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VALUING GROUNDWATER AS A SOURCE OF LIVELIHOOD IN PUNJAB – PAKISTAN

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Abstract

Groundwater is a vital natural source which is used for drinking, irrigation, industry, livestock, environment and other commercial sectors and is playing an essential role in expanding irrigated agriculture for societal needs associated with food, fiber and development of mankind. It is largest reservoir of freshwater which accessible. The Pakistan like India and Bangladesh is the largest groundwater irrigated country. The canal irrigation water supply is insufficient to meet the crop water requirement in the previous as well as for current crop water due to enhanced irrigated area in the province. Crop water requirement is met from directly or indirectly irrigated using groundwater. The Punjab province uses more than 90% of the total groundwater abstraction in agriculture. About 60-70 percent, population of Pakistan depends directly or indirectly on groundwater need to produce more food and fibers and to enhance their livelihood and national economy. In last two to three decades, groundwater has used to boost up the agriculture productivity and agricultural industries. Under the current paper the valuing groundwater as a source of livelihood have been narrated and some suggestion have been outlined for the sustainable use of this natural resource in agriculture sector for farmers livelihood.

Keywords: groundwater, irrigation, livelihood, sustainable, Punjab, Pakistan

Introduction

Groundwater is the most abundant natural source and store of freshwater on the planet earth and crucial to life. It is the hidden resource in the pores and cracks underground after percolating from the earth's surface (Fetter 2001; Fitts 2012). It is not only a basic input for existence of life on planet, but also can be utilized any time for other societal needs not limited to drinking, irrigation, industry, livestock, environment and other commercial uses only. It is a necessary requirement for the development of mankind by meeting food, fiber and shelter needs. Humans rely on groundwater-related ecosystems for food and energy production, health, and recreation (Machard de Gramont et al. 2011). Groundwater is the largest source of fresh and accessible global water resources. Currently, 26-33% of total freshwater global withdrawal comprises of groundwater to meet with almost half of the drinking water needs and 40-43 percent of consumptive use in irrigation (Gleeson et al., 2019; WWQA, 2021). Groundwater is the only reliable water resource especially in the arid and semi-arid regions which provides a buffer

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against droughts under changing climate (Famiglietti, 2014; Foster et al., 2013). Groundwater is generally accessible as when and where required but is invisible, which challenges its management and governance (Gleeson et al., 2019). Groundwater has brought an amazing – although not much recognized- boom in agriculture sector underpinning the livelihood and food security of a large number of farming communities. However, the excessive and unplanned/unscientific exploitation of groundwater has created many problems and challenges, and there are fears that the boom may soon turn to bust (Giordano, 2009).

Groundwater irrigation is an important factor to agricultural production in large parts of the world especially in South Asian countries (Shah, 2007). About 38 percent of irrigated lands in the world are equipped for irrigation with groundwater. For these reasons, groundwater is intrinsically linked to various aspects of human development, including poverty eradication (Moench. M, 2003). In the Indian sub-continent more than 85 percent of the groundwater extraction is used for irrigation purposes (Mukherjee et al., 2014). The three South Asian countries i.e India, Pakistan and Bangladesh, the largest groundwater users, have 48 million hectares area equipped with groundwater irrigation which constitutes approximately 42 percent of the global groundwater-fed cropland (Siebert et al., 2010). In the Indian sub-continent, groundwater use soared from around 10-20 km^3 before 1950 to 240-260 km^3 in 2014 (Shah. N.T 2014). Rapid growth in groundwater use is a central aspect of the world's water story, especially since 1950. In British India (which included today's India, Pakistan and Bangladesh), wells accounted for over 30 percent of irrigated land even in 1903 *(http://dsal.uchicago.edu/statistics/1894_excel)* when only 14 percent of cropped area was irrigated.

Pakistan is the 4th largest estimated annual groundwater extraction after India, USA and China (NGWA, 2010) and the 3rd groundwater user among South Asian countries (Qureshi. A.S., 2020). To feed the tremendously increasing population, cropping intensity has increased from 67% to 150% or even more in some areas which is major driver for excessive extraction of groundwater (Hassan et al., 2019). With 5.2 million hectares groundwater irrigated area, Pakistan irrigates 4.6% of the global groundwater-fed cropland. Pakistan is an agricultural country and ranks 8th largest food producing country. Most of its irrigated area is located in the Indus River Basin (IRB). Pakistan's economy heavily relies on agriculture sector accounting for over 22 percent of GDP, contributing over 60 percent of foreign exchange and employs two-fifths of total labor force of the country. Around 63 percent of country's population living in rural areas is indirectly or directly linked with water sector for their livelihood (Hassan et al., 2017). The irrigated agriculture of the country relies more on groundwater compared to the other South Asian countries due to insufficient and highly variable supply of surface water coupled with inadequate storage capacity of surface water resources. Pakistan's agricultural performance mainly depends on the Indus Basin Irrigation System (IBIS) for 90 percent of its irrigation needs, which is also a source of generation of about 30 percent energy of the country. Groundwater in the IRB basin contributes around 35 percent to the total water available for agriculture. Groundwater quality

