Chapter 5
Groundwater Irrigation in Punjab: Some Issues and a Way Forward

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5.1 Background

5.1.1 Concerns in Agriculture

Punjab located in the northwestern part of India comprising a mere 1.54 % of the total geographical area, and little over 2 % of the total population in the country accounts for 12 % of the national food grain production. It is the largest contributor of wheat (around 55 %) and second largest contributor of paddy (around 42 %) to the central pool of the country, though its relative contribution in central pool of food grains for both wheat and paddy has been declining during the last few years (Singh et al. 2012; Tiwana et al. 2007). Sustainability of agriculture in Punjab is thus important for the state's economy and also for food security in India.

Thrust on agriculture in Punjab started during the green revolution period. Supported by a mix of institutional and technological factors, 85 % of the area in the state is under agriculture. The area sown more than once has increased by 250 % since the late sixties. Consolidation of landholdings, reclamation of new agricultural lands, development of irrigation, and use of biochemical inputs comprising high-yielding variety seeds, chemical fertilizers, insecticides, and mechanical inputs were among the important factors which helped agriculture in the state in making rapid strides.

The emerging scene of agriculture in Punjab is facing some serious concerns. Green Revolution sustained till the eighties, after which the agricultural production in the state showed the signs of stagnation.[1] This has been largely attributed to

[1]Signs of stagnation in agriculture were not limited to Punjab alone.

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continuous cultivation of rice–wheat cropping system[2] having negative implications for soil quality (nutrient balance) and infestation of weeds and pests. In the nineties, increase in the cost of inputs (increased application of fertilizer and insecticides was necessary to address soil health and pests issues; falling water tables required additional investment for irrigation) further aggravated the situation through squeezing the profitability of agriculture adversely affecting the socioeconomic condition of farmers in the state. According to (GoP 2013), the agriculture in state has reached a plateau making it very hard to make further progress under available technologies and the natural resource base, and the very sustainability of rice–wheat production system is under threat and climate change is posing new challenge on future agricultural growth.

5.1.2 Concerns in Groundwater

Groundwater has played a key role in success of green revolution in India in Punjab, Haryana, and western Uttar Pradesh (UP). Data from minor irrigation census 2011 show that these states account for 55 % of the tube wells in India. On an average, there are 28 tube wells per sq. km. of net sown area in Punjab alone. Punjab has 85 % of its area under cultivation with an average cropping intensity of 188 %. The water demand from agriculture in the state is therefore very high.

High water demand is also attributed to the water-intensive commercial crop models promoted during the green revolution. This was further incentivized by, among others, procurement and price support policies leading to massive surge in groundwater development for irrigation in Punjab.

The net area irrigated by wells covers 71 % of the total irrigated area of the state, while the remaining 29 % is irrigated by government canals.[3] Punjab's water table has been reducing at an alarming rate, with most of the demand coming from irrigation. The rate of fall in water table was 18 cm during 1982–87, which increased to 42 cm during 1997–2002 (Hira et al. 2004) and further to 75 cm during 2002–2006 (Singh 2006). The current situation of groundwater development in Punjab is the most critical in the country as 80 % of the monitored wells are considered overexploited (CGWB 2012). Annual groundwater extraction in Punjab is 31.16 billion m^3 as opposed to 21.44 billion m^3 availability. Very high level of groundwater is being extracted in Amritsar, Fategarh Sahib, Jalandhar, Kapurthala, Mansa, Ludhiana, Moga, Nawanshahr, Patiala, and Sangrur Districts. Out of the 137 blocks in the state, only 25 are safe; 103 are overexploited, 5 critical, and 4

[2]Almost no rice was grown in Punjab prior to 1950. According to Johl 2002, 35 % of gross cropped area was under rice in the state.

[3]Punjab hosts three main perennial rivers-Sutlej, Beas, and Ravi; and a seasonal river Ghaggar. This water is mainly supplied through a vast canal network of about 14, 500 km. The canal water supply is more extensive in the south-western zone of the state which receives less rainfall and has high salinity in soils and ground water. http://www.pbirrigation.gov.in

semi-critical (IDFC 2013). Area identified by CGWB for groundwater recharge is 2.275 m ha. The issue of overexploitation of groundwater is concentrated mostly in central Punjab. Other areas have waterlogging and salinity and poor water quality issues.[4]

This clearly is resulting in significant and increasing social and economic costs. Farmers are being confronted with the need to move to deeper wells with inevitable increase in cost of farming, making it especially difficult for small and marginal farmers. This also has implications for intersectoral distribution and equity. Subsidized agricultural power supply is putting an additional and unsustainable burden on state budgets.

This precarious situation calls for an integrated approach including a mix of regulatory, technological, and economic instruments to address groundwater management in Punjab besides high-level policy reform.

5.1.3 The Questions Asked in This Paper

This paper therefore aims to ask and assess three questions: Why groundwater? what has been done in Punjab and other states to address decline in groundwater levels? and What evidence and insights does a selective review of empirical literature provide on water demand and supply dynamics? Based on these analyses, the paper identifies the main issues and suggests a way forward in this context.

