

Drip Irrigation for Sustaining Irrigated Agriculture in Punjab, Pakistan: Issues and Strategy

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Abstract. *Pakistan is one of the world's most arid countries with an average annual rainfall of 240 mm. There is, therefore, enormous reliance and relies enormously on irrigation for food production of its ballooning population as well as for industrial raw materials. The sustainability of this major sector of the country's economy is at risk because of inefficient irrigation practices besides escalating water scarcity. Realizing the situation, recently a number of interventions have been introduced for water conservation and productivity enhancement in Punjab's agriculture. Drip irrigation has emerged as one such method having substantial water savings and productivity gains in comparison to the crops cultivated under conventional irrigation. The water saving under drip irrigation was 50 percent and increase in yield was 34, 39 and 105 percent for potato, sugarcane and citrus, respectively with several allied remunerations including irrigation cost curtailment, enhanced quality of produce etc. The study also investigated potential areas for drip technology to efficiently utilize the available farm level irrigation supplies.*

Keywords. Irrigated Agriculture, Drip Irrigation, HEIS, Punjab, OFWM, PIPIP

1. INTRODUCTION

As in many parts of the world, irrigated agriculture is one of the major contributors to economic development in Pakistan. Irrigation consumes about 85 percent of available water in developing countries and 62 percent in developed countries (Mark, 2010). In arid climates like Pakistan, where an average annual rainfall is less than 240 millimeter, role of irrigation becomes very crucial in sustaining agriculture (John et al., 2006). Evidently, more than 80 percent of Pakistan's cultivated land is irrigated, whereas this ratio further jumps to 86 percent in case of the Punjab province. The contribution of irrigated lands to total national agricultural output is more than 90 percent (PDS, 2011 and Khan, 2006) revealing unquestionably the conspicuous prominence of irrigated agriculture in Pakistan. The sector has strong linkages with almost all major sectors of the economy as it absorbs 45 percent of total labor force and contributes substantially to exports by supplying raw materials to downstream industry. Despite its critical importance to national development, the sector could not perform sustainably because of structural issues, lack of mechanization and water shortages. Amid many problems, adequate water availability and its efficient use for crop production remained the main impediment to low productivity (PES, 2011). The level of agricultural production is directly related to the availability and effective use of water as a major input. Efficient use of all other production inputs depends on adequate irrigation for crop production (Bakhsh et al., 2008).

The balance between population and available water already makes Pakistan one of the most water stressed countries of the world. According to a study published by the World Bank (2006), *“Pakistan’s Water Economy: Running Dry”*, Pakistan is one of the most water-stressed countries in the world and its performance in terms of capacity, water use as well as quality has remained poor despite having enormous potential for water resource development and management. If the current trend continues, it will soon enter a condition of absolute water scarcity (Figure 1). Irrigated agriculture utilizes only 30 percent (42 million acre foot) of available water resources for crop production (Khan, 2006 & Mahmood, 2012).

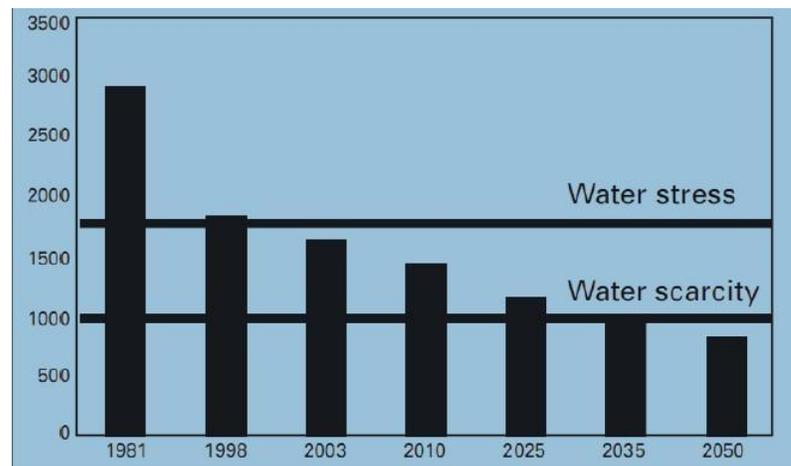


Figure 1. Water availability (m³/capita)

Even though Pakistan has bestowed with largest contiguous Indus Basin Water System (IBWS), a huge volume of water is wasted in conveyance and application because of mismanagement. Furthermore, the IBWS was designed for low irrigation intensity (67 percent) and farmers are still practicing inefficient and unproductive traditional irrigation methods and practices (PDS, 2011). Crop water requirements are not met timely because of supply based irrigation water delivery, which negatively affects the overall productivity. The irrigation efficiencies at the farm level are dismally low that is a major constraint in attaining potential production from otherwise highly productive agricultural lands. Another peculiar threat is the unregulated groundwater abstractions at an alarming rate causing mining of subsurface reservoirs besides intrusion of saline water from brackish aquifers to freshwater areas. This is evident from the fact that the number of tubewells in only in Punjab has increased from less than 10,000 in 1960 to about 1,000,000 in 2011 (PDS, 2011).

