential fiscal tool for sustainable groundwater use in India (Moench 1995; Saleth 1997; Kumar 2005; Kumar et al. 2011). Many argue that a flat rate based pricing structure in the farm sector creates an incentive for farmers to over-extract it, as the marginal cost of extraction is zero (Kumar 2005). Some researchers have argued that since the price at which groundwater is traded in regions like north Gujarat reflect the scarcity value of the resource, tariff hike would not have significant impact on groundwater use (Mohanty and Ebrahim 1995). However, such arguments are contested on the ground that the actual annual demand for irrigation services in hourly terms is much smaller in comparison to the total amount of groundwater the well owners can pump out during a year and that they are not confronted with the opportunity cost of using excess water for irrigating their own fields (Kumar and Singh 2001). Nevertheless, some scholars continue to advocate that the flat tariff regime with power supply rationing and supply management is the highly rationale, sophisticated and scientific pricing regime (Shah et al. 2007). But field studies suggest that power rationing with good quality supply but without metering and unit pricing has failed to arrest groundwater over-exploitation (IRAP 2010).

It is quite true that the policies with regard to water and electricity pricing are guided by strong political and economic considerations (Moench 1995). Once a subsidized regime is set, it is politically very difficult to return to energy prices that actually reflect the cost of energy to state (Kemper 2007). But the recent past has seen some remarkable success in introducing metering, and charging a power tariff based on actual consumption in some states. These include West Bengal (Mukherji et al. 2009), Uttarakhand (Bassi et al. 2007), and Gujarat (Kumar et al. 2011). In many Indian states farmers have been crying foul over the deteriorating power supply, which is free or highly subsidized, and instead were demanding a good quality power supply with a price. A field research study undertaken in Madhya Pradesh confirmed that it is actually small and marginal farmers who have been affected most by the subsidized power driven groundwater overexploitation as they have limited resources and access to groundwater (Bassi et al. 2008). It was further analysed that the aggregate net returns per farmer for small landholders were 41 % less than the large landowners. Similarly, aggregate net returns per well for small landholders were 39 % less than the large landowners (Fig. 3.4).

Citing the case of the aquifers of the Lower Jordan River Basin, Venot and Molle (2008) argued that any substantial increase in volumetric charges is unlikely to enable regulation of groundwater abstraction and would further decrease the income from low-value or extensive crops. They emphasized that significant reduction will

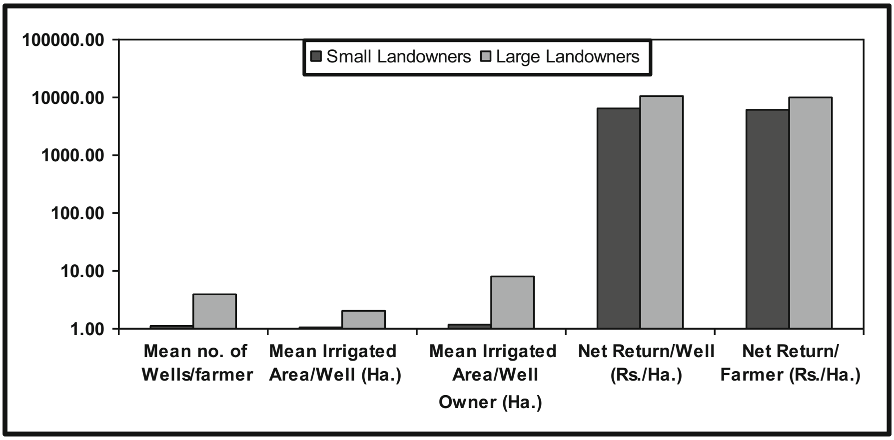

Fig. 3.4 Well irrigation characteristics and returns, Bagli block, Madhya Pradesh (Author's analysis of primary data)

