MANAGING GROUNDWATER PUMPING AND QUALITY FOR SUSTAINABLE IRRIGATED AGRICULTURE : A PERSPECTIVE FROM PAKISTAN

By

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Abstract

In Pakistan, on-demand availability of groundwater has transformed the concept of low and uncertain crop yields into more assured crop production. Increased crop yields has resulted in food security and improved rural livelihoods. However, this growth has also led to problems of overdraft, falling water tables and degradation of groundwater quality, and yields generally remain well below potential levels. Over the last three decades, Pakistan has tried several direct and indirect management strategies for groundwater management. However the success has been limited. This paper argues that techno-institutional approaches such as introducing water rights, direct or indirect pricing and permit systems are fraught with difficulties in Pakistan due to its high population density and multitude of tiny users. Therefore there is a need to develop frameworks and management tools that are best suited to Pakistani needs. Pakistan should follow both supply and demand management approaches. For demand management, adoption of water conservation technologies, revision of existing cropping patterns and exploration of alternate water resources should be encouraged. For supply management, implementation of the groundwater regulatory frameworks and introduction of institutional reforms to enhance effective coordination between different organizations responsible for the management of groundwater resources should be given priority.

Keywords: *groundwater management, Pakistan, institutional reforms, groundwater development, regulatory framework*

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Introduction

Groundwater has emerged as an exceedingly important water resource and its increasing demand in agriculture, domestic and industrial uses ranks it as a resource of strategic importance. Global estimates show that approximately 4430 cubic kilometers of fresh water resources are abstracted annually, of which 70% are used in agriculture, 25% in industry and 5% in household (Kinzelbach et al., 2003). On the whole, annual groundwater abstracted for the world can be placed at 750-800 cubic kilometers, which is about one-sixth of the total freshwater abstraction (Shah, 2000). The amount of groundwater contribution is less as compared to surface water on the global scale, yet its unique advantages like reliability, accessibility, on-demand availability, less capital investment and high productivity outweighs the volumetric access of surface water.

In Pakistan, the difference between the crop water requirements and surface water supplies, combined with the generally unreliable nature and relatively inefficient delivery systems, has led to the exploitation of the groundwater, where conditions allow. In fact, much of the groundwater that is pumped for irrigation is actually surface water “recharged” from the surface systems. Given this interconnectivity, caution needs to be exercised in estimating the total available water resources.

In the Indus basin, groundwater exploitation has enabled farmers to diversify their income base and to reduce their vulnerability against seasonality of agricultural production and external shocks such as droughts. The benefits of groundwater are multi-dimensional and ranged from drinking water supplies to urban and rural population to economic development as a result of

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higher agricultural production. In Pakistan, about 10% of the total groundwater exploitation (4 x 10^9 m^3) is used to meet domestic and industrial requirements. In the most populous province of Punjab, about 90% of the population depends on groundwater for their daily domestic needs. In Balochistan about 4% of the population depends on groundwater but it is estimated to reach 50% in the next 10 years. Due to increasing urbanization, improved living standards and industrialization, the share of groundwater for non-agricultural uses is expected to increase further which will have a direct impact on the availability of groundwater for agriculture.

Recognizing the important role that groundwater is playing to meet Pakistan's growing demand for food and fibre, its proper availability and protection from pollution needs to be ensured. Therefore, it is imperative to understand the issues regarding groundwater management in Pakistan and to suggest possible pathways for systematic management and regulation of this precious resource. This paper gives an overview of groundwater development and its associated problems in Pakistan. The paper also discusses challenges facing groundwater management and suggests possible pathways to ensure sustainability of this resource within the Pakistani context.

Development and patterns of groundwater use

The use of groundwater for agriculture in Pakistan has a long history. Large-scale extraction and use of groundwater for irrigated agriculture in the Indus basin started during the 1960s with the launching of Salinity Control and Reclamation Projects (SCARPs). Under this public sector program, 16,700 wells (supplying an area of 2.6 million ha) with an average capacity of 80 l s^{-1} were installed to control groundwater and salinity problems (Bhutta and Smedema, 2007). The pumped groundwater was discharged into the existing canal system to increase irrigation supplies at the farm gate (Qureshi et al., 2008).