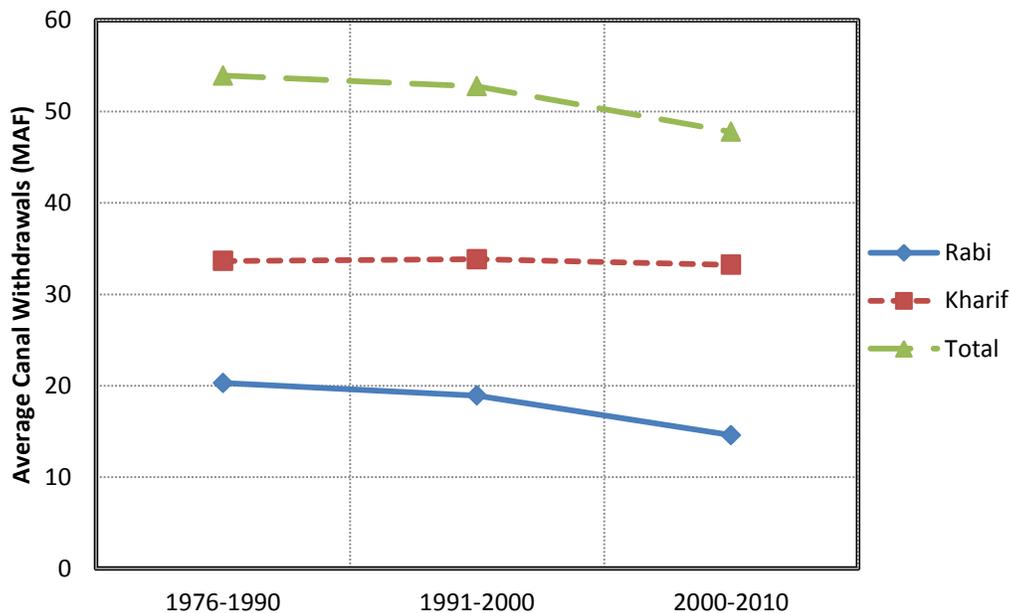


Figure-2: Average Canal Diversions (1976 to 2010)

The World Bank (2006) indicated that the water productivity for wheat in Punjab (Pakistan), California (USA), and Indian Punjab have shown productivity ratio of 5:8:10 per unit of water, respectively. Another study reported that water production in Pakistan is less than 0.1 kg/m^3 as compared to 0.39 kg/m^3 in India (PES, 2011). In view of escalating water shortages and rapidly increasing demands, the situation would simply be unsustainable for irrigated agriculture on which national economy is based. Resultantly, the efficient and judicious of scarce irrigation supplies through adopting water conservation and resource productive technologies for maximizing per unit production of water is inevitable.

There is now the emergence of a class of farmers who are growing high-value crops for both domestic and export markets, and are willing to invest in and adopt better and advanced irrigation practices, in which water plays a central role not just in evapotranspiration, but as a mechanism for delivering fertilizers and pesticides to crops.

Raising crop water productivity is the cornerstone of any demand management strategy to sustain crop production under escalating water shortages. In recent past, micro irrigation technologies called as high efficiency irrigation systems (HEISs) have been introduced in the country on a larger scale for enhancing water use efficiency and improving crop water productivity. Several studies have proved the technically feasibility, economic viability, and environmental compatibility of these micro irrigation systems in terms of water saving and yield increase. Keeping in view the potential of this technology, an attempt has been made in this paper to contemplate the issues and strategy relating to adoption of drip and sprinkler irrigation in Punjab.

2. The Issues

Irrigated agriculture is the central framework around which the entire economic and social fabric of Pakistan's development is woven. While the transition to an urban and industrial economy can and must continue, agriculture will remain central for the well-being of large number of people. Better water management is a key constraint to improving agricultural productivity and generating jobs. There is no denying that this sector requires more and more attention to bring it at par with developed nations if the country is to avert ever nearing looming food disaster. To formulate a viable strategy it is, however, necessary to ascertain some of the major issues related to irrigated agricultural production. The complexity and intertwining of myriad problems in boosting production per unit of water is beyond the scope of this paper and attention is focused on major issues.

2.1 Land Resources

Demographically, Punjab is the largest province of Pakistan with a total geographical area of 20.64 million hectares (Mha), out of which 0.50 Mha (2.42%) are under forests, 3.04 Mha (14.7%) are uncultivable, 3.88 MA (7.6%) are culturable waste, 7.28 MA (14.9%) are non-reported, 1.57 Mha (7.5%) are currently fallow and 11.03 Mha (53.5%) are net sown. Nearly 76 percent of irrigated area lies in Punjab. Its share in total agricultural production of the country is more than 80 percent in case of cotton, almost 70 percent for wheat, nearly 60 percent for sugarcane, and 50 percent in rice. Over all contribution of the province towards agriculture sector is estimated to be more than 80 percent. Geographically, the province is situated at the center of the World's largest Indus Basin link canal irrigation system and has the greatest irrigated area and largest amount of irrigation assets in Pakistan. Despite its everlasting significance, the province is facing acute water shortages creating threats for food security to its people.