only be achieved through policies that reduce the number of wells in use. However, the empirical studies carried out so far on the issue of energy pricing on groundwater use in India show that the introduction of consumption-based pricing of electricity and an increase in unit charges, if combined with improvement in the quality of power supply, will lead to greater agricultural income and a reduction in use of groundwater (IRMA/UNICEF 2001; Kumar 2005; Kumar et al. 2011). Scott and Shah (2004) held that a zero or flat-rate tariff provides no incentive to limit pumping; however, the increases in metered tariff required for elastic demand behaviour are likely to be significantly higher than are acceptable to either farmers or politicians (also refer to de Fraiture and Perry 2002). However, empirical studies in North Gujarat (Kumar 2005) and in South Bihar, Eastern UP and north Gujarat (Kumar et al. 2011) established that the levels of pricing at which demand for electricity and groundwater becomes elastic to tariff are socio-economically viable.

Some researchers have also questioned the feasibility of installing meters at such a large scale because of the huge transaction cost involved in it (Shah et al. 2007). However they were found to be rather excuses used by officials and other functionaries of electricity departments to cover up the revenue losses due to poor operational efficiencies, resulting from transmission losses and distribution losses, including thefts (Kumar 2009). With the advent of pre-paid electronic meters which work through scratch cards (Zekri 2008) and work on internet or mobile technology and remotely-sensed meters (Kumar et al. 2011), the transaction cost of metering can be minimized to a great extent. The use of remotely-sensed meters can also avoid the huge transaction cost of metering. The technology used in these meters enables them to be installed in places where tampering by farmers and meter readers will be difficult, yet where readings can be easily obtained. This is now used for measuring electricity consumption by agro wells in West Bengal (Mukherji et al. 2009).

But, such fiscal instruments are required in regions experiencing over-draft. In India, overdraft appears to be occurring in regions which experience low to medium rainfall with high aridity (Kumar and Singh 2008). Metering and pro rata pricing of electricity may not be required in those regions which have abundant groundwater, if the issue of cost recovery in electricity supply can be addressed through other modes of pricing. The reason is that metering is essentially an economic decision and the benefits of metering have to justify the efforts involved (Arghyam/IRAP 2010). In water-abundant regions, the social and economic benefits of groundwater conservation through metering may not be very significant. Therefore, in those regions, the pricing structure should be designed in such a way that it encourages greater use of groundwater for boosting agricultural production. But caution should be exercised, to see that it does not create negative effects on equity in distribution of energy subsidy benefits. The flat system of pricing, based on the connected load of the pump set, can be a good basis for pricing electricity in groundwater abundant areas (Kumar et al. 2011).

3.7 Conclusion and Policy Implication

The number of groundwater wells in India has almost doubled during the last two decades. Further, incidence of well failures has been on rise especially in regions characterized by poor specific yield and groundwater potential. These instances give clear signs of aquifer depletion which requires some immediate solution. However, existing state regulations concerning groundwater management have been able to achieve little. Additionally, compliance with age old colonial laws and policy of providing free or subsidized energy supply for irrigation use has resulted in over-exploitation of aquifer and misuse of abstracted groundwater. Though started as a pro-poor policy initiative, energy subsidies are quickly turning into pro-rich policy initiatives by allowing resource rich farmers to continue more pumping.

Enforcement of private and tradable water rights in groundwater can together bring about a significant increase in farm outputs, with a reduction in aggregate demand for water in agriculture. It will also bring about more equitable access to, and control over, the water available from groundwater for food production and ensure household-level food security. In this formal regime, small farmers and the poor will gain water rights, which would empower them, and can serve as additional collateral (Mohanty and Gupta 2002). This has to be complemented by the pro rata pricing of electricity in the farm sector, with improved quality and reliability of the supplied power. Flat tariff regimes, whether rationed or managed, can do little to control groundwater and energy use in agriculture. Therefore, metering and pro rata pricing of electricity has to receive priority, especially in naturally water-scarce regions which also experience groundwater over-draft. Whereas, in the groundwater-abundant eastern region of India, the pricing structure in the farming sector should be designed in such a way that it encourages greater use of groundwater. However, in such areas there is a limit to agricultural growth as availability of per capita arable land becomes a constraint.

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