**On Farm Irrigation Practices and Climate Change Effects on Economic Growth**

**A. Bakhsh1\*M. Abbas2**

*1Faculty of Agricultural Engineering and Technology, University of Agriculture, Faisalabad*

*2Water Management Research Center, University of Agriculture Faisalabad*

*\*Corresponding Author, email:* *bakhsh @**uaf.edu.pk; Phone: +9241-9200194*

**Abstract**

Although Pakistan has one of the largest contiguous irrigation systems in the world but it operates at a very low level of irrigation efficiency of 40%, which can be improved by adapting efficient on farm irrigation practices. These practices include watercourse improvement, laser land leveling, bed planting and high efficiency irrigation systems. These practices were carried at three sites commanded by Lower Chenab Canal System East (LCCS) under a JICA funded project to demonstrate the impact of water saving technologies on crop yields. About 6000 ft length of watercourses were improved, 2100 acres were leveled, 1000 acres went under bed planting and 10 acres were under drip irrigation system at three sites to demonstrate the effects of these practices on water savings, crop yields and net returns to the farmers. Field data were collected and the analysis revealed that on the average, these practices saved irrigation water in the range of 20 to 70%, increased crop yields by 20 to 30% and increased net income to the farmers by 20%. The success of these practices, however, lies in creating awareness among the farmers, providing backup support and on field intensive trainings to the farmers. Besides these issues, the country is also the state most vulnerable to climate change effects such as facing glacier retreats, rise in temperature of 2oC by 2050, forecasting in floods during next 40 years followed by severe reduction in river flows by 40 to 50%. Moreover, climate change can reduce rice yields from 8 to 30% and wheat yields from 6 to 19%, increasing poverty of 6% by 2050, which stipulates adaptation of efficient irrigation practices and developing new climate resistant crop varieties.

**Keywords**: Bed planting, laser land leveling, high efficiency irrigation system

. **Introduction**

Pakistan’s economy is primarily an agrarian based as agriculture sector is contributing about 21.0 % to its GDP, employing 43.7 % of its work force, and providing livelihood to more than 62 % of its population, which is residing in the rural areas (GOP, 2014). But, contribution of this sector of economy is heavily dependent on adequate supply of irrigation water as the country lies in arid to semi-arid region. Agriculture in Pakistan utilizes about 95% of its water resources, which are diminishing with time while demand for it is increasing due to increase in population. The population of Pakistan is estimated to be about 188 million in 2014, increasing at the rate of 1.95% and is projected to be 363 million in 2050 (GOP, 2014), which shows an increasing demand for food and fiber requirements. This indicates serious food security concerns as more than half the country is considered as food insecure (with less than 2000 calories/person/day) and 28% as sternly food insecure (less than 1700 calories/person/day) (IFPRI’s Food Security Portal at http://www.foodsecurityportal.org/pakistan).

Food security and water security is moving towards water scarcity. The existing water storage capacity of the water reservoirs in the country has decreased from 15 million acre feet (MAF) in 1975 to 11 MAF in 2011, showing 25% decrease in storage capacity, mainly due to sediment loadings. The average river supplies have decreased from 189 MAF in 1922-61 to 120.84 MAF in 2001-08 due to climate change effects. The actual average canal water diversions from river have decreased from 103.5 to 88 MAF over the years of 2006-11 and were 89 MAF during 2012-13 and 98 MAF during 2013-14 (IRSA, 2014). The country is facing drought like situation as mostly the rainfalls are meager and erratic. According to a report released by the Asian Development Bank, “Asia Water Development Outlook, 2007”, Pakistan has been ranked as the worst performer in Asia in terms of water availability, water use efficiency, water quality and quantity. The above mentioned situation is showing clearly that the country is entering into zone of water deficit as water availability per capita is going to reach 915 m3 / capita in 2020 (GOP, 2014). If timely steps are not taken to improve irrigation efficiency of the system, water shortages would increase to 151 MAF by 2025 (SBP, 2012). Although surface water supplies are being augmented by abstraction of groundwater in the range of 40 to 50 MAF as the number of tube wells in the country has increased to more than one million with 0.8 million in Punjab only.

