MAKING AGRICULTURAL ECONOMY GREEN : REDUCING CARBON EMISSIONS THROUGH IMPROVED IRRIGATION MANAGEMENT

By

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Abstract

Increasing use of groundwater for irrigation is consuming huge amount of energy and depleting the resource. Groundwater use is affiliated with high energy demand and consequently high carbon footprint in Pakistan. We have estimated that lifting of 50 km^3 of groundwater in Pakistan consumes more than 6 billion kWh of electricity and 3.5 billion liters of diesel. Carbon emissions attributed to this energy use are 3.8 million mt of C per year, which is 1.2% of the total CO_2 emissions in Pakistan. Therefore there is an opportunity to reduce energy use and CO_2 emission by improving irrigation management and reducing groundwater extraction. This study shows that by adopting improving irrigation practices, 16 BCM of irrigation water can be saved, which in turn, will reduce the energy demand and carbon footprint 37%. This study clearly reveals that improvements in productivity of water can help in coping with water, energy, and climate change issues in the agriculture sector in Pakistan.

Keywords: Improved irrigation practices, CO_2 emissions, energy use in irrigation, groundwater use in Pakistan

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. In view of the high evapotranspiration and salinity environment under which irrigated agriculture in the Indus basin is practiced, the availability of surface water resources is only marginally sufficient for basin wide, year round high intensity cropping (Qureshi et al., 2008). This 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 (World Bank, 2007).

Increasing role of groundwater in agriculture has made it very energy-intensive. Groundwater exploitation enabled farmers to supplement their irrigation requirements and to cope with the vagaries of the surface supplies. This allows them not only to increase their production and incomes but also enhance their opportunities to diversify their income base and to reduce their vulnerability against seasonality of agricultural production and external shocks such as droughts (Bhutta, 2002; Qureshi et al., 2010). Groundwater has also been important to increase resilience against climate change because surface storages have fared poorly on these counts. These benefits will

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become even more important as climate change heightens the hydrological variability. From the society's point of view, aquifer storage is also advantageous because it minimizes the loss of water through non-beneficial evaporation for semi-arid countries like Pakistan where surface storages can lose 3 m or more of their storage every year through pan-evaporation (Shah, 2009).

The major disadvantages of excessive groundwater use are: (a) aquifers are slow to recharge resulting in falling water tables and increasing salt contents in the pumped groundwater; (b) while gravity run irrigation from canals needs no or very little energy, groundwater irrigation is energy-intensive and expensive and (c) since bulk of the energy used in pumping groundwater is generated by burning oil (diesel or electricity), groundwater irrigation is considered as environmental hazard. This paper provides a snapshot of the amount of GHG emissions due to groundwater irrigation to quantify the environmental hazard (Shah, 2009).

Another important aspect of pumping groundwater for irrigation, which is indeed of global importance, is its contribution to carbon dioxide emissions and climate change (Karimi et al., 2012). Pakistan is one of the lowest carbon emitters in the world but the increasing use of groundwater for irrigation is putting extra pressure on energy resources and directly contributes to an increase in CO_2 discharge. Therefore, making productive and efficient use of groundwater at farms and decreasing pumping helps to save aquifers, to consume less energy, and to reduce carbon emissions which could be a key climate change adaptation strategy. This paper explores how improved irrigation management can help in lessening the burden on groundwater pumping, country's energy resources and reducing carbon emissions.

Overview of groundwater irrigation in Pakistan

Large scale irrigation using tubewells started after the demonstration of SCARP tubewells. Economic growth and improvements in wealth of farmers together with the provision of subsidized electricity by the government and introduction of locally made diesel engines provided an impetus for a dramatic increase in the number of private tubewells.

Tubewell water use is associated with several benefits for farmers including ease of access to water and availability of water all throughout the year (Karimi, et al., 2012)). These very facts have given farmers the chance to bring more lands under irrigation and grow high water demand summer crops like maize. From farm water management angle, unlike surface water supported systems, tubewell owners do not need to wait for their turn to irrigate their farms and they can irrigate their farms upon their will. Therefore, crops are unlikely to suffer from water stress and farmers can attain higher yields.

The estimated number of users is over 2.5 million farmers, who exploit groundwater directly or hire the services of tubewells from their neighbors. On average, every fourth farming family has a tubewell and a large proportion of non-owners purchase

groundwater through local, fragmented groundwater markets (Qureshi and Akhtar, 2003). 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).
Figure 1 illustrates development of private tubewells in Punjab. The area irrigated by groundwater alone has increased from 2.7 million 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. In Pakistan the production of major crops such as wheat, cotton, rice and sugarcane is only sustainable because of the use of groundwater for irrigation. On the other hand, the secondary salinization associated with the use of poor quality groundwater for irrigation is still a major threat to the sustainability of the irrigated agriculture in Pakistan.

