Water Productivity Improvements in Indian Agriculture: Potentials, Constraints and Prospects

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Introduction

India is still an agrarian country although the structure of the economy is gradually changing. Industrialization and urbanization set off in the 1990s resulted in a greater contribution from the manufacturing and service sectors to the national economic output. Today, the agriculture sector contributes to only 17% of the gross domestic product (GDP), yet nearly 70% of the country's population live in rural areas and the majority of this proportion depends on agriculture-related economic activities for their livelihoods. Projections show that it would take another five decades before the population starts stabilizing (Visaria and Visaria 1995). Hence, sustaining agricultural production, particularly the production of food grains in tune with population growth and changing consumption patterns, is an important task, which is not only essential for feeding the growing population for a large country like India but also important for supporting livelihoods and reducing the poverty of India's large rural population[2] (Chaturvedi 2000). Moreover, water demand in nonagricultural sectors, including that for the environment, is increasing and many regions in the country are facing severe water stress (Amarasinghe et al. 2005, 2008a). Thus, efforts to manage water efficiently in the agriculture sector and produce more crop and value per drop are gaining momentum now more than ever before.

Agriculture continues to account for a major share of the water demand in India (Amarasinghe et al. 2008a). The southwest monsoon provides a major part of India's annual

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[2] Several studies in the past have indicated that agricultural growth, especially growth in food grain production positively impacted on reducing rural poverty (Hazzle and Haggblade 1991; Rao 1994; Ghosh 1996; Desai and Namboodri 1998). Rural poverty has correlated with relative food prices, which is affected by fluctuations in food supply (Ravallion 1998; Dev and Ajit 1998).

rainfall, and the quantum varies widely across space (GoI 1999). In most places, growing crops require an artificial provision of water during the non-monsoonal seasons and in some places even during the monsoon. In fact, only one-third of the agricultural production in the country comes from rain-fed areas, which account for two-thirds of the croplands. As per official projections, a major share of the future growth in India's agricultural production would have to come from increasing cropping intensity, and bringing rain-fed areas under irrigated production, rather than expanding the net cultivated area (GoI 2002), all of which would require irrigation water.[2]

The extent of net additional irrigation at the aggregate level would depend heavily on three aspects. The first two aspects—the extent of growth needed in agricultural production, particularly production of food grains; and the extent to which we can increase the productivity of water use in agriculture are well recognized and researched. However, the third aspect, how and where those improvements in water productivity (WP) are going to occur are less recognized.

But, the last aspect on WP improvements is extremely important. It is a false notion that raising the production of a particular crop by a certain degree, by increasing WP, would compensate for the increase in future water demand for raising the production of a particular crop by the same degree. Several situations explain this false notion.

1. A region can get all its production from rain-fed crops. In such a case, it is quite possible that the productivity improvement comes from an increase in yield of crops in a rain-fed area, through supplementary irrigation. WP gains through supplementary irrigation would only help us take some of the rain-fed areas out of cultivation, thereby freeing some of the agricultural land for other uses. However, most of the water used up by rain-fed crops, i.e., soil moisture, in these rain-fed lands cannot be reallocated to irrigate crops or for any other use. Thus, it will not reduce the need for diverted water.

2. The sum of the extent of water resource augmentation for irrigation in different regions could be more than the required net increase in irrigation water supply at the aggregate level. For instance, a region could have great scope for WP improvement through reduction in consumptive use of water for irrigation. But these regions may not have much additional land, such as Punjab or Haryana. Such gains in WP will not reduce the need for additional water supply in another region that has additional arable land to produce food. Nevertheless, it would only free up some of the water resources in the first region for reallocating to the environment or to another sector of use.

3. If WP (kg/evapotranspiration) improvements can come from supplementary irrigation of rain-fed crops in one region, such as certain parts of central India or in the Godavari basin in Peninsular India, which has low levels of water resources development, then it would still require a lot of additional water. This additional water, however, can be at the expense of water availability of another region with fully developed water resources for intensive irrigation. The latter, by reducing its irrigated area or improving the productivity in its region by shifting to water-efficient non-food crops, parts with its water for the benefit of the former region.