This public sector groundwater development program was followed by an explosive development of private tubewells with an average discharge capacity of about 28 l s^{-1}. The introduction of locally made diesel engines provided an impetus for a dramatic increase in the number of private tubewells. Currently, about 1.2 million small capacity private tubewells are working in Pakistan (Qureshi et al., 2008). Out of these, only 13% are operated by electric motors whereas the rest 85% are run by diesel engines of various capacities (Qureshi and Akhtar, 2003). Diesel engines are preferred by farmers because of their low installation and operational costs as compared to electric tubewells.

Investments on the installation of private tubewells are of the order of Rs. 25 billion (US$ 400 million) whereas the annual benefits in the form of agricultural production are to the tune of Rs. 150 billion (US$ 2.5 billion) (Shah et al., 2003). The estimated number of users is over 2.5 million farmers. On average, every fourth farming family has a tubewell (Qureshi and Akhtar, 2003). The groundwater abstraction from 1965 to 2006 has increased from 9 x 10^9 m^3 to 48 x 10^9 m^3 (Bhutta, 2002; World Bank, 2007). The groundwater is currently providing more than 50% of the total crop water requirements with the flexibility of its availability as and when needed (Shah, 2007).

In Pakistan, about 70% of the private tubewells are located in the canal command areas where groundwater is used in conjunction with the canal water whereas the rest provides irrigation based on groundwater alone. Although evidence exists that mixing of saline and non-saline irrigation water is less effective in keeping soil salinity levels lower (Hussain et al., 1990), this strategy is widely practiced in Pakistan. The conjunctive use of surface water and groundwater water is now practiced on more than 70% of the irrigated lands of Pakistan. Figure 1 shows that over the last 10 years, a further million hectares in the Punjab has adopted conjunctive use (Qureshi et al., 2004). The area irrigated by groundwater alone has increased from 2.7 million

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1. Most of the privately owned diesel tubewells are power by 10-24 hp engines. These engines are of two types i.e. the 12-16 hp Chinese type locally called the "Petter Engines" and the 20-24 hp locally made slow speed engines locally called the "Black (Kala) engine".

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ha to 3.4 million ha whereas the area irrigated by canal water alone has decreased from 7.9 million ha to 6.9 million ha.

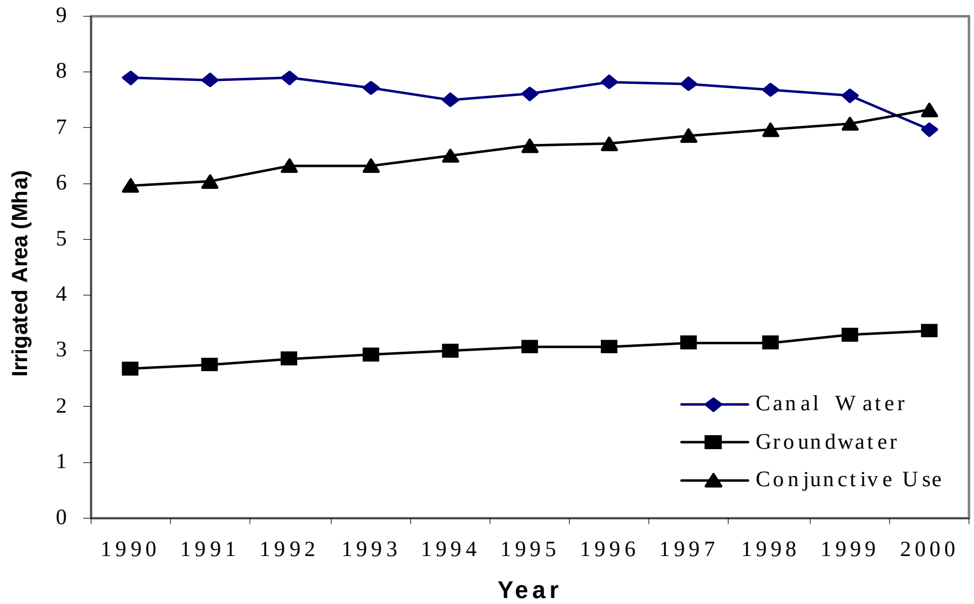

Figure 1. Trends in the use of groundwater for irrigation in the Punjab, Pakistan.