5.2 The Nature, Magnitude, and Drivers of Decline in Groundwater in Punjab

5.2.1 Understanding the Nature and Magnitude of the Problem

The aquifers underlying Punjab are characterized by alluvial deep systems which lead to higher specific yield relative to shallow hard rock formations in some other parts of India. In general, the major sources of inflow into the aquifers are precipitation in addition to other sources of recharge including that from irrigation recharge. The term 'aquifer overexploitation' applies to a physically unsustainable situation in which the extraction of groundwater exceeds the recharge within a given area over a given period of time. Recharge rates that are low relative to

[4]In about 20 % area of Punjab especially in South-West, ground water is of poor quality which led to liberal allocation of canal water. Poor efficiency of canal system covering 70 % area in South-West Punjab as compared to 14 % in Central Punjabhas contributed to fast rise in water table in south west causing poor land productivity.

storage, combined with the common occurrence of saline groundwater at greater depths, or at the same level in other parts (as is the case especially in south-west Punjab), can put these large alluvial aquifers at risk of aquifer mining and irreversible overexploitation as well as contamination of water. The hydrogeological systems and other dynamics underneath the earth are much more complex; however, this simple definition of overexploitation provides a physical indicator for the purposes of classification of groundwater blocks and helps in making an assessment of the environmental and socioeconomic costs of groundwater exploitation (This Para draws from World Bank 2010).

Other indicators of overexploitation of groundwater would be decreasing well yields and frequent well failures, deeper drilling depths, and use of advanced and expensive technology. Also, as the depth to water table deepens, the amount of energy required to pump a unit of water is likely to increase. These indicators not only help make an assessment of economic costs of overexploitation but also distributive aspects.

The water tables in Punjab have been in continuous decline on a widespread basis, with aquifer depletion rates currently in the range 0.7–1.2 m per year (approximately equivalent to a net 100–200 mm per year of excessive extraction) (World Bank 2010). The cost of extracting groundwater depends on the depth of water table. The fixed cost of extracting groundwater at around 8 m shows sharp increase. At 8 m, surface pumps become infeasible to extract water and farmers have to invest in more expensive technologies such as submersible pumps to extract groundwater. Punjab had the largest area experiencing such decline (Sekhri 2012a). What is alarming is that the decline has accelerated over time.

An important aspect of groundwater management is the analytics of water ownership. In India, including Punjab, land owners have the right to dig wells on their land and access and own water underneath (private property right) (Singh 1992). Given the physical and the hydrogeological attributes of the groundwater, it cannot be compartmentalized such that it coincides with the landholding pattern. This unique feature of the resource can potentially constrain the private property right to the extent the wells of neighboring farmers/density of wells in village/block/area interfere with the yield/life of a given/set of well(s).[5] Since only the landowners can own groundwater, it cannot be characterized an open access resource. Further, interactive effects of wells make it difficult to assign common property rights to groundwater (Chandrakanth et al. 2011). This study however notes that a number of studies have attributed common property rights to the groundwater resource.[6]

[5]The density of wells per unit area as well as the number of wells per million cubic meter of groundwater which determine the degree of interactive effects of wells is increasing over time in Hard Rock Areas (Chandrakanth et al. 2011).

[6]See Moench (1995).

5.2.2 Why Groundwater: The Drivers

Groundwater use is strongly contextual and intersectorally linked. It is important to emphasize that in India, in general, the primary driver of private groundwater use is neither resource availability nor well yield potential (Shah 2007), but the inadequacy and unreliability of water provided through the public water supply systems.

In agriculture, for example, groundwater use depends significantly on the availability of surface irrigation, energy options and costs of pumping, and cropping choices. In the elevated alluvial areas of central Punjab, water tables are deeper and coverage of irrigation canals is less extensive than in the lower plains.[7] The primary driver in this case was absence of surface water and the abundance of groundwater. Government support for developing wells however (subsidies on well construction and equipment) contributed to this significantly.

Secondary drivers: Groundwater has advantages like farmers can control the timing and amount of water. Supportive policies that provided flat rate/subsidized/free electricity for irrigation well pumping; cheap diesel; support in terms of assured prices; and procurement for some crops with very high consumptive use of water, such as paddy, wheat, and sugarcane facilitated groundwater extraction.

Being a largely private activity, the groundwater use went unregulated. This led to instances of water 'Landlords' selling surplus water from under their land to small and marginal farmers and for other use.

5.2.3 Welfare Implications

From a welfare perspective, rapid decline in water tables can result in significant social cost. Sekhri (2011) uses groundwater data in conjunction with annual agricultural output data at the district level to show that a 1 m decline in groundwater from its long-term mean can reduce food grain production by around 8 %. Using village level data from UP and the fact that there is a nonlinearity in cost to access groundwater at 8 m, Sekhri (2012b) shows that poverty rate increases by around 11 % as groundwater depth falls from over 8 m to below 8 m. In some parts of Gujarat, where the water tables are falling almost at a rate of 3 m a year, it is estimated that water savings of 30 % can free up 2.7 billion units of electricity for non-agricultural use. Department of drinking water supply, Government of India, estimates that in 2010, approximately 15 % of the total habitations in the country went from full coverage of drinking water to partial coverage due to drying up of groundwater sources.