of the 60 percent area is marginal to brackish (World Bank, 1997; Ahmad & Rashida, 2001). The variation in surface water runoffs has led to the expansion of a large scale groundwater-fed irrigation system in the IRB. Agriculture sector in Pakistan consumes more than 90% of total water withdrawal from rivers, lakes and underground sources. Per capita availability of water in Pakistan has fallen below the scarcity level of 1000 m^3, climatic changes have further aggravated the situation (Qureshi & Ashraf, 2019**)**. Groundwater has attained vital value in food security and livelihood due to its multi sectoral uses, accessibility and availability under drought conditions. Value of water can be asked from a thirst person, from a farmer whose drop is going devasted due to scarcity of water and an industrialist whose factory cannot produce anything in the absence of water/groundwater. This research study was conducted on the relationship between groundwater development as a source of the livelihood regional, and sub-regional level. The study was focused on the importance of groundwater in enhancing agriculture productivity and its key aspects of human development especially farmers livelihood.

Groundwater Development and Use

Raifall, galciers ice and rivers are major sources of groundwater. Groundwater is the 2nd largest available reservoir of fresh water after glacier ice. Of total freshwater, over 68 percent is locked up in ice and glaciers. Another 30 percent of freshwater is in the ground. Global estimates show that approximately 4430 km^3 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). In Pakistan, the Indus River Basin has a potential of fresh groundwater reserves of about 55 MAF, out of which about 48.69 MAF is being exploited by over one million public and private tubewells for domestic, agricultural and industrial purposes. Groundwater irrigation has been rapidly developed by the private sector.

Population and Groundwater

Over the last century, the global population has tripled, and water consumption has increased threefold. Water use in Pakistan is no exception to this general trend. The main cause of the increase of groundwater uses are growing population and rising food demand. In an agrarian economy like Pakistan, the importance of water for agricultural productivity hardly needs any emphasis. It is observed that groundwater boom in Punjab Province is largely contributed by demand factors, for instance, rural population whose livelihood dependent mostly from agriculture. The most important challenge that most reviews of Punjab's future agriculture is that of exploding population (Patel, 2004)**.** Punjab's population was 20 million in 1951 and now Punjab's current population is around 110 million as shown in **Figure 1** and is projected to increase to about 180 million by 2050. For major part of this population agriculture will remain as the primary source of livelihood. Boserupian hypothesis states that increase in population density increases the intensification of agricultural factor use (Boserup 1981; Boserup 1965). The increase in rural population density will influence the groundwater-irrigated area.