4. If reduced consumptive water use in irrigated crop production can improve WP, then this would lower the need for increased irrigation only if additional land is available for

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[2] However, this does not mean that growth in production from rain-fed areas is not possible without large irrigation infrastructure. Sharma et al. (2009) showed that small supplementary irrigation in critical periods of water stress can significantly increase productivity in rain-fed lands.

cultivation in the same area to achieve a greater crop output with the saved quantum of water. If the improvement comes from an increased use of fertilizers in certain regions, which also brings about crop yield improvements, then this would mean there would be a reduced need for augmenting irrigation.

All of the above-mentioned hypothetical situations actually exist in India. So, in the ultimate analysis, it would appear that the benefit of WP improvement cannot be fully translated into an equivalent reduction in the requirement for developing additional water resources, although significant reductions could still be possible. However, the outcomes of WP improvement would be multiple. It increases the streamflows in some areas; reduces pressure on groundwater in some other areas; boosts productivity and production freeing up rain-fed land in yet some other areas with a consequent increase in streamflows from the river catchments owing to change in land use hydrology. All these are important for the country. So improving WP in agriculture is an important component of a water-sector perspective plan. A water-perspective plan for water resources for India should indicate:

- How the demand for water will increase in different sectors, including the environment, and in different regions.
- How much of the additional demand for water can be managed through improvements in WP in different competitive sectors of water use in different regions.
- What kind of interventions would be required for improving productivity of water use and at what scale (supplementary irrigation, controlled water allocation, micro-irrigation, conservation technologies, etc.).
- How much of this gets translated into real reduction in irrigation water demands in every region where it matters, or does it actually increase water demand in some regions.
- What should be the increase in utilizable water supplies in different regions. And what should be the aggregate increase in water supplies, after considering interregional reallocation of the freed-up resource.

This book explores the potential interventions for WP improvement in Indian agriculture, the scale of adoption of these interventions and their potential impacts on future agricultural water demand.

The papers in this book are the results of various research activities conducted in Phase III of the project on ‘Strategic Analyses of National River Linking Project’ (NRLP) of India (CPWF 2005). Phase I and II of the NRLP project assessed ‘India’s Water Futures: Scenarios and Issues’ (Amarasinghe et al. 2009) and ‘Social, Hydrological and Environmental Cost and Benefits of the River Linking Project’ (Amarasinghe and Sharma 2008), respectively. Phase III studies explored various options to interlinking of rivers, which can contribute to an alternative water-sector perspective plan for India. As part of this, Saleth (2009) explored the potential and prospects for, and constraints in, promoting demand management strategies in the Indian irrigation sector. The chapters in this book assess potential and prospects for, and constraints in, promoting WP improvements in the Indian agriculture sector. They provide fresh empirical analyses based on primary data across India on crop inputs and outputs and also district-level secondary data on crop production, crop yields and agro-meteorology. They cover both rain-fed areas and irrigated areas. In addition to field crops, the analysis also included dairying under composite farming systems.

This book discusses various complex considerations involved in analyzing WP in agriculture in India that goes beyond the conventional ‘crop per drop’ paradigm. It further examines how integration of these considerations in assessing WP provides us with new opportunities or sometimes induces constraints in the traditionally known approaches for enhancing WP in agriculture. It discusses various improvement measures of WP in both rain-fed and irrigated areas, not only at the field level but also at the farm level and regional/ basin level. It also specifies the regions where these measures would work, by using empirical evidence from various locations in India. But, while doing this, it also analyzes the macro-level constraints induced by physical, technological and infrastructure-related, socioeconomic, and institutional and policy environments, which can limit the scale of adoption of these interventions. Finally, it discusses the scale of WP improvements in rain-fed and irrigated agriculture, and qualitatively assesses their implications on future agricultural water demand. The book has seven papers, including this one.

The second paper by Amarasinghe and Sharma analyzes WP in food grains (kg/ET) in India to assess the potential scale of improvement. It uses district-level data on crop yields, production, and cropped area under both rain-fed and irrigated food grain crops, along with data on crop evapotranspiration estimated using agro-meteorological data. It analyzes the role of the key determinants of overall WP of food grain crops at the regional level, such as cropping pattern, irrigation pattern, and crop consumptive use (ET), in driving WP improvements in food crops. The paper identifies three key interventions for improvement in physical productivity of water in food grain production in India, and the number of districts to which each one of them is applicable.