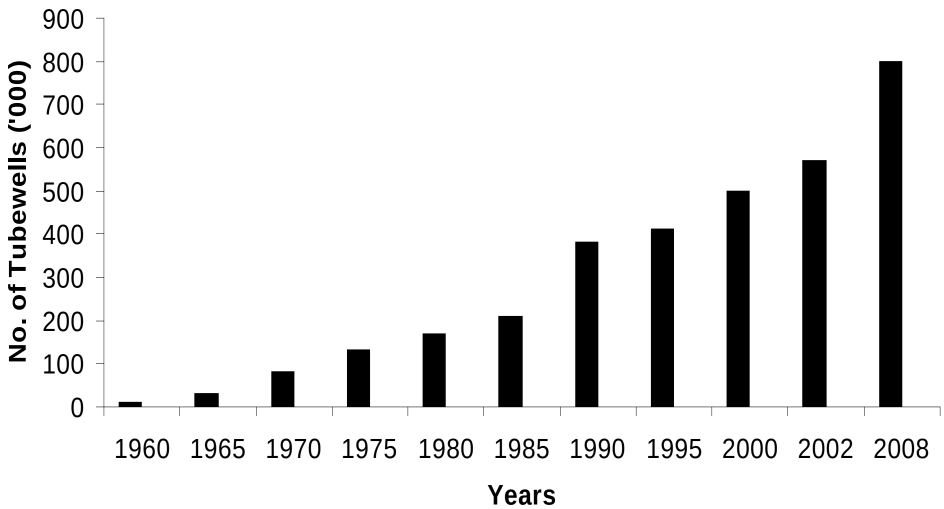

Figure 1: Development of private tubewells in the Punjab Province.

Carbon emissions from groundwater irrigation

The latest estimates suggest that in 2010, farmers lifted 50 km^3 of groundwater through 1.2 million diesel and electric tubewells (Qureshi et al., 2010). Out of this, about 0.8 million are located only in Punjab. About 200,000 tubewells are operated by electric motors whereas the rest one million are run by diesel engines of various capacities[1]. Out of total 50 km^3 of groundwater extraction, about 12 km^3 is lifted using electric pumps and the rest 38 km^3, using diesel pumps.

Total electricity consumption in groundwater irrigation in Pakistan can be calculated based on the energy requirement to lift the water. Based on Karimi et al. (2012), 2.73 KWh of energy is required to lift 1000 m^3 of water from 1 meter depth at 100% efficiency and without considering friction losses. The average overall pumping plant efficiency[2] (OPE) of the electric pumps in Pakistan is probably about 40%. Thus, considering 25% electricity transmission and distribution losses, the electricity that is actually used to lift

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1. Mostly privately owned diesel tubewells are powered by 10-24 hp engines. These engines are of two types i.e. the 12-16 hp Chinese locally called as "Petter Engines" and 20-24 hp slow speed engines locally called as "Black (Kala) engine".
2. OPE is the product of power plant efficiency (engine, alternator, and etc), shaft efficiency and pump efficiency.

1000 m^3 of water from 1 meter depth is 9.1 kWh. If we assume that a representative electric pump lifts water to a dynamic head of 60 m, then lifting 12 km^3 of groundwater would require 6.0 billion kWh of electricity. This estimate is highly sensitive to the assumption about the dynamic head over which a representative electric pump lifts water.

Diesel powered tubewells are even less efficient but they lift water to a smaller head; moreover, diesel does not face the transmission and distribution losses that electricity suffers and a liter of diesel provides the equivalent of 10 kWh of energy. Diesel tubewells are usually installed in shallow groundwater table areas (6.0 to 15 meters). The fuel consumption of diesel engines (Chinese and slow speed diesel engines) is 1.5-2.5 liters per hour whereas the tractor operated tubewells burn 3.5-5.0 liters per hour (Qureshi et al., 2003). The utilization factor of private diesel tubewells is between 10-15 percent (1350 hours per year). Therefore total annual fuel consumption of one million diesel tubewells (assuming 2.5 liters/hour and 1350 hours per year) would be 3.5 billion liters.

According to Karimi et al. (2012), carbon intensity of electricity and diesel is 0.4062 kgC per kWh and 0.732 kgC per liter, respectively. This implies that annually a total some of 3.8 million mt of carbon emits as a result of groundwater irrigation in Pakistan. Of this figure which is roughly 1.2% of Pakistan's total carbon emission, 1.4 million mt emit through electricity consumption and 2.4 million mt through diesel combustion. In other words, on an average, extraction of every cubic meter of groundwater in Pakistan comes with a hidden environmental cost of 80 grams of carbon emission.

Taking into account the consumption of 6 billion kWh electricity and 3.5 billion liters of diesel, it can be estimated that on average extraction of 1 m^3 of groundwater requires 0.80 kWh of energy in Pakistan. This amount of energy is equivalent to light up a 100 watt bulb for more than 8 hours.

Potential for reducing CO_2 emissions

There are two potential ways of reducing energy use in agriculture. First option is related to improving the efficiency of pumps and electric motors which is extremely low in Pakistan. Increasing overall pumping plant efficiency through use of high quality engines and pumps could be an option for improving energy efficiency. But such interventions perhaps are expensive and have limited scope. The second option is to reduce the irrigation water demand through improved management practices. This option is particularly relevant to Pakistan because our irrigation water use efficiencies are extremely low.