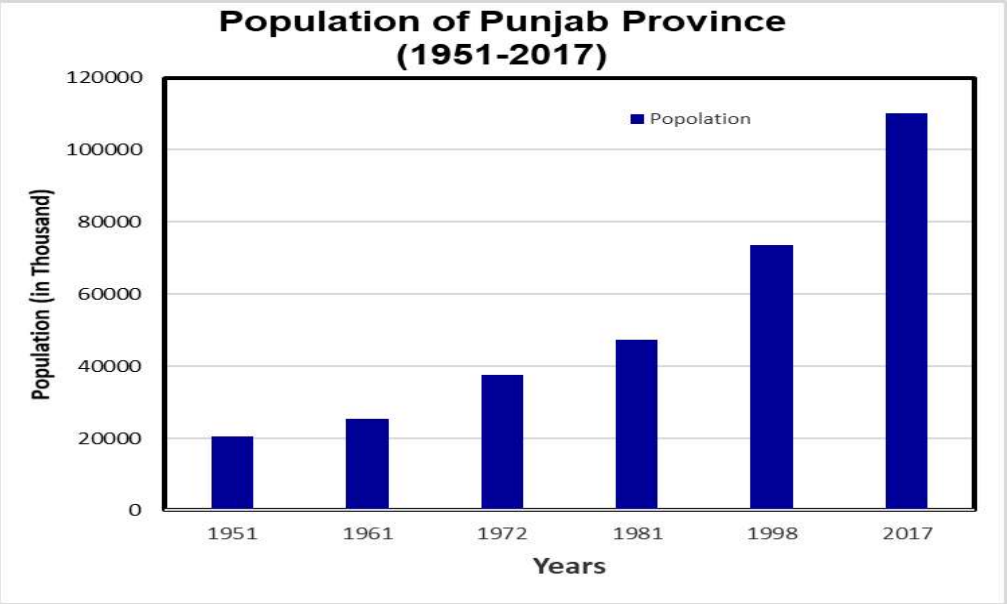


Fig. 1: Population trends in Punjab Source: (PDS Report 2019)

Groundwater for Livelihood Supporting

Agriculture is by far the biggest user of water which consumes more than 90 percent of total water. Groundwater provides people with a multitude of benefits in various forms. Groundwater valuation is an instrument for efficiently allocating groundwater resources over time and between uses. About 60-70 percent population of Pakistan depends directly or indirectly on groundwater for its livelihood (Lashari et al. 2007). Farmers need to produce more food and fibers than are needed for economy. In terms of groundwater quantity and number of people involved, by far the largest growth in groundwater use has occurred in sustaining subsistence crop and livestock farming, which are the mainstay of billions of poor people in developing agrarian economies around the world. In last two to three decades, groundwater has become increasingly important in meeting water needs in agriculture and industrial agriculture in the Pakistan like other South Asian countries. Groundwater is intrinsically linked to various aspects of human development, including poverty eradication (Moench 2003). Overall, the economic benefits of abstracting groundwater exceed those of surface water per unit volume (Burke and Moench 2000).

Punjab, being the chief domain of Pakistan, contains about 60 percent of total population among which 84 million people are living in rural areas and 7 percent of all its population depends on dug wells and rivers for water supply. The irrigated area, actual intensity was 122 and 117 percent in 1985 and 1998, respectively, compared to projected values of 131 and 150 percent. About 40 to 50 percent of crop water requirements at farm-gate and about more than 90 percent of drinking water demands are being met from groundwater by means of tubwells. The dependence on groundwater and its importance (value) in the Punjab province is

set to increase over the coming decades as water resources face increasing pressures related to the growth in populations and economies of the region. Due to insufficient surface water supplies, the desire to expand the irrigated area to produce more food for the ever-increasing population and supply-driven policies of the governments and subsidized energy and pumps are the major factors behind this exacerbated the use of groundwater for agriculture in these countries (Siebert, S. et al, 2014 & Shah, T, 2014).

Tubewell Development and Groundwater use in Agriculture Sector

Currently, it depicts usage of groundwater in agriculture sector is higher as compared to surface water usage. Access to groundwater allows farmers to intensify and diversify their cropping systems, improve household food security and incomes, and shield against droughts. Over the past half century, groundwater has boosted agricultural production and underpinned agrarian transformation in large parts of Asia, North Africa and the Middle East. The increase in agriculture area has led to the over exploitation of groundwater from the aquifers to increase crop production and to enhance the economy. A sharp increase in the groundwater use over the last half-century has evolved as a “silent revolution” carried out by millions of farmers in pursuit of reliable irrigation water supplies. During early 1960s the tube-well adoption was encouraged by the government's support policies such as rural electrification, subsidization of electricity price, diesel and drilling services, supply of free pump sets and easy to get long-term loans. However, higher yields and greater economic returns from groundwater use encouraged farmers to adopt tube-wells in subsequent periods (Falcon and Gotsch, 1968, Johnson, 1989, van Steenbergen and Oliemans, 2002).

Concurrent with the development of SCRAP, private groundwater development started in the Punjab Province. The demand of additional irrigation water arising from increased cropping intensities and changes in cropping patterns triggered a rapid growth in tube wells. Enhanced power generation from Terbela and the government policy of price incentives for electric power motivated farmers to install electric tubewells. Consequently, there was more than threefold increase in the number of tubewells in 1990 - 91 as compared to the situation before Terbela. The innovative and low cost development of tubewell technology in the country further motivated the farmers to install diesel - operated tubewells. The contribution of public and private tubewells was third of total irrigated agriculture in 1990 (WASIP 1990; Bandaragoda, 1993; Bureau of Statistics, 1995). Progressive increases in electricity tariffs starting in the early 1990s resulted in trend towards the decrease the growth of electric tubewells installation and farmers turned more and more towards the installation of diesel pumps. However, a twofold increase in diesel tubewells was observed during 1990 to 1995. This is a clear indication of the effect of Terbela and power policy of the government during the late 1970s and 1980s on the growth of tubewells and development of innovative tubewell technology. The common reasons for preferring diesel pumps include low installation costs, continuous access (no power cut downs), suitability for fragmented land (mobility of diesel engines), and non-requirements of any reserved money (Qureshi and