Problems of groundwater development

Groundwater overdraft

Over 80% of the groundwater exploitation in Pakistan takes place through small capacity private tubewells. These shallow tubewells (up to 6 m depth) were initially installed by farmers to capture the seepage from unlined canals to supplement irrigation supplies for meeting crop water requirements. Due to excessive mining of aquifers in fresh groundwater areas, water tables started falling at a rate of 2-3 m annually. As a result, the groundwater dropped to depths that were inaccessible in 5 and 15% of the irrigated areas of Punjab and Balochistan provinces, respectively. Under the business as-usual scenario, this area is expected to increase to 15% in Punjab and 20% in Balochistan in the next decade (PPSGDP, 2000).

Increasing groundwater table depths (>15 m) forced farmers to drill deeper wells. The construction cost of a deep electric tubewell (>20 m) is US$ 5000 as compared to US$ 1000 for a shallow tubewell (<6 m). The present cost of pumping groundwater from a shallow tubewell is US $ 4.2 per 1000 m^3 as compared to US $ 12 per 1000 m^3 from a deep tubewell. Beyond 20 m depth, turbine/submersible pumps are needed to extract groundwater. The average cost of installation of such a pump is about US $ 10,000 in Balochistan. In Balochistan the installation of more than 20,000 deep private tubewells over the last 10 years has negatively affected the traditional karezes and spring systems. Declining groundwater table has resulted in the desertification of lands and drying up of high value fruit orchards.

Groundwater overdraft has also led to sea water intrusion in the coastal areas of the Indus basin which is threatening ecology of wetlands. Important aquatic resources, mangrove forests and coastal areas need to be protected. Mangrove forests cover 130,000 ha and are an important source of firewood and provide the natural breeding ground for shrimps. Similarly fresh water fish are an important source of protein along the Indus.

Deterioration of groundwater quality

Lack of planning capacity and strong management, as well as frequent disagreements with provincial governments over water allocation have contributed to major water resource problems. These issues are compounded by application of excessive irrigation water, causing increased salinity and water-logging. As a result, 36 percent of groundwater resources are now

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highly saline and untreated effluent discharges from municipalities and industrial areas make the quality of water resources increasingly critical. The number of tubewells has increased significantly but despite the unsustainable mining of groundwater, additional wells continue to be installed to meet rural, urban and agricultural needs.

The quality of groundwater in the Indus Plains varies widely, both spatially and with depth and is related to the pattern of groundwater movement in the aquifer. Areas subject to heavier rainfall and consequently greater recharge, in the upper parts of Punjab, are underlain with waters of low mineralization. Similarly recharge occurring from the main rivers and canals has resulted in the development of wide and deep belts of relatively fresh groundwater along them. In Punjab 23% of the area has hazardous groundwater quality, while it is 78% in Sindh (Haider, 2000). Figure 2 presents the spatial distribution of groundwater quality in the Indus Basin of Pakistan (Qureshi et al., 2004). The groundwater quality varies from 0.3 dS/m to 4.6 dS/m in the Punjab province. The water quality is fit to marginal fit for agriculture in upper and central Punjab but in lower Punjab groundwater quality is almost unfit for agriculture purposes. Here irrigation is possible only by mixing groundwater with the canal water.