2.2 Surface Water Resources

The single most irrefutable factor in Pakistan's water resources is that there is near future no more additional surface water that can be injected into the system. In the present situation there is no feasible intervention which would enable the country to mobilize appreciably more water than it now uses. On the contrary, the international scenario indicates decreased flows in some rivers. Furthermore, if environmental concerns in the delta areas are to be addressed, there is an argument for reducing the overall use for irrigation needs in upper agricultural areas.

The water economy of Pakistan depends fundamentally on a huge and complex hydraulic infrastructure system known as the Indus Basin Water System. Significant portions of this system are now reaching the end of their design lives, and have to be rebuilt or repaired. This dependence on a single river system also means that there is little room for maneuvering that most countries enjoy by virtue of having a multiplicity of river basins and diversity of water resources. If the system fails there is no latitude for error.

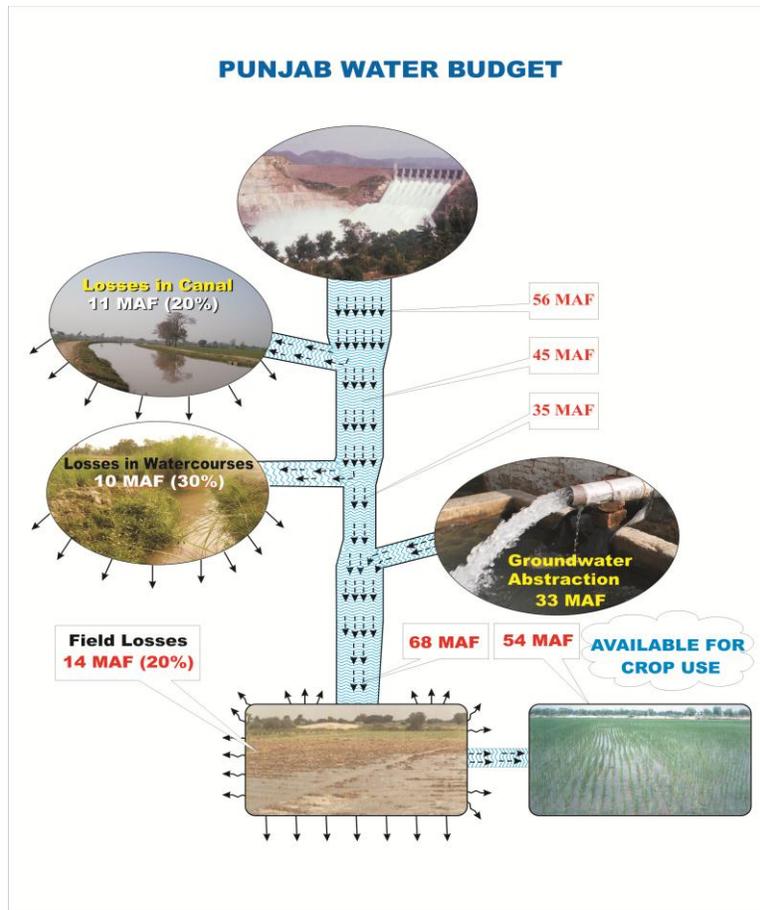


Figure-3: Punjab Water Budget

The total surface water allocation for the Punjab as per Water Accord 1991 is 55.54 MAF. An analysis of canal water withdrawals during Rabi and Kharif from 1976 to 2011 has shown a declining trend as shown in (Figure-3). The canal water supplies have declined to 47.80 MAF in the last decade. This is due to reduced reservoirs storage capacity because of sedimentation. Rabi has shown a major deficit of 5 MAF compared to water withdrawal in 1976. Moreover, there are huge water losses in the distribution network comprising of main/branch canals, distributaries, minors, and tertiary conveyance systems comprising of about 58,000 watercourses. According to Khan 2006, only 45 percent of diverted water into the canals is used for intended purposes and remainder lost in conveyance. The only possibility of augmenting water supplies is through heavy investment in storage dams on the Indus River which is controversial. With continuing sedimentation of major reservoirs, the increase in canal diversions with new dams is uncertain.

2.3 Groundwater Resources

Over the past 40 years, the exploitation of groundwater, mostly by private farmers, has brought enormous economic and environmental benefits. Groundwater now accounts for more than half of all irrigation requirements. Punjab withdraws almost 50 MAF of water from groundwater, which has reached its limit and further withdrawals are not possible without serious mining and extraordinary cost of pumping. Now, although, there is clear evidence that groundwater is being

over-exploited, yet tens of thousands of additional wells are being put into service every year. In the sweet water areas of the Indus Basin, depletion is now a fact in all canal commands. Furthermore, there are serious and growing problems with groundwater quality, a reality that is likely to get worse because there are 20 million tons of salt accumulating in the system every year.