Mujeeb, 2003). The drought of 2000-2001 was so severe that farmers in the Punjab and Sindh provinces have installed tubewells at a very rapid rate. It was expected that about 60 000 tubewells or lift irrigation systems were to be installed in 2001 to meet the historical shortfall in canal supplies. **Figures 2, 3 &4** show the historical development of electric and diesel tubewells in Punjab. In Punjab, more than three million farmers are directly or indirectly benefiting from tubewells. On average, one in four farming families owns a small tubewell, whereas the others purchase water from their neighboring farmers through informal groundwater markets to increase their crop yields, diversify cropping patterns, and to cope with extreme events such as droughts (Leghari, A.N., 2012 & Shah. T, 2007). The investment in private tubewells in Punjab has been estimated at USD 750 million. Farmers in many areas have started growing water-demanding crops such as rice and sugarcane due to better economic returns which has resulted in a situation where current net groundwater abstraction is higher than recharge (Alam & Bhutta, 2004) .

Limited to less than 30 thousands in 1960s, the number of tube-well has now gone over one million. Since 1960, groundwater share to the total irrigation water input in agriculture by public and private tubewells has increased by more than 50 percent (Byrelle and Siddiq, 1994, Qureshi et al., 2009). **Figure 4** shows tube-well development trends of total tubwell and share of electric and diesel types over time. Those who do not own tube wells irrigate their lands by informally buying surplus pumped water from their nearby tube-well owners (Meinzen-Dick, 1996, Qureshi et al., 2009).

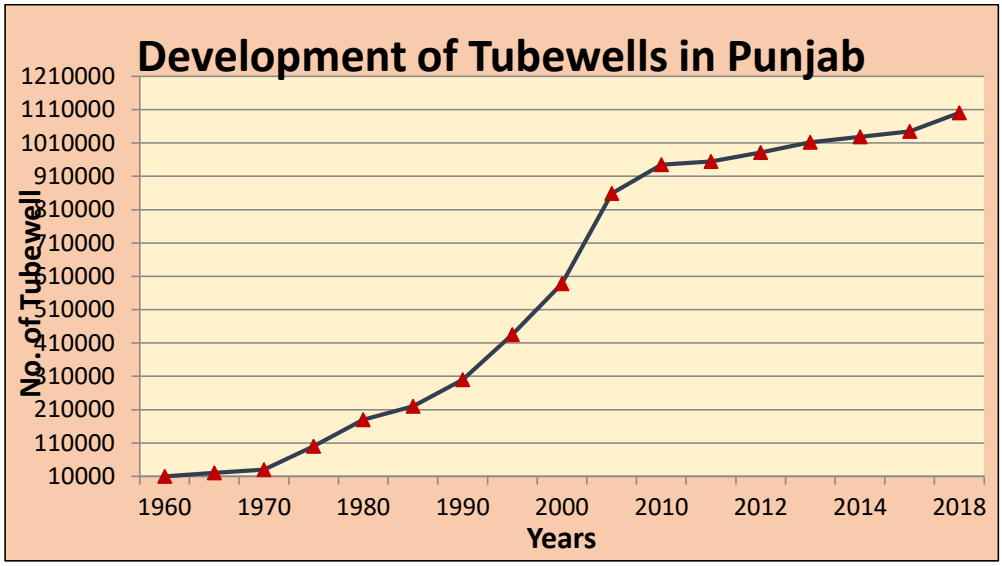


Fig. 2: Temporal growth of tubewells in the Punjab province; data source:(Punjab Development Statistics Report, 2019)