[7]Central Punjab provides the most significant and illustrative example for considering the issues and approaches for addressing excessive groundwater exploitation (World Bank, 2010).

5.2.4 The Main Issues

The groundwater situation in central Punjab can be characterized by overexploitation (largely attributed to crop intensification and unsustainable crop mix), negative externalities (due to interactive effects of wells), inefficiencies (low productivity of water), and inequities (initial and premature well failure). Both the primary and secondary drivers coupled with weak or absent water management policies and institutions are said to be responsible for much of the problem. Incentives and penalties are thus crucial in bringing about sustainability, efficiency, and equity in water use.

5.3 Policy and Programmes for GroundWater Management in India

Legislative provisions: The Indian Constitution provides the states jurisdiction over the groundwater within their boundaries. Also, state governments have the primary responsibility for water supply and irrigation with powers to devolve these functions to up to village level institutions.

At the central government level, the Ministries of Water Resources (MoWR) and of Environment and Forests (MoEF) are responsible for evolving policy guidelines and for enforcing protection of surface and groundwater resources both in terms of quality and quantity. Since water is a state subject, the policy guidelines are mostly of an advisory nature with the implementation left to the state governments.

In the recent times, the Courts have played a proactive role in evolving policy guidelines and enforcement. The Supreme Court of India on the basis of public interest litigation passed several orders in 1996 and issued directions to the Government of India for setting up the Central Groundwater Authority (CGWA) under the Environment Protection Act, 1986 (EPA 1986), for the purposes of regulation and control of groundwater development. The Court further directed that the CGWA should regulate indiscriminate boring and withdrawal of groundwater in the country and issue necessary directions with a view to preserving and protecting the groundwater.

The CGWA in consultation with the Ministry of Law has opined that though the states are competent to make their own laws pertaining to groundwater and constitute state groundwater authorities, the provisions of the EPA (1986) would override the state under Article 253. The CGWA has notified sixty-five areas in various parts of the country for registration of groundwater abstraction structures. Based on data thus generated, vulnerable areas are notified for the purpose of groundwater regulation.

In an effort to control and regulate the development of groundwater, the MoWR prepared and passed a model Bill in 2005 for adoption by all the states and UTs. The main thrust of the Bill is to ensure that all the states and union territories form their own state groundwater authorities for proper control and regulation of groundwater resources. Some of the states (see Planning Commission 2007) have already enacted groundwater legislation, although at various stages of development. The Planning Commission's Expert Group on Groundwater Management and Ownership has argued that the legislative framework is reasonably robust, in that in principle, it enables the groundwater management practices that are likely to be pragmatic and effective in India. The priority lies in the enforcement of existing measures, supported by innovative approaches such as an expansion of community-based management.

Administrative and organizational set up: Management of groundwater suffers from fragmentation of responsibility at both central and state levels. Many agencies in various sectors have mandates relevant to groundwater, but there is little coordination among them and a lack of regulatory oversight. Not all states have dedicated groundwater authorities, and in almost, all cases groundwater-related agencies suffer from under-staffing, lack of capacity, marginalization, and outdated mandates that prioritize survey and development ahead of resource management.

Although the CGWA and Central Groundwater Board (CGWB) have the potential to become champions of sustainable groundwater management in India, the continued lack of clarity over their status and chronic under-staffing means central government institutions cannot properly fulfill their functions and effectively support state agencies (World Bank 2010).

5.3.1 Policy and Programmes for Groundwater Management in Punjab

The Punjab state government is yet to formulate groundwater legislation despite serious depletion of groundwater levels (particularly in central Punjab). Also, Punjab does not mandate rainwater harvesting. However, recent initiatives such as (i) incentives for changing cropping pattern, (ii) regulation mandating delayed paddy nursery and sowing activities (The Punjab Preservation of Sub Soil Water Act 2009), (iii) considering reforms in agricultural power sector, and (iv) other demand- and supply-side measures are significant positive steps.

5.3.1.1 Crop Diversity Programmes in Punjab, Haryana, and Western Uttar Pradesh

The purpose of this program (Government of India designed and funded program)[8] is to motivate farmers in Original green revolution States to divert the area of paddy

[8]Crop Diversity Programme in Punjab, Haryana, and western Uttar Pradesh(2013-14), Ministry of Agriculture, Government of India.

to alternate crops (maize, *kharif* pulses, oilseeds, cultivation of *rabi* and *kharif* intercrops) from ensuing *kharif* season. Through this program, the following is expected to be achieved:

(i) To demonstrate and promote the improved production technologies of alternate crops for diversion of paddy cultivation;
(ii) To restore the soil fertility through cultivation of leguminous crops that generates heavy biomass and consumes less nutrient intake.

