# Assessing and Improving Water Productivity in Conservation Agriculture Systems in the Indus-Gangetic Basin*

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Will there be enough water to grow enough food? Lack of water or access to water has emerged as constraint to producing food for hundreds of millions of people. Additionally, in the face of intense competition for water resources, the economic value of water in agriculture is much lower than in other sectors (Barker et al., 2003). Objectives of conservation agriculture and improving agricultural water productivity- producing more food, income, livelihoods, and ecological benefits at less social and environmental cost per unit of the agro-input (or water)- are very similar. Put simply, the researchers and practitioners strive to grow more food or gain more benefits on sustainable basis with less input. However, realisation of this objective function in case of water is becoming increasingly difficult as in several regions of the world (about 16% ) further appropriation of water for human use is not possible because limits have been reached and in many cases breached ( Molden, 2007). Several of the basins are effectively "closed", with no possibility of using more water. Yet, there is a great opportunity through closing the gap in agricultural productivity in many parts of the world, including Indus-Gangetic basin, and in realising the unexplored potential that lies in better water management and innovative changes in policy and production techniques.

## 1. Indus-Gangetic Basin

Indo-Gangetic basin, one of the world's most populous, has emerged during the past 40 years into an intricate mosaic of interactions between man and nature, poverty and prosperity and problems and possibilities. Rapid expansion in agricultural water use is a common theme across these interactions and access to water is central for the livelihoods of the rural poor. Given the diversity of agro-climatic, social and economic conditions in the four riparian countries—Pakistan, India, Nepal and Bangladesh—the IGB is clearly one of the most complex river basin systems in the world. The total basin area is 225.2 million ha and the net cropped area is 114 million ha. The population of IGB is 747 million as per 2001 census. Rural population in Bangladesh, India, Nepal and Pakistan is 79.9%, 74.5%, 86.0% and 68.0%, respectively of the total population. In 2000, about 30.5% population in IGB is below poverty line. However, poverty in rural areas where agriculture is the main livelihood is substantially higher. In India much of the rural poverty is concentrated in few states that fall in the Ganga basin.

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Irrigation is a critical factor in agricultural productivity in the Indus and Ganges basins. Indus and Ganga basin account for about two-third of the total grain production in India. Among the grains, IG basin produces a major part of wheat production (93%) and more than half (58%) of rice production at present. In the lower parts of the Ganges basin in India and Bangladesh inland fisheries also form a significant component of the agricultural production system. The Indus basin is quite productive in India and Pakistan and food surplus in this basin meets the food requirements of several other food deficits basins. Combined rice-wheat productivity is estimated to be 8-12 tons/ha/year in the region, although quite variable. Among the three IGB regions it is the Eastern Indo-Gangetic Plains, comprising of eastern U.P., Bihar and West Bengal in India, eastern Nepal Terai, and all of Bangladesh that has the greatest differences between potential and actual productivity. The eastern region has the highest population densities, was bypassed during the Green Revolution era and is still weak in rural infrastructure, developed markets, institutions, energy and credit for agricultural operations, location specific technologies, storage based surface irrigation systems and well developed groundwater resources. Additionally, parts of the region are frequently devastated by seasonal floods and subsequent water congestion. The western region was the seat of Green Revolution, has high productivity and good irrigation (now dominated by groundwater) and rural infrastructure and markets. However, the second generation problems of rapidly declining water tables, deteriorating (and shrinking) surface irrigation systems, waterlogging and salinity in large pockets and large subsidies on agricultural inputs raise serious questions for the long term sustainability of intensive production systems. At the country level eastern Indian region, Nepal hill regions and Bangladesh plains need immediate attention for improving agriculture and water productivity.

## 2. Assessment of Water Productivity (WP)

At present, WP of India is stubbornly low in comparison with other major foodgrain producing countries in the world (Molden et al. 1998, Rosegrant et al. 2002, Cai and Rosegrant 2003). In 2000, WP of foodgrains in India was only 0.48 kg/$m^3$ of consumptive water use (CWU). This was primarily due to low growth in yields. India's food grain yield was 1.7 tons/ha in 2000, which has increased only 1.0 tons/ha during 1960-2000 (FAO 2005). Meanwhile, China with a similar level of yield (and soil-climate conditions) in 1960 (0.9 tons/ha) has increased to about 4.0 tons/ha by 2000. Also, India produces less grain in more cropped area (205 million mt in 124 million ha), while China has much larger production and with less water from a significantly smaller crop area. Indeed India has a significant scope for raising the levels WP by increasing its crop yield alone. Better water management can create additional increase in WP in many regions. Regional estimates show a significant spatial variation in WP across states and districts in India.