The groundwater resource in the country has also been recognized as a reliable source of supplemental irrigation water because of its easy and flexible access to the farmers. The farmers can irrigate their crops using groundwater according to their choice and crop water requirements. With additional irrigation supplies from groundwater, cropping intensities have increased to more than 150% in some areas over the last two to three decades, and groundwater has become a key input in agricultural production (Ahmad et al., 2007a). ENERCON has reported about 19,000 tube well addition per year. More number of tube wells means more groundwater abstraction, more energy consumption, falling groundwater levels and deteriorating groundwater quality. The increase in groundwater usage over the last few decades has become more than recharge and has resulted in declining groundwater levels (Ahmad et al.,2005; Jehangir et al., 2007; Cheema, 2012).These indicators present an alarming situation for us because of the diminishing and deteriorating groundwater resources in wake of soaring energy prices. According to a survey conducted by ENERCON, most of tube wells in the country are working at an average efficiency of about 30%, which is much lower than the achievable potential of about 60%. A recent survey by PITCO has revealed that after investigating energy requirements of a typical electric driven tube well, according to its discharge and total pumping head and replacing its parts by the adequate required HP motor and efficient pump, there is net saving of 20% in electricity as well as in electric charges, which can result in savings worth of billions rupees when adapted all over Pakistan. But climate change is another crucial factor affecting surface as well as groundwater resources, and crop yields, which deserves to be considered while developing future plans.

Climate change is the factor, which has been recognized as the most influencing factor for agriculture productivity. According to an estimate temperature is expected to increase by 2oC by 2050, affecting drastically the frozen water reservoirs in northern parts of the country. Moreover, World Bank report “water economy, running dry” (2005) has predicted that in the coming 40 to 50 years, there would be higher flows by 40% in the Indus River and its tributaries, which will decrease during the next 50-years to 40%. This indicates that there would be entirely a different scenario during the next century, which requires prudent planning especially on part of the water resource management. The rise in temperature can increase the crop water requirements i.e. evapotranspiration, which can accelerate groundwater falling rates, and even can induce shortages in drinking water supplies. Further climate change can increase occurrence of the extreme events i.e. droughts, floods, storms.

Keeping in view the above scenario, there is a dire need to make judicious use of our diminishing water resources including surface, groundwater and rainfall. Surface water resources conservation in fact originates from watershed management, developing water reservoirs, minimizing conveyance losses from head works to Mogha (canal outlet) and especially below Mogha i.e. watercourse improvement, precision land leveling, improving irrigation practices and adapting high efficiency irrigation systems (HEIS). But at the same time we must think of the groundwater reservoir when we go for adapting HEIS, lining canals and improving water courses. The underlying aquifer has been built from the water losses taking place from the irrigation network i.e. canals, distributaries, water courses, and irrigated fields. When all these losses are minimized by adapting HEIS then what will happen to the groundwater reservoir especially in wake of the increased pumping which is taking place as more and more number of tube wells are being drilled.

**Water Management Practices**

The Government of Pakistan in collaboration with the World Bank, Asian Development Bank, OECF and USAID has launched a number of on-farm water management (OFWM) projects such as OFWM-I (1981-85), OFWM-II (1986-91), OFWM-III (1992-96), which enabled improvements of about 45,000 watercourses out of 140,627 in the country. Moreover, National Program for Improvement of Watercourses (NPIWC) was launched in 2004 to 2009 over an extended period of six years to improve 86,000 watercourses on the basis of 20% cost sharing by the farmers. This project improved 54,695 watercourses including 5,000 water storage tanks in Balochistan. The project lined 30% of length of the watercourse in saline areas and 20% in fresh water areas while involving complete earthen renovation. The project envisaged water saving of 8 MAF annually with 10% reduction in waterlogging and salinity areas, increasing cropping intensity from 5 to 20%, improving crop yields from 10 to 15% in addition to improving equity in water distribution and reducing poverty in the rural areas.