The current approach to groundwater pumping is of laissez-faire, there being no regulation or policies to govern this sector. There is an urgent need to develop policies and approaches for bringing water withdrawals into balance with recharge. Since much groundwater recharge in the Indus Basin is from canals, an integrated approach to surface and groundwater is required.

2.4 Institutions

The main canal network is operated and managed by the Provincial Irrigation Department. Beyond the farm outlet, however, the system is run by the water users. The On Farm Water Management wing of the Provincial Agriculture Department is the primary agency for promoting resource conservation technologies, which are contributing significantly in enhancing water availability at the farm level and minimizing water losses to a great extent since 1976-77. There has been no incremental water resources development taken place during this period in the province. The only source of increased water availability at the farm level has been through adoption of conservation measures e.g. canal rehabilitation and lining, improvement of watercourses, LASER land leveling, bed and furrow irrigation etc. Farmer institutions are organized as Water Users Associations (WUAs) under an Act. These WUAs have an active participatory role in most of the water conservation activities implemented by OFWM.

Conceptually the task to move water in a predictable, timely manner to those who have a right to it and to ensure its efficient and judicious use seems relatively simple. Yet this has not been the case. It has been a slow and painstaking process leading from basic conservation practices like watercourse remodeling to more and more advanced techniques like high efficiency irrigation systems over a span of more than 30 years.

2.5 Productivity

As indicated earlier, there is abundant evidence that irrigated agriculture in Punjab is not efficient. It is becoming increasingly apparent that water not land is the main constraint, and the focus of attention will have to shift from productivity per unit of land to productivity per unit of water. The major challenge is to get more from less – more crops, more income, more jobs per unit of water. Recently, there is growing attention to the different water requirements of different crops. An acre of sugar-cane, for example, consumes as much as eight times the water needed by sugar bet. Increased attention is accordingly now being given to producing crops that can yield more with less water, withstand water-scarce and drought conditions, and thrive on low-quality (saline/alkaline) water and to the effect of different agronomic practices on water productivity.

Improving the productivity of water used in agriculture is a central challenge facing a water-scarce Punjab. It has been determined that the water required to grow enough food for one person – between 3,000 and 5,000 cubic meters a year – is about 100 times the amount required for household purposes (100 lpd or about 35 cubic meters a year). Accordingly, urban demands are important locally but not at a national scale.

3. Past Efforts

On Farm Water Management (OFWM) program has successfully promoted resource conservation technologies in Punjab which are contributing significantly in enhancing water availability at the farm level and minimizing water losses to a great extent since 1976-77. Since there has been no incremental water resources development taken place during this period in the province, the only source of additional water at the farm level has been through adoption of conservation measures e.g. canal rehabilitation and lining, improvement of watercourses, LASER land leveling, bed and furrow irrigation etc. Over the years there has been a gradual transition from elementary conservation practices like remodeling of earthen watercourses to the relatively more complex interventions like high efficiency irrigation systems.

Most of early OFWM projects were funded through assistance of donor agencies till last decade when the Government implemented some major initiatives out of its own resources. A mega initiative “National Program for Improvement of Watercourses (NPIW)” was launched in 2004 to improve the tertiary level irrigation conveyance system through a community driven implementation approach. Improvement of about 19,000 canal commanded watercourses and development/ rehabilitation of 3,734 irrigation schemes outside the canal commands have been completed during 2004-2011.

Similarly, a major project for provision of subsidized LASER land leveling equipment to farmers and service providers was launched in 2005, wherein 2,500 systems were provided. The scheme proved to be highly beneficial due to its immediate impact in minimizing cost of operation, better degree of accuracy in lesser time, saving of irrigation water, uniform seed germination, increased fertilizer use efficiency, and resultantly enhanced crop yields.