**Variations of water productivity among Indian states**: WP varies from 1.01 kg/$m^3$ in Punjab (the highest) to 0.21 kg/$m^3$ in Orissa (the lowest) among states (Table 1). These differences are mainly due to varying cropping and land-use patterns, yield levels and CWU. Among the large variations, we observe:

- Punjab, Haryana , and Uttar Pradesh (UP) in the Indo-Gangetic basin (IGB) are having the highest water productivities. These states, with rice-wheat dominated cropping pattern, share 26% of the total CWU in India, but contribute to 40% of the total foodgrain production. Importantly, they contribute to 70% of wheat and 26% of rice production in India. A major part of area under foodgrain in these states is irrigated. It is 67, 85 and 97% in Uttar Pradesh, Haryana and Punjab, respectively, and contributing to 48, 72 and 75% of the CWU.

- Low share of irrigation to total CWU in Uttar Pradesh means that effective rainfall contributes to a significant part of CWU. In fact, substantial variation in WP also exists within Uttar Pradesh. For example, water productivity in 53 districts in Uttar Pradesh varies between 0.40 to 1.02 kg/m$^3$. Western region with 20 districts has 34% of the grain area, contributing to 40% of the total foodgrain production. Average WP in

| Sr. No. | State | Total (Irrigated+Rainfed) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | CWU | NET | Area | Production | Yield | CWU | WP |
| | Unit | km$^3$ | km$^3$ | M ha | M Mt | ton/ha | mm | kg/m$^3$ |
| | India | 424 | 154 | 123 | 205.4 | 1.66 | 344 | 0.48 |
| 1. | Uttar Pradesh | 71.4 | 34.4 | 20.3 | 43.4 | 2.13 | 351 | 0.61 |
| 2. | Madhya Pradesh | 31.3 | 14.3 | 11.2 | 11.1 | 0.99 | 278 | 0.36 |
| 3. | West Bengal | 29.5 | 4.5 | 6.6 | 15.2 | 2.31 | 447 | 0.52 |
| 4. | Bihar | 26.3 | 8.7 | 7.1 | 12.1 | 1.71 | 373 | 0.46 |
| 5. | Rajasthan | 25.7 | 13.4 | 11.7 | 11.7 | 1.00 | 220 | 0.46 |
| 6. | Punjab | 25.4 | 18.9 | 6.3 | 25.5 | 4.07 | 404 | 1.01 |
| 7. | Haryana | 15.6 | 11.2 | 4.3 | 13.4 | 3.13 | 363 | 0.86 |
| 8. | Uttaranchal | 3.0 | 0.7 | 1.0 | 1.7 | 1.75 | 298 | 0.59 |
| 9. | Jammu &Kashmir | 2.4 | 1.0 | 0.9 | 1.2 | 1.38 | 271 | 0.51 |
| 10. | Himachal Pradesh | 2.0 | 0.2 | 0.8 | 1.5 | 1.78 | 245 | 0.73 |

western region is 0.75 kg/m$^3$. Eastern and Bundelkhand regions with 23 districts have 48% of the area under foodgrains, contributing to 42% of the total foodgrain production. Average water productivity in these two regions is only 0.54 kg/m3. A key difference among between the western and eastern and Bundelkhand region is the irrigated area, where 82% of the area is irrigated in western region compared to 54% in the eastern and Buldelkand regions.

Table 1. Water productivity of grains across states covering IGB parts of India

Source: Authors' estimates

- Bihar, also in the IGB, with 82% of the area under wheat and rice, however has lower WP and share 6.2% of CWU and 5.9% of the foodgrain production in India. Irrigation contributes to 60% of the area and 33% of the CWU in Bihar. Although a major part of grain area is irrigated, effective rainfall meets much of the CWU in Bihar at present. Irrigated areas contribute to 65% of total CWU in Bihar, but irrigation contributes to only 51% of CWU in irrigated areas.