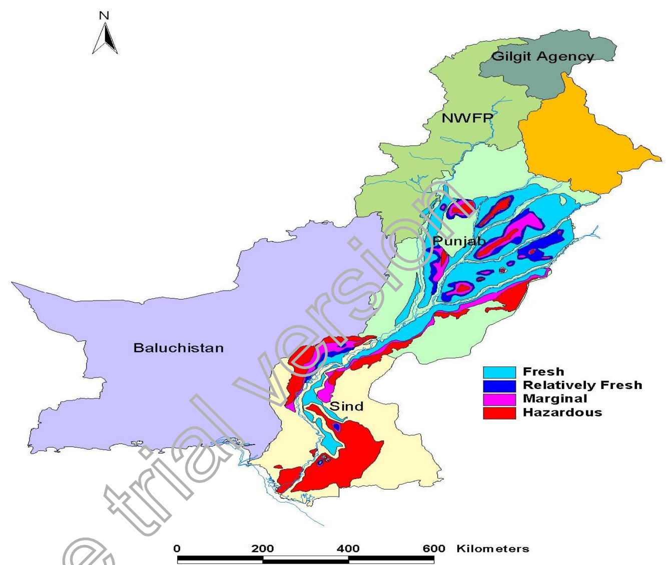

Figure 2. Comparison of Saline Areas in Four Provinces of Pakistan

In the lower parts of the Indus plain, the area of fresh groundwater is confined to a narrow strip along the Indus River. Similar situations can also be found in central areas of Punjab where a layer of fresh groundwater floats over the saline water. The depth of this layer is very thin and temporal changes are less significant. Due to excessive pumping of this thin fresh groundwater layer, the downward gradients are increasing thereby inducing salt water intrusion into fresh groundwater areas. As a result of saline groundwater intrusion, about 200 public tubewells initially installed in the fresh groundwater zone of Punjab and Sindh provinces had to be abandoned due to increase in salinity with time.

In Sindh, 28% of the area has fresh groundwater suitable for drinking and irrigation purposes. There is a very wide range of groundwater quality distribution in Sindh i.e. 0.5 dS/m to 7.1 dS/m. The native groundwater of the Lower Indus Plain is very saline being of marine origin. Some of the saline groundwater is found in the delta, where the samples with salinity as high as double of seawater, have been found. The problem is further compounded due to the presence of high fluoride in groundwater in some areas.

The quality of groundwater in the valleys, which is largely derived from infiltration of rainfall and seepage from canals and fields, is generally good (0.1 dS/m to 0.7 dS/m). However, in Banu basin, the groundwater quality of the upper horizons ranges from 0.7 dS/m to 2.5 dS/m.

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In the northern regions of Balochistan, comprising Zhob, Pishin, and Lora, the quality of groundwater is generally good. In the western and south-western parts of Balochistan, quality of groundwater is saline to highly saline at all depths. Salinity of groundwater, some time, exceeds more than 5 dS/m such as in Nokhundi, Dalbandin, Saindak areas, Kachi plains, Nushki plain and coastal areas. The groundwater quality in the northern part of the plain is rated as good.

Soil salinization

Soil salinity remains a hazard for the Indus basin and threatens the livelihood of farmers, especially the small-scale ones. Land degradation is reducing the production potential of major crops by 25%, valued at an estimated loss of US $ 250 million per year (Haider et al., 1999). The extent of salt-affected lands has decreased to about 4.5 million hectares from about 6 million hectares in 1980s (WAPDA, 2007). Due to differences in annual rainfall and geo-morphological conditions, the problem of soil salinity is much more severe in the lower part of the Indus basin (Sindh province) where about 56% of the total irrigated land is affected with salinity. This is mainly because of the presence of marine salts, poor natural drainage conditions and the use of poor quality groundwater for irrigation. Furthermore, leaching opportunities are also very limited due to highly saline soils at shallow depths and highly saline groundwater at deeper depths. These problems have brought into question the sustainability of the system and the capacity of Pakistan to feed its growing population.