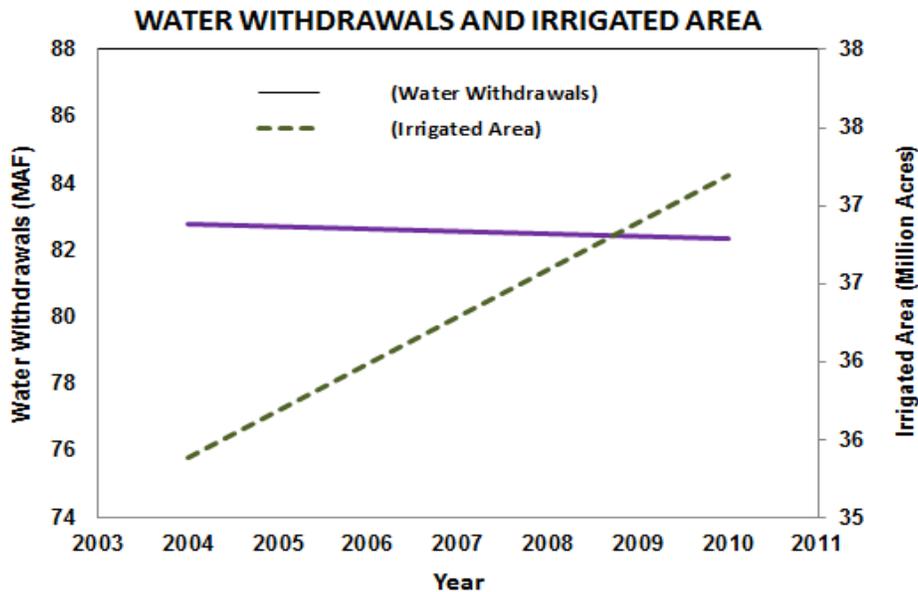


Figure-4: Water Withdrawals versus Irrigated Area

In the introduction of HEIS, a number of attempts were made in the past by various organizations including OFWM on a limited scale. Such efforts did not gain much acceptance

among the farming community despite the obvious water saving benefits. Analysis of the reasons for failure of these projects indicated following major issues;

- a. Lack of organization/institutional support for technical assistance and capacity building.
- b. Insufficient technical expertise and knowledge base in designing, installation and operation
- c. Inefficient technological package for follow-up and crop establishment i.e. irrigation schedule and fertigation schedule, plant protection and other agronomic practices.
- d. Inadequate participation and knowhow of all stakeholders at planning, designing, installation and operation
- e. Ineffective follow-up for assisting the farmers to successfully adopt the new technology
- f. High initial cost of the system that requires fixed investment

The project titled “Water Conservation and Productivity Enhancement through High Efficiency (Pressurized) Irrigation Systems”, called HEIS project, was launched to install drip and sprinkler irrigation on about 140,000 acres during four years (2008-09 to 2011-12) at a total subsidized cost of Rs. 6,917 million in the entire province. The project was implemented by OFWM through pre-qualified supply and services companies (SSCs), which installed the systems on turnkey basis in farmer’s field. Under 18th constitutional amendment, this project was, however, abandoned because of some administrative and financial problems regardless of its encouraging impacts. Under the scheme HEIS, systems were installed on 9,500 acres spread over the entire Punjab. The system-wise breakup of the installed systems is given in Table-1 below.

As evident from Table-1, drip technology has major share covering over 68 percent including orchards (32 percent) and row crops (26 percent). The sprinklers are installed on 32 percent of total area for cereal crops to supplement rainfall in rain-fed tracts and provide light irrigations in canal commands. This indicates a clear need and preference for drip irrigation over sprinkler irrigation systems.

Table 1: Distribution of Installed Drip Irrigation Systems in Punjab

Particulars	Micro Irrigation	
	Acres	% of total
Total Installed systems	11,500	100
<i>Drip</i>	7,850	68
<i>Sprinkler</i>	3,650	32
Drip Systems		
Orchards	4,870	62
<i>Citrus</i>	2,625	33
<i>Mango</i>	1,200	15
<i>Others</i>	1,045	13

Row Crops	2,980	38
<i>Cotton</i>	2,135	27
<i>Sugarcane</i>	240	3
<i>Vegetables</i>	605	8

The Government of Punjab also implemented an innovative undertaking for promotion of cotton cultivation under desert environment with drip irrigation on 2,000 acres at a total cost of Rs. 267 million during two years (2009-10 to 2010-11). The “Pilot Project for Promotion of Cotton Cultivation in Thal Region with Drip Irrigation” was designed to harness maximum potential of land, water, and other inputs for increasing agricultural productivity demonstrating cotton cultivation in water scarce desert environment through effective utilization of irrigation water under drip irrigation. The farmers were provided 90 percent of the total system cost in addition to construction cost for water storage pond required for drip irrigation system. The project achieved considerable success wherein, it was reported that cotton yielded upto 1.86 tons per acre with an average of 1.12 tons per acre vis-à-vis 0.60 tons per acre average in the area. Drip irrigation also made it possible to grow cash crops first time on sand dunes without land leveling in the project area including oil seeds, onion, vegetables in tunnels, maize, water melon etc.

4. Strategy

The experiences and lessons learnt during implementation of above two projects led to the development of strategy and design of a major initiative titled “Punjab Irrigated-Agriculture Productivity Improvement Project (PIPIP)”, which has been set forth to maximize output of available water by adopting a comprehensive OFWM technological package for minimizing losses at various levels of tertiary conveyance network and improving its application efficiency at the farm level. The project has been formulated based on following strategic considerations.