Extent of irrigation and cropping patterns partly explain the variation of water productivity among the states. At national level, in 2000, irrigation covered 43% of the area under foodgrains, but contributed to 68% of the total production.

**Rice water productivity in the IG Basin:** Increasing WP in IGB requires not only more food production but also less water consumption and especially for rice production. Rice water productivity in IGB (Table 2) is generally low compared with other parts of the world. The mean WP for rice over actual evapotranspiration is 0.618 kg/m$^3$, which is at the lower end given by Zwart and Bastiaanssen (2004) from a review of 84 studies. Low WP values are primarily due to low rice yield. The average yield in 2005 is only 1.94 ton/ha while the ET over rice growth season remains 335 mm. The four major countries India, Pakistan, Bangladesh and Nepal showed similar levels of rice WP. At the country level, Nepal takes the lead with average of 0.701 kg/m$^3$ while India has the lowest of 0.603 kg/m$^3$.

Table 2. Rice water productivity in the Indo-Gangetic basin countries

| **Country** | **Admin. Unit** | **Mean WP (kg/m$^{3)}$** | **Country** | **Admin. Unit** | **Mean WP (kg/m$^3$** |
|---|---|---|---|---|---|
| **Bangladesh** | Chittagong | 0.445 | **Pakistan** | North-west Frontier | 0.451 |
| | Dhaka | 0.496 | | FATA | 0.525 |
| | Khulna | 0.796 | | Baluchistan | 0.657 |
| | Rajshahi | 0.856 | | Sind | 0.732 |
| | | | | Punjab | 0.755 |
| **Average** | | **0.625** | **Average** | | **0.617** |
| **Nepal** | Lumbini | 0.542 | **India** | Madhya Pradesh | 0.393 |
| | Sagarmatha | 0.556 | | Himachal Pradesh | 0.407 |
| | Janakpur | 0.578 | | Bihar | 0.408 |
| | Bagmati | 0.583 | | Jammu & Kashmir | 0.430 |
| | Gandaki | 0.607 | | Uttar Pradesh | 0.560 |
| | Seti | 0.699 | | West Bengal | 0.718 |
| | Bheri | 0.713 | | Rajasthan | 0.720 |
| | Rapti | 0.715 | | Haryana | 0.746 |
| | Narayani | 0.754 | | Delhi | 0.818 |
| | Mahakali | 0.792 | | Punjab | 0.833 |
| | Kosi | 0.904 | | | |
| | Mechi | 0.964 | | | |
| **Average** | | **0.701** | **Average** | | **0.603** |

Significant spatial variations were observed in the basin as well as individual countries. Generally the Mechi and Kosi of Nepal, Rajshahi Division of Bangladesh, Punjab state of India, and Punjab Province of Pakistan showed higher WP values of 0.964, 0.904, 0.856, 0.837 and 0.755 kg/m$^3$ respectively. The Indian states of Jammu & Kashmir, Bihar, Himachal Pradesh and Madhya Pradesh have the lowest WP ranging from 0.39 to 0.43 kg/m$^3$.

While many opportunities still exist in improving WP in irrigated and rain-fed conditions with the existing level of water use or with proper cropping patterns, shifting production frontiers of rain-fed foodgrain crops through new irrigation could also boost WP significantly. These regions require not only better water management but also better non-water input application. Depending on CWU and actual irrigation at present, improvements in WP with better water management require various interventions-- from full irrigation to small supplemental irrigation, no additional irrigation to deficit irrigation, wide scale use of resource conservation technologies and laser levelling and policy measures for revitalising the surface irrigation systems and better governance of the groundwater systems.