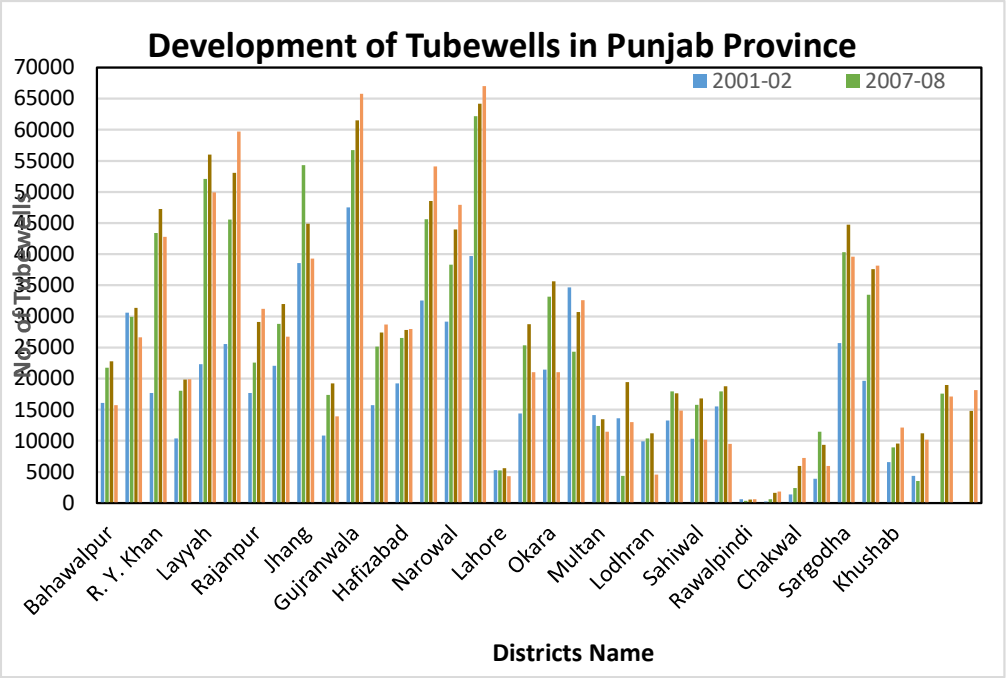


Fig. 3: Temporal growth of tubewells in different districts of the Punjab Province from 2001 to 2016, Data Source: (Punjab Development Statistics Report, 2019)

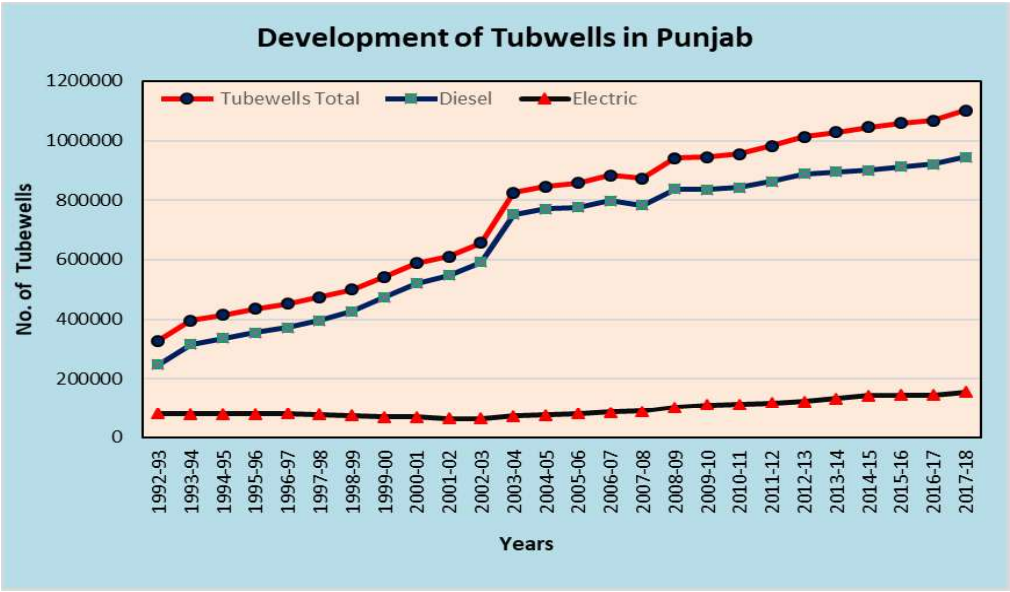


Fig. 4: Temporal growth of diesel and electric tubewells in the Punjab Province from 1992 to 2018; data Source: (Punjab Development Statistics Report, 2019)

Groundwater use and Development of Irrigated Area

Agriculture is responsible for changes in land-use that affect the way that water is collected, stored and released into the environment. Different sources of irrigation contribute in increasing the gross irrigated area (GIA). These sources include canal irrigation, tank irrigation, and groundwater irrigation which includes both tube wells and dug wells. Improved reliability of water supply through canals or, more significantly through groundwater, has significantly contributed to the increase in irrigated area and agricultural productivity in Province. Groundwater irrigation has contributed in much of the increase in the net irrigated area of the country over the last few decades. It is popularly believed that the recent groundwater irrigation expansion was taking place in and close to irrigation command areas, where recharge from canal irrigation is the main source of groundwater availability. If we look at the water productivity, it is very low as compared with many countries (Hussain et al., 2003). There is need of lot of water to grow main field crops along the river basin. The water requirement for different major crops are given in **Table 1**.