4.1 Feasibility of Drip Irrigation in Punjab

Foremost, it is necessary to determine the efficacy and quantum of benefits to be accrued with investments in drip irrigation systems under conditions in Punjab. Experiments at Mona Reclamation Experimental Project (MREP), International Waterlogging and Salinity Research Institute (IWASRI), reported about 85 percent water saving as compared to conventional irrigation for citrus crop. Trials at the Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad to compare effects of 15% (D15) and 30% (D30) deficit irrigations on water use efficiency of cotton in comparison to no deficit (D0) irrigation using drip irrigation system. The D0 treatment produced 8% and 33% more cotton yield than of was those of D15 and D30, respectively. Likewise, the water use efficiency of D15 was 5% more than D0 and 15% more than D30. The study concluded that drip irrigation has the potential of increasing water productivity even under deficit irrigation environment. In another study on adoptability of trickle irrigation system for small farmers in Punjab and found 50%, 47% and 43% water saving for cotton, sugarcane and chilies, respectively.

Some impact assessment studies for performance evaluation of drip/sprinkler irrigation on different crops were undertaken by technical committees of Punjab Agriculture Department. The performance of the drip irrigation system showed 57 percent water saving in case of sugarcane while 50 percent for both citrus and potato crops against conventional irrigation methods. The increase in yield in drip irrigated areas was 34, 39 and 105 percent for potato, sugarcane and citrus, respectively as show in Table-2.

Table-2: Increase in Yield in Drip Irrigated Areas

Sr. #	Particular	Sugarcane	Citrus	Potato
		(R.Y.Khan)	(Layyah)	(Chiniot)
1	Water saving	57	50	50
2	Enhancement in yield	39	105	34
3	Saving in fertilizer application	28	-	40
4	Reduction in labor	60	-	-
5	Curtailing irrigation cost	-	72	-
6	Increase in juicy contents	-	30	-
7	Sugar recovery	11.2	-	-

Sugarcane is one of the major row crops suitable for drip irrigation. Input management was the key difference in drip irrigation over the conventional surface flooding method by providing efficient, balanced, and timely inputs. Accordingly, the fields under drip irrigation exhibited uniform sugarcane stand with 16 percent longer nodes, 25 percent more tillers, and 24 percent lengthy millible cane. All these factors contributed towards significantly increased weight per cane in fields under drip irrigation. It was reported that entire farm area could be cropped after adoption of drip irrigation whereas previously almost half the farm land used to remain uncultivated due to water shortage.

Potato is another row crop that was adopted successfully on drip irrigation. In arid regions, potato is sensitive to water stress and irrigation has become very essential in comparison with the other crops as it needs frequent irrigation for suitable growth and optimum yield. In district Chiniot, an early potato variety Kuroda (Red Skinned) was planted on 17 acres with drip irrigation, 2 acres under sprinkler irrigation and 19.5 acres with flood irrigation. Drip irrigated field gave 34 percent more yield as compared to flood irrigation whereas the increase in yield was 9 percent in case of sprinkler irrigation. In addition to significant increase in yield under drip irrigation, 50 percent saving of water and 30 percent reduction in weeds attack were also observed under drip irrigation compared to flood irrigation.

The drip irrigation of citrus orchards started exhibiting its effects after a very short period in terms of visual plant growth. Moreover, drip irrigation offers/facilitates dense orchard planting, which is the simplest and most effective means of increasing yield. Planting of about 10,329 extra plants (47 plants per acre) could be possible only with drip irrigation by reducing interplant distance due to judicious use of water. There was about 58 percent increase in plant population per acre which will manifold the benefits of drip irrigation on reaching fruiting stage. The mortality rate of 10-15 percent under flood irrigation became negligible with drip irrigation of young plants because of timely and balanced application of inputs. It was reported that drip technology has saved 85 percent water for citrus crop as compared to farmer's conventional method. Another study showed that water productivity with drip irrigation for citrus was as high as 450 percent as compared with traditional farming method.

Table-3: Fruit Quality Characteristics of Citrus (Kinnow)

Sr. No.	Fruit Quality Characters	PHDEB*	Drip Adopted Area
1.	Average Fruit Weight (g)	160	166.23
2.	Average Size (mm)	45	66.88
3.	Peel Thickness (mm)	3.5	4.2
4.	Peel (%)	35	35.3
5.	Juice (%)	33	37
6.	T.S.S. (%)	10	12.9
7.	Acidity (%)	1.0 (max)	0.81
8.	Taste	Good	Good

* Pakistan Horticultural Development & Export Board

Furthermore, the citrus produced under drip irrigation have better physiochemical characteristics. Size is the most common and impressing factor used for assessing the quality of citrus. The citrus produced under drip irrigation was found intact, sound, clean, and more importantly of uniform size. The average weight, size, peel thickness, peel content, TSS and juice percentage are contributing factors towards improved fruit quality under drip irrigation, which ultimately led to higher sale price of the orchard. The quality characters of citrus grown with drip irrigation fulfilled all minimum quality requirements set by Pakistan Horticultural Development and Export Board.



Figure-5: Pictorial view of installed HEIS in Punjab

4.2 Implementation Strategy

The Punjab Irrigated-Agriculture Productivity Improvement Project (PIPIP) envisages installation of drip and sprinkler irrigation systems on 120,000 acres. The overall project development objective (PDO) of PIPIP is to improve water productivity i.e. producing more crop per drop which will be achieved through increasing delivery efficiency, adopting improved irrigation practices, promoting crop diversification, and effective application of non-water inputs.