In this regard, the University of Agriculture, Faisalabad (UAF), recently ranked among top 100 Universities in the World, is carrying out research and outreach projects encompassing a number of water management practices being demonstrated at farmer’s fields to improve irrigation efficiency, crop productivity, and economic benefits to the farmers. The Water Management Research Center (WMRC) at UAF is executing international projects such as “On-Farm Research and Development Component, Rehabilitating Lower Chenab Canals System Part-B” financed by JICA (Japan International Cooperation Agency) in collaboration with provincial Irrigation and Power Department. In its 1st phase (2006-2012), three sites were selected on three distributaries of LCC-east i.e. Khurrianwala, Killianwala and Mungi distributaries, (Fig. 1) where on-farm water management practices were performed on the farmer’s fields to transfer these technologies to the farmers. These technologies comprised water course improvement, laser land leveling, bed planting, drip irrigation system, skimming well technologies. Currently, this project in 2nd phase being executed at three new sites at Lakhuana, Shahkot and Khikhi distributaries. The farmers of these areas are very happy to get their lands laser leveled and adapt modern water management practices as outlined above. The achievements under this project and their impact on economic returns to the farmers are given below:

Fig. 1- Sites selected under the project on LCCS-East.

**Water Course Improvement**

Water losses in the water courses have been reported to vary from 30 to 50% depending on the soil type, topography, watercourse alignment, uniformity of cross-section, adequate channel size and silting. The WMRC improved three watercourses at three sites in collaboration with the farmers by introducing participatory approach. Farmers played very active role in improving these watercourses and funds were provided under JICA project. Three water courses of 2200 feet in length each at three sites were improved, which reduced the conveyance losses significantly in the range of 15 to 20%. The cropping intensity increased by 20 to 30% and crop yields was increased by 20%. The economic returns to the farmers from lining of these water courses were increased by 20%. The 2nd phase three water courses were also improved at three new sites at Lakhuana, Shahkot and Khikhi distributaries. 2000 ft in length each water course was lined to increase conveyance efficiency by 20%, resulted in increasing cropping intensity by 25%. Improvement of water courses provided farmers an opportunity to increase crop yield at fields.

**Laser Land Leveling**

At these three sites 3000 acres were laser levelled, resulting in saving water, improving irrigation efficiency and increasing crop yields significantly. Efforts were made to involve and convince the farmers for adapting laser leveling technologies to receive the benefits in terms of water saving and yield increase. The farmers of the areas are fully convinced from benefits of this water resource conservation technology and now the farmers are willing to level their fields on their own. The laser levelled fields saved water by 30-50% and increased crop yields by 15-25% and economic returns by 20%. A review of various studies suggested that laser land leveling in Pakistan resulted in about 25% reduction in irrigation water application and an increase of about 30% in wheat yield as compared to conventional practices (Humphreys et al., 2005, 2010). During 2nd phase 2000 acres of land water laser levelled for poor farmers to increase crop yield by 20%. This technology has been emerging as water saving technology because farmers saved 35% irrigation water which was lost during water application at field.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Site name** | **Area****Under laser levelling** | **water applied under laser levelling (ft3)** | **water applied without laser levelling (ft3)** | **Water saving (ft3)** |  **Percent Water saving %** |
| Khikhi | 606 | 10332 | 14590 | 4258 | 29 |
| Dijkot | 432 | 10675 | 14590 | 3915 | 27 |
| Shahkot | 457 | 10000 | 14590 | 4592 | 32 |

Table 1. Comparison of water applied under laser levelling and without levelling

Fig 1. Comparison of water applied under laser land levelling and without laser land levelling

The table and graph clearly indicates water applied under laser land levelling and without land levelling, about 29-32% water is conserved under laser land levelling.