The program will be implemented in the notified overexploited and critical blocks based on the recommendation of CGWB. At least 5 % of area under paddy in identified blocks will be diverted toward alternate crops. The program provides for assistance for land development, farm mechanization, and establishment of agro-based processing units for value addition and marketing support to generate additional income and restore soil fertility. The program will be implemented by the central government through a Central Steering Committee constituted for the purpose. An amount of Rs. 500 crore has been earmarked under *Rashtriya Kisan VikasYojana* for the year 2013–14.

5.3.1.2 The Punjab Preservation of Subsoil Water Act, 2009

It is encouraging that the Government of Punjab has recognized that overexploitation of groundwater is an issue of serious concern and has recently implemented this Act to contain it. The main purpose of the Act is to save groundwater by prohibiting sowing and transplanting paddy before specified dates in hot and dry summer[9] period. The Act prohibits farmers from sowing nursery of paddy before 10 May and transplanting paddy before 10 June in a year. Any farmer, who contravenes the provisions of the Act, shall be liable of penalty of rupees ten thousand for every month or part thereof, per hectare of the land till the period such contravention continues.

The authorized officer, either *suo motto* or on the information brought to his notice regarding the violation of any provision of the Act, shall be competent to issue directions to the farmer, who has violated any provision of this Act to destroy the nursery of paddy or sown or transplanted before the notified date. In case, a farmer does not act as per the directions of the authorized officer given under the Sect. 5.5 and the authorized officer shall cause such nursery of paddy, or sown or transplanted paddy, as the case may be, to be destroyed at the expenses of such farmer.

According to, Singh (2009), the fall in water table can be checked by about 30 cm by delaying the transplanting with the effective implementation of the Act.

[9]There is hardly any rainfall up to 15th June in Punjab and the relative humidity is lowest, wing speed is highest and temperature is maximum, due to which water evaporates very fast (Singh, 2009).

The savings in electricity have been estimated at 276 million units.[10] In contrast to these findings, a recent study (Sekhri 2012a), which evaluated the impact of this Act, finds that the annual ground level situation worsened in rice-growing areas after the policy change. The intuitive reason for this could be in farmers' response to policy in increased number of irrigation applied or more water used per irrigation. The study observes that in the absence of farm level data on number of irrigation applied and water use, it is not possible to establish the mechanism.

5.3.1.3 Introducing Reforms in Agricultural Power

Based on personal communication with government officials in Punjab, the following insight into current deliberations in Punjab in this context can be summarized as follows:

- All tube wells would be electrified by 2015 although there are no plans of metering of electricity at the tube well level which is estimated to cost Rs. 700 crores.
- Electricity consumption is currently monitored only at the feeder level. It appears that the government is open to learn from experiences based on the Gujarat model of separate feeders for agriculture and 24 × 7 electricity provisions.

5.3.1.4 Other Measures

Policy on use of technological solutions such as happy seeders, laser levelers for promoting water use efficiency, and other resource conservation technologies (RCTs) for water saving and increasing productivity is under consideration. Some of these technologies are already in use although there is no government policy yet on promoting the same.

Artificial recharge project in Moga district

As per the available estimates, all the blocks in Moga district are categorized as overexploited where groundwater withdrawal has exceeded natural recharge by more than 200 %. The decline of water levels has severely impacted the farmers of the area especially those having land less than 2 ha. It was reported that in this area many farmers started migrating to non-farming activities such as dairy farming or even selling off their lands to big landlords having adjoining farmlands. In order to augment the dwindling groundwater resources, a project for artificial recharge was taken up for augmenting the depleted aquifer through artificial charge in Bassian

[10]These estimates are based on simulations using historic data from central Punjab and does not account for selection issues (Sekhri, 2012a).

Drain in Moga district. The project is reported to have shown encouraging results. In an area of 11 km^2, the observed rise in water level was 0.20 m that could also save 15 MW of energy due to reduced lift of pumps. The farmers of the area also reported that there is appreciable increase in the discharge of their shallow tube wells due to artificial recharging of aquifer system of the area. This project can potentially be replicated (Gupta and Marwah 2012).

5.4 Potential Measures and Instrument for Promoting Sustainable Use of Groundwater

Significant social and economic consequences of overexploitation of groundwater in Punjab require a focused approach for effective intervention. A mix of regulatory, economic, and institutional options with focus on irrigation efficiency in general and economic efficiency in the use of irrigation water in particular can be used. In this context, two broad categories of intervention are water demand management measures and supply management measures that would target resource enhancement.

5.4.1 Supply-Side Measures

These measures target resource enhancement as a means of recovery in water tables (which is a very complex phenomenon) mainly through measures which would enhance the recharge of the aquifer through infiltration. This can be done by: (i) retaining runoffs (by building physical structures, forest conservation, afforestation, plantations, rainwater harvesting, etc.), (ii) artificial recharge (uses surface water and runoff)[11] practices, and (iii) adopting agricultural practices including RCTs such as laser levelers, tensiometers, and happy seeders[12] which promote infiltration and/or reduce loss of irrigation water. Alluvial settings in Punjab with abundant excess runoff as well as groundwater storage capacity required for recharge provide good potential for recharge (World Bank 2010). It appears that these measures have not yet received the desired attention. It is important to note here that there is little or no public investment on groundwater development/resource enhancement. While surface water is provided by public

[11]A project was taken up for augmenting the depleted aquifer through artificial recharge in Bassian Drain in Moga district. In an area of 11km2 the rise in water level observed was 0.20m. See Gupta and Marwaha (2012).