## 3. Improvement in Water Productivity in Irrigated Systems

In the broadest sense water productivity reflects the objectives of producing more food, income, livelihoods, and ecological benefits at less social and environmental cost per unit of water used, where water use means either water delivered to a use or depleted by a use (David and Oweis, 2008). Improving physical water productivity in agriculture and especially through conservation agriculture reduces the need for additional water and land in irrigated and rainfed systems and is thus a critical response to increasing water scarcity, including the need to leave enough water to sustain ecosystems and to meet the growing demand of cities and industries. Many promising pathways for raising water productivity are available over the continuum from fully rainfed to fully irrigated farming systems. These include supplemental irrigation ( small irrigation to supplement rainfall), soil fertility management, deficit irrigation; small-scale water harvesting and storage, delivery and application methods, auxiliary storage ( melons on the wine) in the canal command areas, precision irrigation technologies ( as drips, micro-sprinklers, sprinklers); and soil and water conservation through mulching, zero or minimum tillage, bed planting and laser leveling. Most farmers in developing countries, including countries of the Indus-Gangetic basin, can raise water productivity by adopting proven agronomic and water management practices because raising land productivity also leads increase in water productivity. Some of the more recent and innovative techniques and policies for improving water productivity include the following:

### i. Supplemental irrigation

It is quite established that water stress in critical periods of crop growth is a key determinant of low yields in the rain-fed areas. With proper and timely application of a small quantity of supplemental irrigation in water stress periods by itself could reduce the yield gap, and additional irrigation with better application of non-water inputs could push up the average yield in parallel to the increasing path of maximum yield. Recent studies by Sharma et al. (2008) estimated that frequent occurrence of mid-season and terminal droughts of 1 to 3-weeks consecutive duration during the main cropping season happens to be the dominant reason for crop (and investment) failures and low yields. Provision of critical irrigation during this period had the potential to improve the yields by 29 to 114 per cent for different crops. A detailed district and agro-ecoregion level study comprising of 604 districts showed that on a potential (excluding very arid and wet areas) rainfed cropped area of 25 M ha, a rainfall surplus of 9.97 M ha-m was available for harvesting. A small part of this water was adequate to provide one critical irrigation to 18.75 M ha during drought year and 22.75 M ha during normal year. Water used in supplemental irrigation had the highest marginal productivity and increase in rainfed production above 50% was achievable. More specifically, net benefits improved by about, 3-times for rice, 4-times for pulses and 6-times for oilseeds. Droughts appear to have limited impact when farmers are equipped with rainwater harvesting and application systems.

In another national level study for India, Upali and Sharma (2008) found that one of the significant methods for improving WP is providing additional irrigation. The districts with low CWU have the highest potential for increasing yield by increasing CWU. Marginal yield curves showed that increasing CWU could significantly increase maximum yield in many districts with low CWU. With 100 mm of additional CWU, maximum yield can be doubled in districts with less than 150 mm of CWU. With 200 mm of additional CWU, yield can be doubled in districts with less than 225 mm of CWU. Many of these districts can increase yield by providing small to moderate irrigation or by increasing the amounts of effective rainfall through in-situ conservation and storage.

However, growth in foodrain yield with supplemental irrigation decreases in districts with high CWU. Both scenarios of supplemental irrigation (100 or 200 mm), marginal growth in yield decreases and become negative after 475 mm of CWU. This is also due to the fact that most foodgrain crops grown under rain-fed conditions (sorghum, pealmillet, local maize, small millets) have very low values of harvest index with only a fraction of biomass converted into grain yields. If increasing yield is the sole objective then providing additional irrigation (with existing crops and their varieties) would only benefit the areas with CWU less than 475 mm.