In Pakistan, the average cost of irrigation with groundwater is 30 times higher than that of surface irrigation (World Bank, 2007). The cost of canal water per year per hectare is US$ 5.5, whereas the groundwater is marketed as 167 US$ per hectare per year. Therefore, exploitation of groundwater for agriculture is not a sustainable practice both economically as well as environmentally. Therefore it needs very careful analysis to decide pumping rates, pumping schedules and design of the well to avoid saline water intrusion as well as salt addition to the irrigated agricultural lands of Pakistan.

Socio-economic and environmental impacts

Declining groundwater tables and land degradation as a result of poor quality groundwater use for irrigation has seriously affected the social fabric of Pakistani society. Drying of karez systems in Balochistan have increased the livelihoods burden on women due to out migration of spouses for income supplementation. On average, a woman must carry more than 200 liters of water every day, which creates an enormous burden on her time and physical capacities. Similar conditions also exist in the Cholistan areas of Punjab where women have to walk miles to bring fresh drinking water from natural streams as groundwater is very deep and hazardous to health.

Opportunities for groundwater management

Irrigation dominates water use in Pakistan and it is expected to continue as the major user of both surface and groundwater into the future. As the development proceeds and the population as well as country's economy grow, competition of water resources will become a major concern. Therefore water will need to be diverted from irrigation to these other uses. Therefore there is a need for action in this area, before the problems of competition among different users becomes critical.

Demand management strategies

Future prosperity will depend to a considerable extent on how well we harness our fresh water resources and how efficiently we use them. The way water is being used will have to change significantly if sustainable development is to be achieved in Pakistan. The greatest effort in water conservation should be made in the irrigated agriculture sub-sector because this is by far the greatest user of water. Even relatively modest improvements in irrigation efficiency will result in significant reductions in water use, which can then be reallocated to other uses. Water pricing structures which make water savings financially attractive are unlikely to be introduced in the near future. Farmers should be encouraged to adopt water conservation measures. Resource conservation technologies such as precision land leveling, zero tillage, bed and furrow planting have also shown considerable reduction in water application at the field scale. Furrow-bed

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method of irrigation can save up to 40% of applied irrigation water as compared to basin irrigation method (Qureshi *et al.*, 2003). Farmers should also be encouraged to use water efficient irrigation techniques such as sprinkler and drip irrigation systems. The sprinkler irrigation for crops and drip irrigation for fruits/forests plants provides an alternate option for farming and resource conservation in these areas.

Rationalizing cropping patterns

The traditional crops such as rice and sugarcane have benefited from increased irrigation supplies. Since rice is a water-intensive crop, it is essential to review whether Pakistan should continue to grow rice for export or instead use this water for other crops where the country has a comparative advantage. In the rice growing areas of Pakistan, more than 70% of irrigation water is supplied through tubewells (Qureshi et al., 2006), restricting the rice production to its domestic needs and converting to less water intensive crops could reduce the pressure on the groundwater.

Adoption of irrigation strategies such as alternate wet and dry irrigation (AWADI) for rice can also help save groundwater. Direct seeded rice requires 23% less water as compared to traditional transplanted rice (Qureshi et al., 2006). Similarly strategies should be developed to replace sugarcane with low water demanding and high market value crops. Introduction of high value crops like sunflower, pulses, vegetables and orchards can also increase farm incomes substantially. Presently the country is importing more than one billion US dollars of edible oils.

Managing conjunctive use of surface and groundwater

In most of the canal command areas, conjunctive use of surface water and groundwater is equally practiced in head and tail ends of the canal system. One of the key disadvantages of this unmanaged conjunctive use is that upstream areas are subjected to rising water tables and waterloging due to excessive irrigation whereas tail-end users are aggravating their salinity problems due to the poor quality of groundwater. In Pakistan, the canal water delivered to the head-end farmers is generally 32% and 11% more than to the farmers of tail-end and middle-end, respectively (Haider et al., 1999). Therefore planned conjunctive use should be encouraged whereby the upstream farmers make better use of groundwater and spare surface supplies for tail-end farmers. For this purpose, canal department need to regulate the canal flows to match with the requirements and farmers need to be educated on proper mixing ratios of surface water and groundwater resources.