[12]As per the personal conversation with officials of farmers' associations in Punjab some progress has been made in this direction by promoting and improving farmers' access to these technologies.

investment on tanks, dams, and reservoirs, groundwater has to be extracted and used by farmers' private investment.

Delhi was the first state to mandate rainwater harvesting. Many states followed the suit. In Gujarat, concentrated efforts to recharge groundwater began in the Saurashtra region after the 1987 drought. Initial efforts to divert runoff to groundwater wells led to widespread adoption of the practice by farmers throughout Saurashtra without government intervention. Over time, farmers experimented with new technologies and farmers began constructing check dams in streams and rivers to reduce water speed and to allow the river water to seep into the ground and replenish the groundwater supply (Mehta 2006). Farmers continued constructing check dams through the 1990s with the assistance from NGOs who also bore some of the costs. In January 2000, the Gujarat government introduced the Sardar Patel Participatory Water Conservation Project in response to the work of farmers and NGOs in the Saurashtra, Kachchh, Ahmadabad, and Sabar Kantha regions. The program initially funded 60 % of the estimated cost of new check dams, and beneficiaries/NGOs financed the remaining 40 %. In 2005, the government increased its financing to 80 % of the estimated cost, and the pace of construction increased outside of the Saurashtra region.

5.4.2 Demand-Side Measures

While broader interventions in groundwater management through groundwater legislation and other sectoral policies will certainly be needed to bring down groundwater extraction/use in the state within the sustainable limits, in this section we explore suitability of some demand management measures with potential to make a difference in Punjab situation.

Broadly speaking, demand-side measures can be categorized into three types of instruments: regulatory instruments, economic instruments, and other instruments—a residual category.

5.4.2.1 Regulatory Instruments

In the present context, such measures would include metering and rationing of water/electricity, prohibiting nursery and planting of identified crops before specified dates, promoting substitution of less water consuming crops for water-intensive crops, and farming practices for improving water use efficiency.

Effective regulation in general requires not only sound legislation but also the administrative capacity to monitor and enforce rules. Moreover, metering water/electricity will involve significant transaction costs when there are very large numbers of small users, as in the case of Punjab due to fragmentation of land. Standard environmental economics theory tells us that a price-based instrument is expected to be potentially more successful in such a setting unless it is a case of severely threatened resources/blocks[13] which would require urgent focus on the quantity of water.

The Punjab state government is yet to formulate groundwater legislation. As discussed before, measures such as crop diversity program for promoting alternate crops in paddy areas and Punjab Preservation of Subsoil Water Act, 2009, for promoting water saving are being implemented.

According to Kulkarni and Shah (2013), in many ways trajectory of water resource development in Punjab has been following a simple principle of 'developing' which in the case of groundwater means extracting more water to produce more grain. The consequences of intensive water resource mobilization, in the absence of systematic groundwater management backed by robust water governance mechanisms, have been extreme depletion of groundwater resources on the one hand and a rising water level, leading to waterlogging and soil salinity on the other (Kulkarni and Shah 2013; Perveen et al. 2012).

5.4.2.2 Economic Instruments

These can be categorized into price-based instruments and quantity-based instruments.

Price-based instruments

These would include pricing in the form of a tax, cess, user fee, etc. These can act as incentives to conservation of water. Actual impact will depend on the price elasticity of demand for water/electricity for pumping groundwater. In designing, these instrument issues such as the equity considerations of the groundwater-dependent farmers vis-à-vis those who have access to surface irrigation[14] and equity and affordability of small and marginal farmers will need to be addressed. However, implementation and transaction cost issues are similar as in the case of regulatory instruments. Although if designed well, due to inherent static cost minimization and dynamic efficiency, price-based instruments will result in more efficient allocation and use of water resources.

Tradable groundwater rights

While a well-defined rights regime helps water users to reach optimal outcomes, the measure can involve very high transaction costs of implementation. However, if this instrument is implemented in a framework of shared/community/public well and is appropriately mixed with regulatory and/or price-based instrument, this can

[13]A regulatory instrument or a quantity based economic instrument such a tradable permits is recommended in such settings.

[14]Surface irrigation has huge subsidies. Fixed costs do not enter the price; only a small fraction of operating cost is recovered.

overcome the scale and public monitoring constraints and thus result in lower transaction costs.

Shared/community/public wells concept may be tried as a pilot. Sekhri (2011) shows that public wells provision can reduce the rate of depletion, and if an optimal price is charged, it can also reverse depletion. But this can work only where cost of groundwater extraction is high, or in areas where water tables are deep. Foster and Sekhri (2008) find evidence that bilateral trade arrangements between farmers who sell and buy groundwater also decelerate depletion rates. Malik et al. (2008) show that in a shared well situation in Bist Doab area of Punjab under conditions of rationed water allocation, the farmers have high motivation to allocate more water to crops that are economically more efficient and also use it more efficiently for the chosen crops than the farmers who have unrestricted access to groundwater by virtue of having wells under individual ownership. In this case, their access is limited in terms of number of hours per day access to pumps which is linked to the size of shareholding (land/crop). The benefit of promoting such arrangements is that these do not require top-down monitoring. It has been argued that water rights without tradability will lead to wasteful use (Frederick 1993). On the contrary, Rosegrant and Ringler (1998) indicate that tradable water rights would lead to farmers allocating their water for high-value crops. A clear understanding on this can contribute to designing appropriate institutions and policies for sustainable use of groundwater.