 **Bed Planting**

It is reported that raised beds result in considerable water savings (Bouman et al., 2007; Choudhury et al., 2007; Humphreys et al., 2010). In the project, there was a special focus on promotion of raised bed technology as it saves water and improves yield of the crops. Project target for this activity was 3000 acres with 1000 acres on each site. The activity was performed on 6000 acres indicating that farmers have been convinced for this technology. Bed-furrow planting has potential of water saving of 30-50% and increase in yield for wheat (5 to 10%) (Fig. 2) with improved fertilizer use efficiency, which addresses dire need of the country both for water and food security. The economic benefits derived by using bed technology ranged from 20 to 30% in comparison to traditional sowing of crops.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Site name** | **Area (acre)** | **Bed Planting Yield (monds/acre)** | **Conventional Yield (Monds/acre)** | **% increase in Yield** | **Bed Planting water applied ft3** | **Conventional sowing water applied (ft3)** | **Water saving (ft3)** | **Perce ntage in Water saving %** |
| Khikhi | 222 | 42 | 40 | 4 | 7830 | 13510 | 5680 | 42 |
| Dijkot | 53 | 41 | 39 | 5 | 7690 | 14590 | 6830 | 46 |
| Shahkot | 54 | 41 | 38 | 8 | 7209 | 12580 | 5371 | 43 |

Table 2. Yield and water applied under bed planting and conventional sowing methods

Fig. 2- Comparison of wheat yields on beds with flat sowing.

**Drip Irrigation System**

Drip irrigation system has the potential to save water from 70 to 80% and improve irrigation efficiency by 95%. Drip irrigation system offers full control on applying irrigation water allowing adapting the concept of “when to apply and how much to apply irrigation water”. Drip irrigation can increase the crop yields more than two times when coupled with balanced fertilizer application i.e. fertigation. This system has been very productive especially under tunnel farming by controlling humidity, decreasing use of chemicals, improving fertilizer use efficiency. The system can increase net income to the farmers by Rs. 0.5 to 1 million per acre when growing high value crops. We have installed three drip irrigation units at sites to demonstrate the benefits of drip irrigation and fertigation at farmer’s field. The farmers are willing to adopt this technology because it has increased their production yield and its saves 40% irrigation water compared to conventional method.

**Climate Change**

Climate change is a global phenomenon, which is leading to increase in temperature, rise in sea level, retreat of glaciers, and frequent occurrence of extreme events such as floods, droughts and shortages of fresh water. According to German watch report (2012), Pakistan has been ranked as the third most vulnerable country to climate change effects. As outlined above the effects of climate change on agriculture is adverse, which can lead to decrease in crop yields. The agriculture in Pakistan requires application of irrigation water throughout the year as country has lesser average rainfall of 240 mm against evapotranspiration of 1500 to 2000 mm. Water resources of Pakistan are highly vulnerable to climate change especially in view of the glacier retreat. About 70 to 80% of river flows of Indus and its tributaries are derived from melting of the glaciers. According to World Bank report (2005), it has been predicted that as a result of change in temperature in the range of 0.03 to 0.15oC/year, there would be increase in Indus River flows from 20 to 40% during next 40-years followed by reduction in river flows from 30 to 60% in the subsequent 40 to 50 years (Fig. 7). When water supplies are being affected so drastically due to climate change then there would be multiplying effects on agriculture production. Pakistan’s agriculture depends on adequate supplies of irrigation water to grow crops round the year. Therefore the country has to develop strategies to cope with the threatening effects of climate change not only on water security but also on food security and national security.

According to findings of a study conducted at UAF for Punjab, Pakistan, under AgMIP project, it has been reported that climate change in Pakistan is already affecting occurrence of the extreme events in the form of drought and causing excessive floods such as in 2010. The temperature is expected to rise by an average of 2oC by 2050, although which seems to be on the higher side but it will have devastating effects on extreme events of floods and droughts. The findings further highlight the impact of climate change on crop yields in Punjab, in the form of reduction in rice yields from 8 to 30% and wheat yields from 6 to 19% by 2050, which may also increase poverty by 6%. As a result of climate change impacts on agriculture, the adaptation measure stipulates development of drought resistant crop varieties, farming packages, building of water reservoirs and rain water harvesting.