Despite the overall shortage, present irrigation practices of farmers include a tendency to over-irrigate, whereas the opposite should be accomplished. This situation is directly related to poor irrigation management and low efficiency of irrigation systems. In practical terms, about 40% of the applied irrigation water is lost by seepage from the irrigation canals and deep percolation in the fields (Bhutta and Smedema, 2007). Even though much of this lost water is now captured by the extensive groundwater pumping, this does not apply to the saline groundwater zone, and the pumping involves extra costs. The productivity of water in Pakistan is among the lowest in the world. For wheat, for example, it is 0.6 kgm^{-3} as compared to 1.0 kgm^{-3} in India. Maize yields in Pakistan (0.4 kgm^{-3}) are nine times lower than those (2.7 kgm^{-3}) in Argentina (Bastiaanssen, 2000). This reveals a substantial potential for increasing the productivity of water.

Studies done by IWMI have shown that farmers current irrigation practices are aimed at applying maximum amount of water in an attempt to get maximize their crop yields. Qureshi et al. (2001) have shown that applying 320 mm of water to wheat and cotton is enough (against current practice of 450 mm for wheat and 400 mm for cotton) to produce near optimal crop yields without increasing salinity levels in the soil. Other studies have also shown that water conservation techniques such as furrow-bed can save up to 40% of the irrigation water. This is also equal to 260-300 mm for wheat and cotton crops (Rafique and Qureshi, 1987).

Prathapar and Qureshi (1999) have also shown that under existing conditions, irrigation applications can be reduced to 80% of the total ET without compromising on yields and soil salinization. This also refers to about 300-320 mm for wheat and cotton crops. Similarly improved irrigation methods for rice such as direct seeding also reduces the irrigation amounts by 15-20% (Qureshi et al., 2006). The amount of water applied to rice was 1300 mm as compared to 1500 mm usually applied under traditional planting. Table 1 compares the water use and water saving by three major crops under current and improved irrigation practices.

Table 1: Comparison of irrigation water use and total water saving under current and improved irrigation practices in Pakistan.

Crop	Area (ha)	Current irrigation practices		Improved irrigation practices		Total Water saving (BCM)
		Irrigation (mm)	Total water use (BCM)	Irrigation (mm)	Total water use (BCM)	
Wheat	8,578,000	450	38.5	320	27.5	11.0
Cotton	3,100,000	400	12.4	320	9.9	2.5
Rice	1,016,000	1500	15.5	1300	13.0	2.5
Total			**66.4**		**50.4**	**16.0**

Table 1 clearly shows that adoption of improved irrigation practices could save up to 16 billion cubic meters (BCM) of water, which is 12% of the water available in the Indus basin. Under the current surface water availability conditions, this water is likely to be groundwater. Because studies done by IWMI (Shah et al., 2003) have shown that farmers having excess to groundwater tend to apply more irrigation water than those farmers fully relying on surface water. Reducing groundwater extraction by 16 BCM will reduce the diesel consumption by 1.3 billion liters (37%) and CO_2 emissions by about 1.0 million mt of C (40%). With these reductions, total consumption of diesel for groundwater extraction in Pakistan will reduce to 2.3 billion liters. The total CO_2 emissions from groundwater irrigation will reduce to 2.8 million mt of C.

The above analysis demonstrate that adoption of improved irrigation practices will not only help in reducing energy consumption but will also be of great help in reducing the CO_2 emissions to keep the environment healthy. Adoption of these improved practices requires shifting in the thinking of farmers from "*maximizing crop production*" with increased irrigation supplies to "*optimize crop production*" with minimum irrigation supplies. Such change in farmer's mentality could be facilitated by measures like revising the existing energy pricing system. For instance removing or limiting the subsidies on electricity can help lessen groundwater over pumping and encourage more efficient use of water.

Conclusions

Groundwater use in agriculture has increased drastically in the past few decades and it has become a lifeline to Pakistan's agricultural productions. Currently, it provides more than 50% of the total water available at the farm gate and in many areas is the sole resource of water for summer crops. However, rapidly dropping groundwater water tables in the aquifers all over the country indicates that extraction rate is far bigger than the real capacity of these resources. Under these circumstances, groundwater availability might decrease significantly in future which will have serious consequences for the food security of this country. On the other hand, groundwater use also is affiliated with high energy demand and carbon footprint in Pakistan. In Pakistan, lifting 50 km^3 of groundwater to the surface consumes about 30 billion kWh energy. Carbon emissions attributed to this energy use are 4.9 million mt C per year. Therefore reducing irrigation water demand through improved irrigation practices is vital for preserving environment and sustaining groundwater resources.

Despite the fact that pumping is an energy intensive activity, so far very little attention has been given to carbon foot print of the groundwater irrigation in Pakistan. This study shows that adoption of improved irrigation practices will save up to 16 BCM of irrigation water, which in turn, will reduce the energy demand and carbon emissions by 37%. This shows that enhancing productivity of water through improved irrigation management can help in coping with water, energy, and climate change issues in the agriculture sector of Pakistan.

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