Internationally, the only developing country where evidence of positive efficiency and equity impacts of tradable property rights in groundwater is seen in Chile (Rosegrant and Gazmuri 1994; Thobani 1997).

5.4.2.3 Other Instruments

This category, in the present, context would include the following:

- Subsidies/user charges for promoting investment in/leasing of water-saving methods/equipment.
- Public disclosure of information on receding resource and potential medium and long-run risks associated with it. Groundwater literacy and sensitization.
- Measures such as supporting environment for uptake/marketing of alternate crops to encourage farmers gradually reduce cropping of water-intensive crops.
- Technology, research, and extension support.

The Andhra Pradesh Farmer Managed Groundwater Systems Project (APFAMGS) shows that sustainable management of groundwater is feasible only if users understand its occurrence, cycle, and limited availability. Preliminary findings in the project area have shown that the project has achieved a closer alignment of water availability and water use, and reductions in groundwater use have been realized through, for example, crop diversification (with an increase in low-water-use crops) and water-saving irrigation methods. Importantly, farmers have not sacrificed profitability to reduce water use. The reductions in groundwater draft in APFAMGS are not coming from altruistic collective action, but from the individual risk management and profit-seeking decisions of thousands of farmers (World Bank 2010).

Another success story in Andhra Pradesh is the system of rice intensification (SRI). Several factors such as depleted water resources, stagnated rice productivity, the growing importance of organic agriculture, increased production costs, and the need for better utilization of family labor among small and marginal farmers called for a shift in cultivation practice. SRI offered a way to not just reduce the demand for water while growing irrigated rice, but also of simultaneously increasing rice production. SRI was introduced in Andhra Pradesh in kharif 2003 in all 22 districts of the state by Acharya N.G. Ranga Agricultural University (ANGRAU). Since 2003, ANGRAU has taken several initiatives to promote SRI in Andhra Pradesh.

RCTs such as zero tillage, laser land leveling, and furrow bed planting have received attention in the context of increasing the productivity of the rice–wheat cropping pattern in south Asia (food security issues) and saving of increasingly scarce water resources. While the impacts of RCTs on yields are easy to measure, impacts on water savings are not well understood beyond the field scale because of the complex movement of water. Ahmad et al. (2014), using both physical measurements and farmer survey data from the rice–wheat cropping system in Punjab in Pakistan shows that the primary drivers for adopting of RCTs were reduced cost of production and labor requirements, higher yield, and reduced field scale irrigation water application. However, the study indicates that the field scale reduction in water application did not always result in real savings due to rebound effect, suggesting that without regulations and policies to regulate the use of saved water, adoption of RCTs can result in overall increased water use. Nevertheless, RCTs can potentially lead to increase in productivity of water. However, a more realistic and practical approach would be to weigh the technical solutions along with behavioral and incentive issues (Singh 2011). This is supported by the findings of a recent study by Columbia Water Center (2012) which using farmer survey and field-level data in Punjab and Gujarat show that in conjunction with other measures RCTs such as tensiometer and direct or dry seeding of rice can potentially lead to increase in productivity of water and that the farmers are open to reliable and cost-effective strategies for saving water in irrigation applications for rice.

5.4.2.4 Energy Subsidy-Irrigation Nexus: A Contentious Issue

This is an important policy question for at least two reasons:

One, electricity subsidies are widely perceived to be one of the main causes of groundwater overexploitation. A general argument against energy subsidies is that they encourage farmers to extract groundwater at unsustainable rates which causes lowering of water tables requiring more energy to extract groundwater, thus raising the cost of agricultural production. Further, use of free/cheap electricity may make electricity more expensive to non-farm users. In Punjab, development of groundwater is preceded by crop choices which, in turn, have been distorted by central government policies rooted in achieving the objectives of food security. Clearly, this is not an energy pricing issue alone and requires that the larger policy issues embedded in demand for water are appropriately addressed. Empirical studies on pricing of irrigation water seem to support this view.

Before we discuss some of these studies, let us put this question in the larger context of irrigation subsidies. In the case of surface water-based irrigation, the entire cost of development is borne by the state. A very small portion of operational expenses are recovered from the farmers. In groundwater irrigation, most of the development cost is borne by the farmers. Chandrakanth (2002) shows that the farmers using groundwater bear a much higher proportion of irrigation cost (77 %) compared to surface water irrigation farmers and that the negative externalities faced by the farmers due to cumulative interference of irrigation wells are largely responsible for well failures in hard rock aquifers. Also, groundwater situation varies across districts/basins, etc.; therefore, the question of subsidy on energy, cost of groundwater irrigation, and water table situation should be considered together and not in isolation.