Fig. 7-Climate change impact on Indus river flows (Source: WB, 2005)

**Summary and Conclusions**

The land and water productivity in Pakistan has been reported to be lower in the range of 0.45 kg m-3 in comparison to 0.8 kg m-3 in India and 6.5 kg m-3 in USA (WB, 2005), which shows significant room for improvement. Moreover, it has been predicted that temperature will rise by 2oC by 2050, which can decrease rice yields from 8 to 30% and wheat yields from 6 to 19%, increasing poverty of 6% by 2050. According to another report by Germanwatch (2012), Pakistan has been ranked as the third most vulnerable country due to climate change effects. Keeping in view these scenarios, following conclusions are drawn:

* Water management practices of laser land leveling, bed planting, water course improvement have potential to save water in the range of 20 to 40% and increase in net return to the farmers by 20 to 30%.
* HEIS can save water in the range of 70 to 90% and can increase net returns significantly especially when switched to high value crops.
* Rainwater harvesting in urban as well as in rural areas need to be promoted for irrigation and for recharging groundwater.
* Pakistan has been ranked as the 3rd country most vulnerable to climate change effects, which has tremendous effects on its water resources especially the Indus river flows originating from melting of glaciers. Building of water reservoirs and developing heat resistant crop varieties can help mitigate the climate change effects on agriculture.

**References**

Ahmad, M.D., Bastiaanssen, W.G.M., Feddes, R.A., 2005. A new technique to estimate net groundwater use across large irrigated areas by combining remote sensing and water balance approaches, Rechna Doab, Pakistan. Hydrogeology Journal, 13(5–6):653–664.

Ahmad, M.D., Turral, H., Masih, I., Giordano, M., Masood, Z., 2007a. Water saving technologies: Myths and realities revealed in Pakistan’s rice–wheat system. Research Report 108. International Water Management Institute, Colombo, Sri Lanka, 38 pp.

Bakhsh, A. 2013. Project Report on “Research and Development Component of Rehabilitating LCCS-East Part (B)” funded by JICA.

Bouman, B., Barker, R., Humphreys, E., Tuong, T.P., Atlin, G., Bennett, J., Dawe, D.,Dittert, K., Dobermann, A., Facon, T., Fujimoto, N., Gupta, R., Haefele, S., Hosen,Y., Ismail, A., Johnson, D., Johnson, S., Khan, S., Shan, L., Masih, I., Matsuno, Y.,Pandey, S., Peng, S., Muthukumarisami, T., Wassman, R., 2007. Rice: feeding the billions. In: Molden, D. (Ed.), Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. Earthscan/International Water Management Institute, London, UK/Colombo, Sri Lanka, pp. 515–549.

Cheema, M.J.M., 2012. Understanding water resources conditions in data scarce river basins using intelligent pixel information Case: Transboundary Indus Basin. Ph.D thesis. Technical University Delft, The Netherlands, 186 pp.

Choudhury, B.U., Bouman, B.A.M., Singh, A.K., 2007. Yield and water productivity of rice–wheat on raised beds at New Delhi, India. Field Crops Research, 100:229–239.

GermanWatch: Harmeling, Sven and David Eckstein. 2012. Global climate risk index 2013.

GOP. 2014. Economic survey of Pakistan. Economic Affairs Division. Government of Pakistan.

Humphreys, E., Kukal, S.S., Christen, E.W., Hira, G.S., Balwinder-Singh, Sudhir-Yadav, Sharma, R.K., 2010. Halting the groundwater decline in North West India—which crop technologies will be winners? Advances in Agronomy, 109:155–217.

Humphreys, E., Meisner, C., Gupta, R., Timsina, J., Beecher, H.G., Lu, T.Y., Singh, Y.,Gill, M.A., Masih, I., Guo, Z.J., Thompson, J.A., 2005. Water savings in rice–wheat systems. Plant Production Science, 8(3):242–258.

Indus River System Authority (IRSA), 2014. Different Reports on Water, Ministry of Water & Power, Government of Pakistan.

Jehangir, W.A., Masih, I., Ahmed, S., Gill, M.A., Ahmad, M., Mann, R.A., Chaudhary, M.R., Qureshi, A.S., Turral, H., 2007. Sustaining crop water productivity in rice–wheat systems of South Asia: a case study from Punjab Pakistan.

Saeed, M.M., Bruen, M., Asghar, M.N., 2002. A review of modeling approaches to simulate saline-upcoming under skimming wells. Nordic Hydrol., 33(2/3):165–188.

World Bank: Briscoe, J. and Usman Qamar. 2005. Pakistan’s water economy: running dry. Oxford University Press. The World Bank.