As HEIS is still the new technology in Pakistan, expertise is lacking with all stakeholders including supply & service companies (SSCs), OFWM staff, consultants and farmers. On initiation of HEIS scheme, over 50 SSCs came forward for provision of services related to drip and sprinkler irrigation but the on and off modes of the project have discouraged the private sector to fully develop its capacity and build confidence about continuity of government support. Moreover, there are several issues to be resolved through adaptive research for technology indigenization. These issues have considerably been incorporated in the modified approach under PIPIP as the technology is not getting its due course of momentum and popularity.

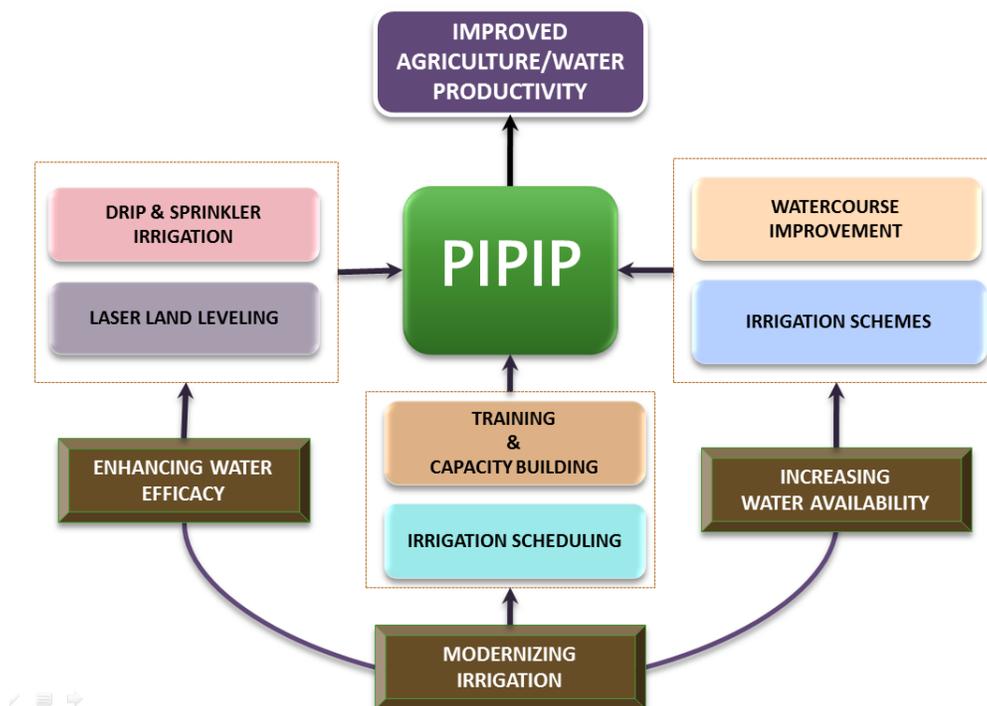


Figure-6: PIPIP Conceptual Framework

The crop production under high efficiency irrigation requires fundamental change in the irrigated agriculture. Accordingly, under PIPIP, the successful promotion and adoption of these technologies has been well addressed through awareness, demonstration, service provision, backup support, training and capacity building as well as research and indigenization. As the role of SSCs, being the major stakeholder in project implementation is very crucial. So,

strenuous efforts have been made to encourage private sector for involvement in provision of various services related to high efficiency irrigation. The prime objective of PIPIP in this regard is to:

- Built confidence of service providers for assured sizeable market/clientage
- Create enabling environment for existing pipe and plastic industry to start local manufacturing of drip/sprinkler components for technology indigenization
- Encourage the firms for establishment of service provision network / backup support centers at regional/district level

Apart from the government efforts, private sector suppliers and manufacturers, extension workers, and research institutes need to play their role in promoting these resources conservation technologies. The implementation role of the various stakeholders is indicated at Figure-4.

The major components of the implementation strategy accordingly include;

- a) Launching of a province wide awareness campaign in print and electronic media as well as establishment of demonstration sites and information centers/kiosks.
- b) Input of international experts both institutional and individual for professional guidance and assistance in technical aspects of engineering, agronomy, horticulture, soil sciences etc.
- c) Capacity building of all stakeholders including farmers, project staff, SSC personnel, supervisory consultants etc.
- d) Conduct on-going research and development for further fine tune various parameters of project implementation.
- e) Establishment of materials and equipment testing facility.
- f) Surveys and designs by registered independent private sector service and supply companies.
- g) Cost sharing of the system with farmers contributing 40 percent of the cost of system.
- h) Decision making at Provincial, Regional and District level
- i) Third party inspection and validation of designs and works
- j) Continuous monitoring and evaluation
- k) Future planning

5. Way Forward

Water scarcity is the biggest challenge confronted by irrigated agriculture in the Punjab. The level of agricultural production heavily depends on water availability and its efficient use as a major input. Under prevailing water scarceness, the sustainability of irrigated agriculture is at risk and adoption of high efficient irrigation modern irrigation techniques and methods, offering water conservation and yield enhancement, is inescapable. Punjab has about 1.57 M i.e. eight percent of total geographical area, of cultivable wastelands. To cope with the dwindling land and water resources, it is viable to exploit all the available resources sustainable for producing enough foods to meet the future demands. A logical way forward is to develop the cultivable

wastelands for crop production. These include two major areas of the Pothwar Plateau and Thal Region in the province.