More scientific studies are required to get a better idea of the costs of the two sources of irrigation to the state and the farmers. Moreover, it can also be argued that the increase in the power subsidy costs in recent decades is the result of the increasing inability of farmers to bear the full costs of pumping from decreasing groundwater levels (Shah 2009; Dubash 2007).

Detailed scientific studies are required to study the impact of reduction in energy subsidies on cropping pattern, and land and water productivity. There is also need to put some basic data in order. For instance, Chandrakanth et al. (2011) indicate that there are conflicting estimates of use of electricity for irrigation and also on proportion of land irrigated by groundwater and surface water at the country level. Data at more disaggregated level pose further problems.

Meenakshi et al. (2013) measure the impact of metering agricultural tube wells (from a flat rate to a metered tariff) on groundwater users (pump owners and water buyers) and informal groundwater markets in West Bengal. Overall, the findings do not show any significant impact on any of the outcomes assessed. On the contrary, Badiani and Jessoe (2011) show that reducing electricity subsidies can potentially affect groundwater extraction rates. A recent study in Gujarat shows that voluntary shift to metering and billing is possible; however, no evidence of response to the price signal was seen (Fishman et al. 2014).

A low flat tariff and the resulting electricity subsidy have also been criticized from an equity perspective because much of the agricultural electricity subsidy goes to big farmers who own a major proportion of the water extraction mechanisms fitted with electric pumps (Howes and Murgai 2003). This, however, is aligned more with targeting of subsidy than subsidy per se.

Two, subsidized/free agricultural power supply is putting an unsustainable burden on state budgets and is the prime cause of bankruptcy of the state boards in India.

As the number of tube wells increased manifold in 70 and 80s, prevalence of unmetered tube wells and flat rate electricity tariff became a norm which was entirely a result of conscious policy decisions made by various levels of government for administrative ease and keeping a check on transaction costs of metering, measuring, and charging the consumers.[15] Slowly it became a potent instrument for appeasement of voters, thus keeping the rate perpetually low or supplying it free of any charge. As a result, the quality of power deteriorated. This affected the small farmers more as, like big farmers, they could not afford to substitute diesel and generators for free electricity. There were equally serious implications for the groundwater sector. Since the marginal cost of extracting groundwater was close to zero, it provided an incentive for overpumping. In many areas, this spawned active groundwater markets. These markets emerged in response to unmet demand for irrigation and the flat tariff system (Meenakshi et al. 2013). It may be argued that the emergence of active groundwater markets would be a positive outcome from economic efficiency point of view. The price at which water would be traded will reflect the opportunity cost for using water. Such transfers can promote access equity and efficiency in use. Moreover, such markets can provide extremely useful information price elasticity of demand for irrigation by crops and size of holdings.

However, the main drawback of the flat tariff system/free electricity has been the total lack of energy accounting, no accurate estimates of the total electricity consumed by the agricultural sector, and the subsidy provided by the electricity utilities. The total annual economic cost of subsidized power remains contested (mainly due to varying assumptions of transmission and distribution losses, the use of off-peak power, and the unreliability or intermittence of the supply (Shah 2007)). Then, there are equity issues in subsidy. Free electricity has implications for poor quality and rationed supply of electricity.

The problems facing the electricity sector due to unmetered supply to agriculture and the consequent lack of incentives among farmers to make efficient use of electricity and among the utilities to do robust energy accounting are now widely acknowledged and are at the top of the policy agenda (Planning Commission, 12th Plan Strategy Challenges).

5.4.2.5 Evidence from Literature: Drawing Inference on Instrument Choice

The context here is the debate on measures for promoting efficient, equitable, and sustainable use of groundwater for irrigation. In other words, we are broadly looking at measures to promote:

Inter-temporal efficiency—reducing overexploitation;
Allocative efficiency—cropping mix;

[15]Unmetered electricity supply also became a convenient garb for state electricity boards to hide their inefficiencies in terms of transmission and distribution losses (Sant and Dixit 1996). Electricity Act of 2003 has made metering mandatory for all categories of electricity consumers (GoI, 2003).

Efficiency in use of water—farming practices; irrigation and farm machinery; Externalities—equity issues

The vast body of literature focusing on regulations and market instruments including the potential linkage between electricity pricing and groundwater use for irrigation and the implication of electricity prices for access to equity, efficiency, and sustainability in groundwater use (see Malik et al. 2008; Kumar 2005; Moench 1995; Chandrakanth et al. 2011 for detailed review) provides empirical evidence and/or insights into approaches such as state regulation on groundwater withdrawal; cooperative management of groundwater; tradable property rights in groundwater[16]; rationing of electricity to farm sector; prorata power tariff in agriculture[17]; community-based ownership and management of groundwater; volumetric rationing in groundwater allocation; and its positive impact on cropping pattern and land and water productivity in Punjab (Malik et al. 2008). These and other studies referred in earlier sections in the chapter point toward differing, often opposite views/empirical results on the equity and productivity impacts of these instruments.