ii. **Resource conservation technologies (RCTs)**

RCTs include zero tillage (or reduced/ minimum tillage), laser land levelling and furrow bed planting. Many studies have shown the effectiveness of RCTs in reducing water application, especially at field scale. Kahlown et al.(2006) showed that the use of RCTs, including zero tillage, laser levelling and bed and furrow planting, reduced water applications between 23% and 45% while increasing yield. Hobbs and Gupta (2003) showed water savings of 30% due to the adoption of zero tillage in rice-wheat systems. Gupta et al (2002) showed 25% to 30% savings and Humphreys et al (2005) a 20% to 35% savings in irrigation water under zero tilled wheat compared to conventionally tilled in the rice-wheat belt of the Indo-Gangetic plains. Additionally farmer surveys showed that their primary reasons for adopting the two technologies were: (i) to increase profitability (97% of adopters respondents) and (2) to cope with water scarcity (87% respondents). Coping with water scarcity is itself related to profitability, because it is strongly linked with productivity and the cost of groundwater pumping. Both zero tillage and laser levelling are perceived by Pakistan Punjab farmers to result in substantial savings in water application (24% for zero tillage and 32% for laser levelling), fuel (52% and 16%) and labor (52% and 14%). Because of the decrease in input use, almost all adopters (87% for zero tillage and 88% for laser levelling) reported a decrease in production costs. The impacts of RCTs on wheat yields were varied, with about 54% farmers reporting an increase, 30% a decline and 16% no change for zero tillage. The comparative numbers for laser levelling were 96%, 0% and 4%, respectively. With generally increased yields and decreased costs, net crop income on fields using the two RCTs rose for majority of farmers, providing good evidence for the large scale adoption and popularity of the two technologies in the Indus-Gangetic basin (IWMI Primary surveys in Pakistan Punjab, Ahmad et al., 2007). Similar studies at Kurukshetra in Haryana state of India showed that tubewell operational hours in bed planted wheat were much lower as compared to wheat in conventional fields (Fig.1). This was very well reflected in improved water productivity under bed planted wheat as compared to conventionally planted wheat (Fig. 2).

However, it remains still to be investigated whether water in fact is ‘really saved’ at larger scales. In a study for the Pakistan’s Indus basin the successful uptake of RCTs and the water savings realised at the field scale allowed expansion by large and medium farmers of the winter wheat area and cropping intensity, requiring net increase in abstraction of groundwater to support the additional cropped area. However by providing incentives to small farmers for RCT adoption, improving the performance of canal water supplies and by minimising evaporation losses in the rice-wheat areas in the lower part of the basin can help in achieving the real water savings at the basin scale ( Ahmad et al., 2007.

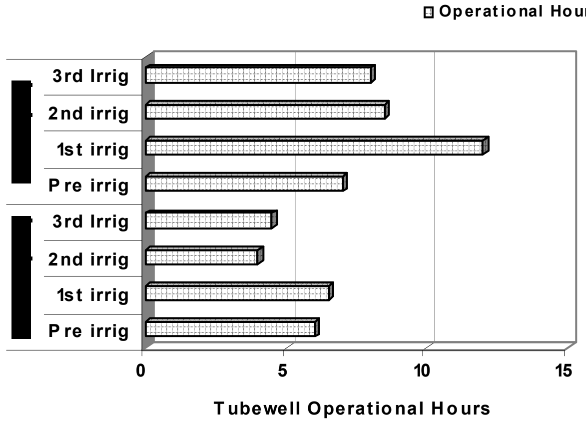


**Fig.1.** Comparison of tubewell operational hours in bed planted wheat (PHB-21) and conventional wheat (PHC-1) at Pabnawa Head in Bhakra Command, Kurukshetra, India