Table 1: Water Intensive Crops in Indus River-Pakistan
Data Source: WWF; Thirsty Crops

Crop	Water requirement (in liters) per kilogram of crop
Cotton	7,000 - 29,000
Rice	3,000 - 5,000
Sugar Cane	1,500 - 3,000
Wheat	900
Potatoes	500

Even in areas where sugarcane is not irrigated, the crop can have a great impact on river flow as it reduces run-off from the catchment into rivers and draws heavily on groundwater resources. Groundwater irrigation has contributed in much of the increase in the net irrigated area of the country over the last few decades. Due to contribution of groundwater irrigation in agriculture, net irrigated area has increased from 12. 45 million hectors to 14.40 million hectors during 1990 to 2017 (PDS, 2003 & 2019). Evidence strongly reveals that during period from 1970 to 2000, groundwater expansion had taken place mainly in the agricultural area like Punjab and the correlation between groundwater irrigation expansion and surface irrigation development is strong in Punjab Province phase. **Figures 5-8** highlight the cropped area and net irrigated area expansion relative to that of the groundwater irrigation which supports the claim that that most of the increase in net irrigated area is caused by groundwater irrigation. In the past, surface water irrigation had played a significant role in increasing the net irrigated area. It is also observed that surface water recharge is a necessary condition for the expansion of groundwater-irrigated area. Groundwater pumping costs generally depend on the water table level, which means that as the groundwater stock is increased, marginal extraction costs falls. Higher surface water withdrawals recharge the

aquifers and induce the farmers to increase groundwater usage and expand the gross irrigated area. Groundwater irrigation contributes higher relative change in gross irrigated area in Punjab Province while canal irrigation contributes less change. Higher relative contribution of groundwater is also witnessed in all geographical zones.

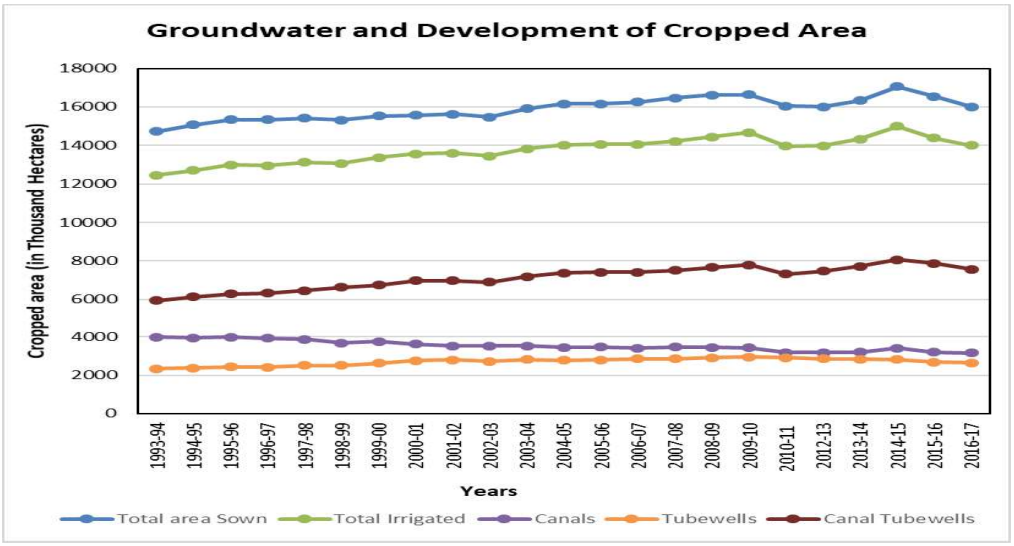


Fig. 5: Development of cropped area irrigated ('000' ha) by different modes of irrigation in the Punjab province (Source: Punjab Irrigation Department and Punjab Development Statistics Report, 2019)