5.1 Pothwar Plateau

The Pothwar Plateau, covering an area of 2.2 Mha, is an arid landscape with denuded and broken terrain characterized by undulations and irregularities. The climate is favorable for crop production on fertile soils having no major problem of salinity and water logging. The occurrence of rainfall is, however, highly erratic both in space and time that demands water harvesting, storage, and supplemental irrigation for successful crop production in the region. Reportedly, about 3.40 MAF water is lost from the area due to surface runoff annually. The total area under cultivation in this area is about 1.0 Mha and agriculture is at sustenance level mainly because of assured irrigation supplies shortages.

The Small Dams Organization (SDO) of Provincial Irrigation Department, so far, has constructed 48 dams in Pothwar region, which are designed to irrigate over 50,000 acres. The command area of these dams has, however, not been developed substantially. The cropping intensity is also very low (about 50 percent) against planned average of provincial Irrigation Department. Nevertheless, there is high potential for the development of irrigated agriculture in the region by managing supplemental irrigation through storage of runoff water and irrigating crops with high efficiency irrigation systems i.e. drip and sprinkle.

5.2 Thal Region

Thal is a vast desert in Punjab with undulating topography consisting of large sand dunes, which often keep on shifting from one place to another due to random wind storms action. It encompasses entire districts of Bhakkar and Layyah as well as parts of Khushab, Mianwali, Jhang, and part of Muzaffargarh district spreading over an area of about 7 MA. The land in the Thal is generally undulating and soils are sandy in nature having extremely low water holding capacity. The gravity irrigation through conventional practices on such soils is grossly inefficient resulting in precious water wastage through seepages. Thal has following comparative advantages for application of drip irrigation.

- The groundwater is mostly suitable for irrigation and available at appropriate depth, which is recharged by perennial rivers (Indus and Jhelum).
- The upper layer of the sandy soils in the area is very fertile having no waterlogging and salinity problems.
- Drip irrigation does not require leveling of undulating sand dunes that entails huge capital investment, time, and heavy machinery.
- Desert environment is less susceptible to insect/pest and diseases due to dry conditions.
- Climate is very conducive for cultivation of high value sensitive crops e.g. cotton, vegetables.

The command areas of newly developed canal systems like Greater Thal Canal (GTC) may be developed using modern irrigation. There are some areas where the canal water supplies are limited only for 80 percent of cropping intensity because of which vast land remains uncultivated every year which could be brought under cultivation through drip irrigation systems under limited water supplies.

6. Conclusion

The preceding discussion suggests that the potential of drip and sprinkler irrigation is huge in different regions across the Punjab. The adoption of these technologies is, however, not appreciable as fraction of a percent of total cultivated land is under micro irrigation. Given the benefits of high efficiency irrigation in terms of water saving and productivity increase, its gross benefits would be enormous, if the available potential is utilized.

The study clearly demonstrates that drip irrigation have many advantages over conventional flooding that is primarily followed in Punjab. Drip irrigation, being the most efficient irrigation system, reduces cost of production as well as increases crop productivity. Drip irrigation facilitates raising of tropical crops like sugarcane in arid climates and offers dense planting of orchard as well as cotton cultivation under drip irrigation in Thal has proved highly efficacious. Acquired benefits of this resource conserving technology suggest its adoption on larger scale, especially in the potential areas in first stage. Since the adoption of drip and sprinkler systems is in the take-off phase in Pakistan, an active role of the major stakeholders is pivotal in promoting these technologies as well as developing confidence among the farming community about the utility of this new technology.

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References

1. Mark, W., 2010. Rosegrant. Simulation of World Market Effects: The 2010 World Market With and Without Bt Corn and GR Soybeans, 2001. Genetically Modified Organisms in Agriculture: 39-45.
2. John Brisco and Usman Qamar. 2006. Pakistan's Water Economy, Running Dry. World Bank Publication.
3. Punjab Devolvement Statistics. 2011. Planning and Development Department, Government of Punjab, Lahore.
4. Mahmood Hassan Khan. 2006. Agriculture in Pakistan: Changes and Progress 1947-2005. Vanguard Books (Pvt) Ltd. Lahore.
5. Pakistan Economic Survey. 2011. Ministry of Finance, Government of Pakistan, Islamabad.