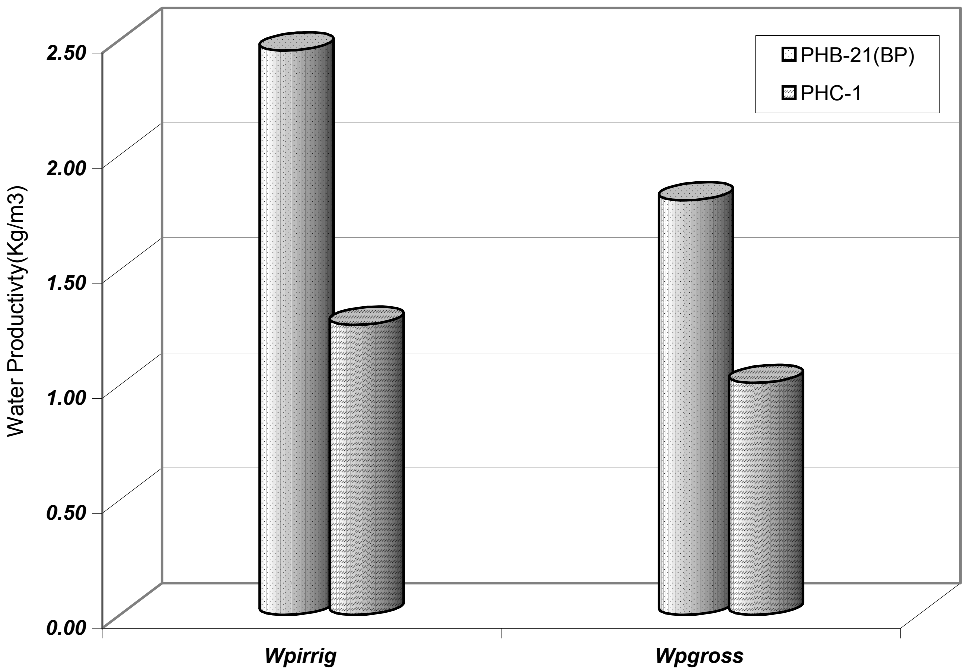


Fig. 2. Comparison of water productivity in bed planted wheat and conventional wheat at Pabnawa Head in Bhakra Command, Kurukshetra, India.

### iii. Improving efficiency of irrigation systems

Considering that under the prevailing policy and pricing systems in the developing countries the marginal and opportunity cost of available water is low, there are large gaps between water demand and supply patterns. In a study by IWMI in Pakistan Punjab ( Jehangir et al, 2007) average input to rice was estimated as 1,458 mm against the potential water requirements of 532 mm. It resulted in low gross depleted fraction of 0.40 indicating about 60% of water was not used in rice ET and mainly left root zone as seepage and deep percolation flows. In contrast farmers tend to under-irrigate the wheat crop and try to best utilise the rainfall. Field scale average of WP was estimated as 0.23 kg/m3 for rice and 1.48 kg/m3 for wheat. This indicates that about 4.35 m3 of supplied water were used to produce one kilogram of rice and only 0.675 m3 for one kilogram of wheat and thus presents a great potential for conserving water for rice irrigation.

Besides the variation in crop to be irrigated, the source of irrigation water also has major role for conserving/ saving water and thus improve the water productivity. Generally, irrigation with groundwater was found to be more efficient due to better control over the amount and timing and manageable flows. Surveys and analyses conducted in Punjab (Kumar et al., 2008) showed that the yields were lowest for farmers using only canal water for both paddy and wheat and farmers with conjunctive use of both canal and well water got higher yields (Table 1). However, the farmers using well water in Jalandhar and Kapurthala districts got the highest yields indicating that reliability and quality of irrigation had the significant role. In unmanaged canal irrigation systems, the depth of each application is much higher than the optimum dosage leading to heavy percolation and nutrient losses.

Table 1. Differences in crop yield of paddy and wheat due to source of irrigation in Punjab

| Region | District | Main source of irrigation | Crop yield (tons/ ha) | |
|---|---|---|---|---|
| | | | Paddy | Wheat |
| Lower Bist Doab | Jallandhar | Tubewell | 6.26 | 4.68 |
| | | | 5.20 | 4.40 |
| | Kapurthala | Tubewell | 5.98 | 4.73 |
| | | | 5.52 | 5.30 |
| Sub-Mountainous | Hoshiarpur | Conjunctive Use | 4.46 | 3.82 |
| | | | 4.65 | 3.79 |
| | | Canal irrigation | 2.77 | 3.52 |
| | | | 3.47 | 2.80 |

Source: Kumar et al., (2008)

Improved methods of irrigation have large potential for water conservation and improved productivity. With drip irrigation, in most cases, water savings of 25-80% have been reported. Recent studies by IWMI ( Kumar et al., 2008) show that states in the IGB have large areas and crops amenable to drip irrigation with 1.884 m ha in Uttar Pradesh, 0.192 m ha in Bihar, 0.6 m ha in Punjab and 0.374 m ha in Haryana state. At the country level, adoption of drip irrigation for suitable crops in the potential areas may lead to reduction in crop water requirements to the level of 44.46 BCM (Table 2). However, the economic viability of micro-irrigation depends upon a wide range of factors including market and

Table 2. Aggregate reduction in crop water requirements possible with drip irrigation in India

| Name of crop | Water productivity (kg/m3) | Improved water productivity (kg/ m3) | Reduction in crop water requirement (BCM) |
|---|---|---|---|
| Sugarcane | 5.950 | 18.09 | 31.00 |

| | | | |
|---|---|---|---|
| Cotton | 0.303 | 1.080 | 10.42 |
| Groundnut | 0.340 | 0.950 | 1.453 |
| Potato | 11.79 | 17.21 | 0.127 |
| Castor | 0.340 | 0.670 | 0.497 |
| Onion | 1.544 | 2.700 | 0.963 |
| **Total** | | | **44.46** |

Adapted from Kumar et al (2008)

rural infrastructure. Creating appropriate institutions for technology extension, designing water and electricity pricing and supply policies besides proper irrigation and power supply infrastructure would play a vital role in facilitating large-scale adoption of different micro-irrigation systems. Subsidies for micro-irrigation promotion should be targeted at regions, people and technologies level , where micro-irrigation adoption results in real water and energy saving at aggregate level, and maximize welfare impacts.