Supply management strategies

To overcome surface water shortages and limit groundwater abstraction, alternative sources of water should be explored. One such source is large amount of wastewater. The total annual quantity of wastewater produced in Pakistan is estimated at 4.5×10^9 m^3. Most of this water is either disposed of in rivers or thrown in open places in the outskirts of big cities. A substantial part of this wastewater is also recharged to the groundwater thus degrading its quality. Unfortunately, no treatment is done before discharging this water into the water bodies thereby creating environmental problems. This amount of wastewater can effectively be used for augmenting the water resources.

The use of wastewater will not only increase the water availability but also reduce the requirement of reducing these pollutants to environmentally acceptable limits. The lack of treatment of wastewater is caused by the lack of investment in this sector and the non-functioning of plants is mainly related to both institutional problems and inadequate maintenance. Major industries responsible for the generation of wastewater should be made responsible for treating their wastewater.

Artificial recharging of aquifers

Aquifer management is considered as the most effective away of establishing a balance between discharge and recharge components. This practice is widely used in industrialized countries such as Germany, Switzerland, the United States, the Netherlands and Sweden,

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although only in the United States are there large abstractions from groundwater for irrigation. The share of artificial recharge to total groundwater use in these countries ranges between 15-25% (Li, 2001). However, while there is evidence that groundwater recharge interventions have produced positive results on the groundwater availability, whether they can have the necessary impact on a broader scale and be costs effective in the context of the Indus basin has yet to be established.

Implementing policy reforms

Due to the peculiarities of Pakistan's groundwater socio-ecology, a multi-dimensional approach is needed. In Balochistan province, for example, the policy of providing subsidies on electricity needs to be reviewed. Currently, the annual subsidy on agricultural tubewells is Rs. 8.5 billion (US$ 140 million). This subsidy is mainly provided to only 2.5% of the farmers who own deep electric tubewells. The majority of small farmers are deprived of this facility, which is creating serious equity concerns in the rural communities.

In the Punjab province, more efforts are needed to review existing cropping patterns for areas where hydrological conditions suggest that additional groundwater resources are insufficient to support intensive agriculture. Separate strategies should be developed for large commercial farmers and for small poor farmers who are totally dependent on groundwater for protecting their livelihoods. Cropped areas for different crops should be fixed on the basis of country's food requirements and the availability of water resources.

Conclusions

The governance and management of groundwater in Pakistan has proved much more complex for multiple reasons. The increasing dependence of irrigated agriculture on groundwater has helped ensure food security for the rising population and has been a fundamental linkage to the livelihood of millions of rural poor, which makes the situation even more complicated. Pakistan needs a serious debate about whether to pump their aquifers to the maximum and face the consequences thereafter, or be more proactive now, better manage abstraction and invest in recharge today.

Farmers need to be made aware of the increasing groundwater problems and taken into confidence to implement possible technical, scientific, institutional and political tools to protect key strategic aquifers with regard to quality and quantity. Policies should also be formulated for the economic transition of the population that currently depends on intensive irrigated agriculture to earn their living. This is essential to reduce pressure on groundwater resources and to create political space for direct management of the resource base.

For effective groundwater management in Pakistan, the frontline challenge is not just supply-side innovations but to put in place a range of corrective mechanisms before the problem becomes either insolvable or not worth solving. Most of the industrial units discharge their effluent directly into surface water and the seepage taking from the effluents as well as other anthropogenic activities impair the quality of groundwater and making them unfit for irrigation and drinking purposes. Pakistan needs to pursue conservation aggressively, particularly in the irrigation sector, which is characterized by low productivity relative to other countries. Deteriorating water quality is also of major concern, necessitating the dramatic increase in the treatment of municipal and industrial waste-water as well as modifying agricultural practices.

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