No consensus exists about appropriate tariff structures either, which generate efficiency in resource use, equity in access to groundwater, and sustainability of resource use. Saleth (1997) argues that power tariff policy alone cannot be an effective tool for achieving efficiency, equity, and sustainability in groundwater use and opines that even an imperfect system of groundwater rights will have more sustainable benefits than a most perfectly designed power tariff structure.

The argument is that when tradable property rights are enforced, efficient water markets would develop (Kumar 2005).

In the context of Gujarat, several scholars and institutions have argued for establishing tradable property rights in groundwater (Kumar and Singh 2001). However, there is an absolute paucity of sufficient empirical data to compare and analyze the differential impacts of different levels of pricing of electricity and groundwater rights allocations on water and energy productivity (Kumar 2005).

Since 2004–05, agricultural sector has been recovering—this recovery, however, was associated with renewed dynamism in rain-fed areas in Jharkhand, Chhattisgarh, Andhra Pradesh, Karnataka, Rajasthan, Gujarat, and Madhya Pradesh. Rain-fed area crops mainly cereals *Bajra*, *Jawar*, maize, cotton, and oilseeds had higher yield growth—which came mainly from use of better seeds and better practices, where agricultural extension services primarily driven by civil society, farmer producer organic, and agricultural business companies helped in adoption of better practices. This indicates that different solutions will emerge in different situations. Farmers have valuable knowledge and capacity to assess both the potential and the risks of supportive environment and positive incentives

The question then is how does this literature help inform the policy making? And what inferences can we draw for the policy making/design of instruments that may

[16]Argue that pro rata pricing would have positive impact on equity, efficiency and sustainability in semi-arid and aid regions. Metering has been criticized on account of its negative welfare effects.

[17]It has been argued that water rights will be more effective than evolving energy pricing policy.

encourage sustainable use of water. A modest assessment would be that it provides at least the following broad guidance for interventions. These are listed in the following section.

5.5 Some Suggestions

(i) Understanding groundwater overexploitation/use is complex and very much influenced by numerous natural, economic, and political factors at play, and these factors vary a lot across and within natural, social, economic, and political boundaries and interact in many different ways among themselves. Therefore, no one solution/success story can be successfully implemented/replicated in entirety.

(ii) There is urgent need to put a strategy in place to 'manage' the resource for which the necessary condition is that we know the resource; credible estimates of total consumption of irrigation water, electricity, and diesel disaggregated by crops, regions etc. Similarly, credible information on productivity of water under different crops and other local conditions. This will help identify different aspects (technology, seeds, and other farming practices) which need to be targeted.

(iii) Implementation and enforcement of existing laws is weak. For instance, Electricity Act 2003 made metering mandatory, but to no avail. West Bengal is the only state which has been able to meter agricultural tube wells. Punjab is yet to formulate a groundwater policy. Water harvesting is not mandated in Punjab although some states have made good progress on this.

(iv) Economic rewards and penalties are required for management of groundwater as these can potentially help provide signal to users about economic/opportunity cost of water. This can be achieved by implementing price-based and/or quantity-based instruments. Evidence of some success of implementing various measures in Gujarat, West Bengal, Punjab, western UP, and Andhra Pradesh provides useful reference points.

(v) It would be prudent to involve the stakeholders in decision making for both valuable inputs on local socioeconomic dynamics and environmental and economic risks perceived by them of the status quo, as well as to garner the buy-in for the new approaches/instruments.

(vi) Supply-side measures have the potential to succeed in Punjab. Role of public investment in groundwater should be examined. Although not yet systematically practiced, there is great potential for exploring various resource-enhancing measures including conjunctive use of surface water and groundwater to meet rising demand in both rural and urban settings. In this context, it is important to mention that Punjab has a good number of ponds. This valuable source of water is being lost due to water quality and other issues. Ponds can be revived/developed into a source of irrigation water, among others, and catchment areas as a source of recharge of groundwater table. This however needs to be examined further in detail.

(vii) Since the objective is sustainable groundwater management, the focus should be on water in designing the policy instruments. A policy on number of functioning irrigation wells and provision of water flow meters (with an eye on gradual pricing of water and regulation of water draft from wells) may be introduced in a gradual manner. These initiatives on their own may give rise to different types of institutional arrangements and thus markets. This is likely to be more efficient than top-down approach in promoting institutional arrangements. Till the time, water meters are installed a flat charge on water may be introduced taking cue from the water markets in the informal sector.[18] This should go hand in hand with awareness and sensitization campaigns through extension services.

(viii) Cooperative/shared well framework should be promoted. This is also akin to/sets favorable ground for transferable permits.

(ix) Strong focus on gradual shift in cropping pattern through innovative farming and irrigation methods/technology (examples of AP and other states which are sowing millets and other crops). Enabling environment such as price and procurement support for alternate crops, support for RCTs should be examined in a holistic manner.

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[18]This is aligned to twelfth Five-Year Plan which proposes a paradigm shift in the management of water resources in India, a crucial element of which is the shift in emphasis from development to management, with the empowerment of water users and improved water efficiency (Shah 2013).

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