**iv. Auxiliary storage reservoirs in canal commands**

Unreliable water supply in canal irrigation systems is often cited a major constraint for achieving higher agricultural and water productivity. It also constrains farmers to match water and other agro-input requirements during critical periods of crop growth, limit opportunities for crop diversification and also realise only sub-optimal yields. Unreliable water supply is often associated with rigidly or improperly implemented water delivery schedules in rotational water delivery systems, such as warabandi in north and north-west India and Pakistan. An intermediate or auxiliary water storage, called “diggi” was farmers’ response to increasing unreliability in the IGNP project in Rajasthan and to a lesser extent by the farmers in Haryana and Punjab states of India and Pakistan Punjab. This intervention constructed as series of structures along a canal is popularly known as “melons on a wine” in China plains. These water storage structures improve farmers’ control of on-farm water management and facilitated use of sprinklers for water application. An immediate impact of this was conservation of water and increased irrigable area. Sprinklers reduced the requirement of precision levelling of the undulated sandy fields where gravity irrigation cannot service. Better water and input management have increased crop yields, resulting in resource conservation and higher benefits. An economic analysis of this intervention under IGNP conditions showed that the structure is financially viable intervention for farms with irrigable area more than 5 ha , where the benefit-cost ratio (BCR) and internal rate of return(IRR) at 12% discount rate are 2.2 and 35%, respectively. However, these values were somewhat lower for farmers at the tail reach due to inequitable/ smaller water supplies. These storage structures and application systems can become a viable option for small land-holdings, provided they grow high-value crops (fruits/ vegetables) or diversify agriculture patterns to include fisheries in these tanks or use a shared resource to reduce the capital cost. This is happening on a limited scale by the farmers in Haryana and Punjab, where the farms are well connected to the cities and developed markets (Upali et al., 2008). A similar intervention known as “system tanks” has also been planned in the public irrigation systems in some of the canal commands in Tamilnadu and has been found highly successful in conserving water resources and achieves high levels of physical and economic water productivity.

**Conclusions**

Irrigation and management of water resources is a critical factor in agricultural productivity in the Indus Gangetic basin- one of the most populous and complex basin of the world. Presently, water productivity of the riparian countries-India, Pakistan, Nepal and Bangladesh- is stubbornly compared to other major food grain producing countries in the world though there is considerable variation among the countries and the states. Rice water productivity is particularly low due to low rice yields and high water applications. Several promising pathways are available for raising water productivity over the continuum from fully rainfed to fully irrigated farming systems. Supplemental irrigation in the regions with low consumptive water use has the potential to double the existing yield levels. Analysis showed that by providing just one critical irrigation in 25 M ha of the potential rainfed areas the yield of most crops shall improve by 50% and the intervention is economically viable especially for rice, pulses and oilseed crops. Resource conservation technologies can help in realising water savings to the level of 20-45% at the field scale under most conditions. But real benefits can be lower in case the non-adopters tend to utilise all the saved water through area expansion and excessive irrigation. Canal irrigation systems particularly need revitalisation for better use of the available resources and improved productivity as groundwater irrigated fields showed higher productivity for both wheat and rice crops. Improved irrigation systems as drip irrigation with better adoption rate and targeted subsidies has the potential to conserve about 44.5 BCM of irrigation water under Indian conditions. Auxiliary storage in the canal irrigation commands is another innovative intervention, presently practised mainly under the IGNP command, which provides improved control and incentives to save water and improved productivity. These physical interventions when supplemented with enabling policies and thrust for large scale adoption hold the potential to grow more food or gain more benefits on sustainable with less inputs.

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