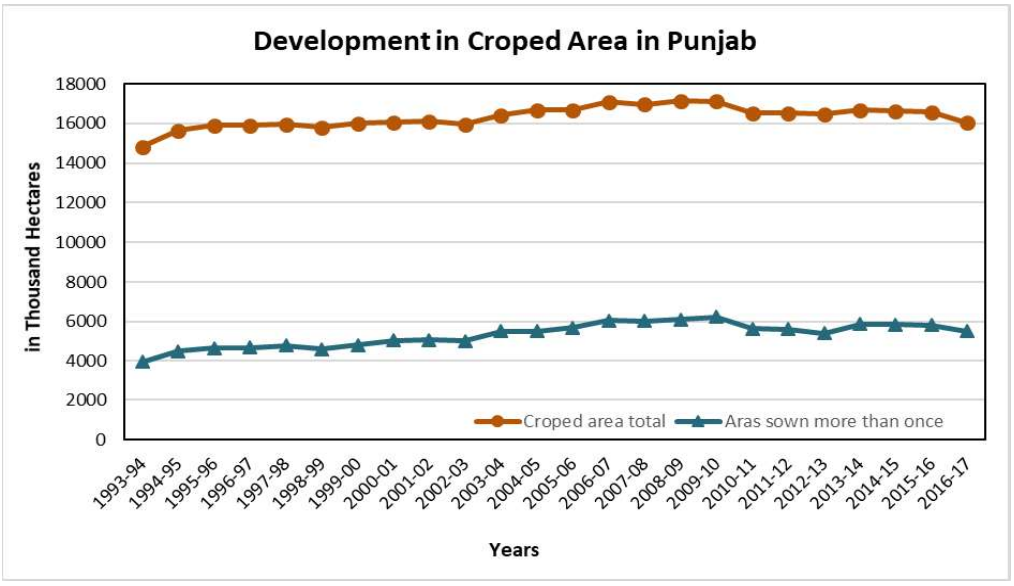


Fig. 6: Development of area irrigated ('000' ha) and area sown more than once due to tubewells development in the Punjab Province from 1992 to 2018 Data Source: (Punjab Development Statistics Report, 2019)

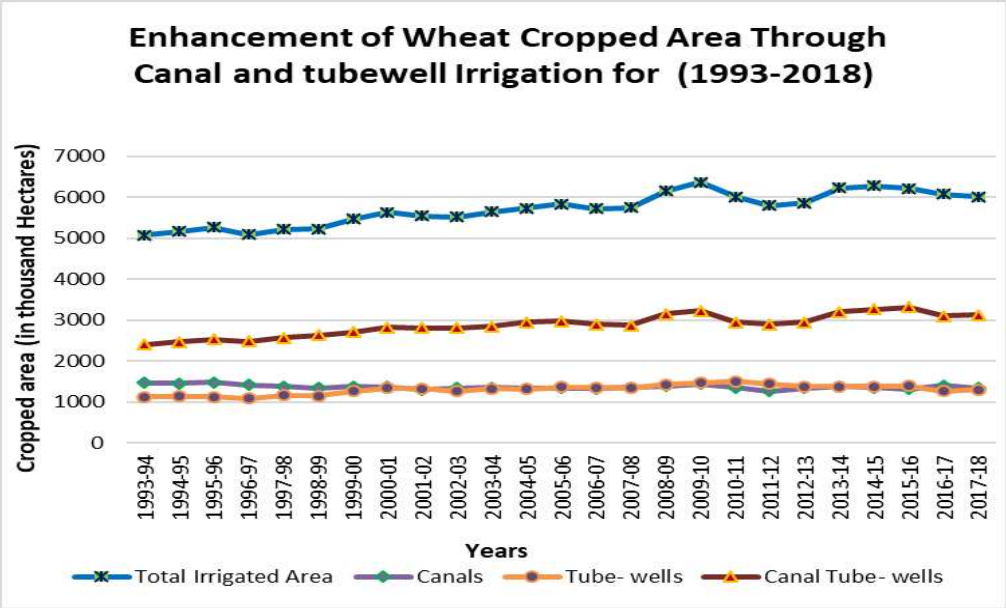


Fig. 7: Development of Wheat Cropped Area irrigated ('000' ha) by different modes of irrigation in the Punjab province (Source: Punjab Irrigation Department and Punjab Development Statistics Report, 2019)

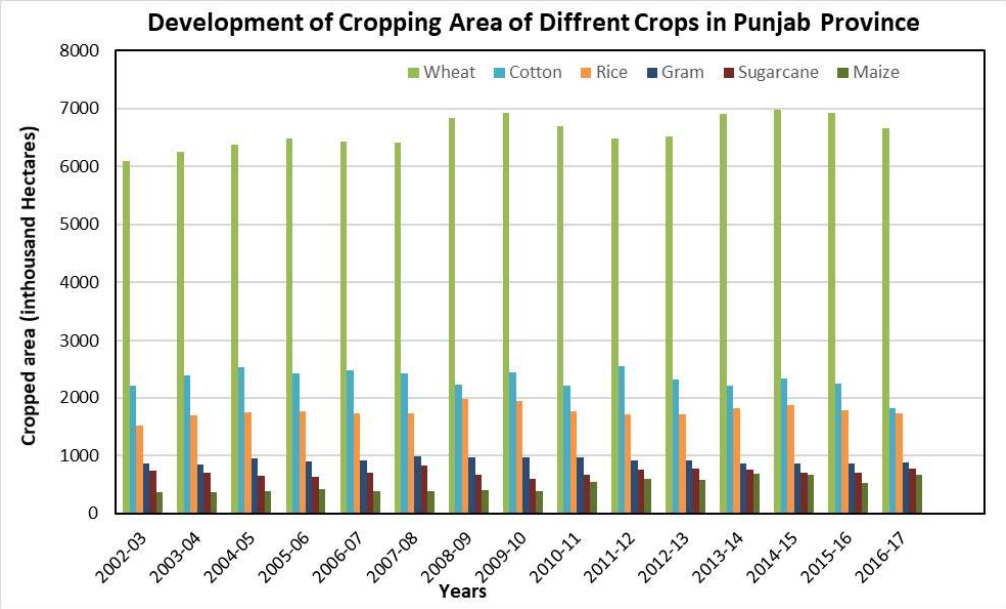


Fig. 8: Development of cultivated area of six major crops in Punjab; Data Source: (Punjab Development Statistics Report, 2019)

The increased cropped area in the province has depended on groundwater in the province. It has been observed from the figures 7 & 8 show increased cropped area of different crops and groundwater consumption in Province. Cotton cropped

area has been decreased while the maize cropped area is increasing. Tubewell density and numbers of tubewells raised in the Punjab to meet the water requirement for different crops especially maize and wheat.

Conclusions

First, groundwater irrigation

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- Development of farmer's tube wells and expansion of groundwater irrigation is driven mainly by the demand conditions-the population pressure.
- Development of farmers tube wells and expansion of groundwater irrigation is driven mainly by the surface water supply system including water seepage losses, "*wara bandi*" (irrigation scheduling) system, unreliable and variable surface water supply etc.
- Irrigation System was developed at 67 percent cropping intensity but now cropping intensity has reached more than 150 percent which is major driver for groundwater over-extraction.
- Development of farmer's tube wells and expansion of groundwater irrigation is due enhancement of irrigated area, need and production of more food and deficiency, fix of surface water system.
- High cost of electric tubewells has promoted the availability of low-cost diesel pumps and tubewell.
- Groundwater has been a major driver to enhance irrigated area, more crop production has supported the livelihood of the farming communities especially in rural areas .
- Groundwater irrigation is the most reliable driver to increase the intensive use of irrigated land, one of the criteria of agricultural productivity
- Extensive development of groundwater has helped to achieve food security and protected livelihoods of millions of people living in the Province.
- Over exploitation has resulted in declining groundwater tables and incipient secondary salinization which has caused overall low productivity.
- Depletion of groundwater level causes increased high cost of installation and operation of tubewell which poses adverse impacts on livelihood of farming families.

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intensive use of irrigated land, one of the criteria of agricultural productivity

Recommended strategies

For sustainable development, management and use of groundwater leading to enhanced agricultural production through reliable and ensured availability of water; following strategic reforms and actions on both demand and supply sides are suggested: -

- Integrated use of surface (canals, rainfall) and groundwater (tubewells)
- Enhanced aquifer recharge- natural and artificial
- Scientific and judicial extraction and use of groundwater – assessment of climate smart aquifer potential.
- Involvement of stakeholders at all levels- participatory groundwater monitoring, development and implementation of local participatory groundwater management plans
- Resource assessment- proper, reliable and adequate monitoring to generate data base for planning, operation, protection of aquifer on sustainable basis.
- Public awareness regarding water saving and use-mass education through media (print, electronic, social) campaigns, walks, seminars, dialogues involving all stakeholders up to grassroots level.
- Encourage the efficient use of water- subsidies/incentives linked with water saving instead of water supply.
- Capacity building of all stakeholders- planners, managers, users
- Strengthening the research organizations- resources evaluation, future response of reservoir, innovative tools and models, nature based solution,

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