The third paper by Kumar, Trivedi and Singh analyzes the impact of quality and reliability of irrigation on crop WP, by comparing field level WP of major crops under well irrigation and canal irrigation and under conjunctive use of well water and canal water. This study first derives quantitative criteria for assessing the quality and reliability of irrigation water. The assessment is based on primary data on farming systems collected from farmers in two agro-climatic regions of the Bist Doab area in Punjab, India, which use different modes of irrigation. The paper evaluates the quality and reliability of water in canal irrigation, well irrigation and conjunctive use in quantitative terms; compares WP (both physical and economic) under different supply sources; analyzes the impact of the quality and reliability of irrigation on crop WP and cropping pattern and identifies the factors responsible for the differential productivity.

The fourth paper by Alok Sikka presents the analysis of WP in various multiple use systems that support fisheries, tree production and dairying within the farm along with paddy, which are generally considered as a single use system. The study argues that WP assessment on the basis of the returns from crops alone and the amount of water applied and used would lead to an underestimation of agricultural WP. This paper discusses the findings of research studies undertaken to assess WP in some specially designed experimental systems of multiple uses in eastern India. The various multiple water use systems include, 1) secondary reservoir-cum-fish ponds in the tube well command in Patna; 2) fish-trench-cum-raised bed for fish-horticulture, and rice-fish farming in seasonally waterlogged areas in Patna under the traditional rice-wheat system; 3) on-dyke horticulture and fish-prawn-poultry system, and subsurface water harvesting with fish culture in coastal Orissa; and 4) rainwater harvesting ponds for fish-prawn farming with fruits and vegetables on the pond bunds in rain-fed areas of Ranchi in Jharkhand in the central plateau. This paper also discusses the impacts of introducing different production systems such as fish, prawn, horticulture and poultry in rice-wheat system on agricultural WP. Furthermore, it includes an analysis of impact of conservation technologies, viz., zero tillage-bed planting and drip irrigation on crop WP in wheat and banana, respectively.

The fifth paper by Singh and Kumar examines the factors determining water intensity of dairy farming other than climate. For this, it synthesizes empirical data available from two locations in India, viz., northern Gujarat, western Punjab, both representing semiarid climatic conditions. But, the two regions are markedly different in terms of the nature of dairy farming. The first one is commercial dairying, which is intensive and depends heavily on irrigated fodder crops. In the second case, dairy heavily depends on by-products from crops. This paper presents the data on feed, fodder and water inputs in dairy production, expenditure on livestock keeping, milk yields, and WP in dairying for different categories of livestock. This study shows that dairy production is highly water-intensive when it is commercial, and is still water-intensive but more efficient when it is part of mixed farming. It also shows that the nature of trade-offs involved in maximizing agricultural WP under the two situations are different. Furthermore, an empirical analysis from Kerala, which is a subhumid area, demonstrates the impact of climatic change on the water intensity of dairy production. It shows that milk production is highly water-efficient in regions like Kerala, but the lack of availability of sufficient arable land becomes a constraint to intensive milk production.

The sixth paper by Kumar and van Dam discusses the various determinants for analyzing WP in Indian agriculture that are markedly different from those used in the west. It also identifies some major gaps in WP research and the key drivers of change in WP. The main arguments are 1) in developing economies like India the objective of WP research should also be to maximize net return per unit of water and aggregate returns for the farmer, rather than merely enhancing ‘crop per drop;’ 2) the determinant for analyzing the impact of efficient irrigation technologies on the basin-level WP and water saving should be the consumed fraction (CF) rather than evapotranspiration; 3) in closed basins, determinants for analyzing basin-level WP improvement through water harvesting and conservation should be incremental economic returns and opportunity costs; 4) at the field level, the reliability of irrigation water and changing water allocation could be the key drivers of change in WP, whereas at the farm level, changes in the crop mix and farming system could be key drivers of change. In composite farming systems, measures to enhance WP should be based on farm-level analyses. At the regional level, concerns of food security, employment and market risks can reduce the ability to significantly improve WP in agriculture.

The seventh paper by Kumar further discusses potential, prospects and constraints for improving agricultural WP in India. It first discusses the various considerations in analyzing WP in India. Some of them are: ‘scale of analyses,’ i.e., field to farm to region or field to system to river basins; objective of WP assessment; food security; and regional economic growth and environmental sustainability. It then discusses how integration of these considerations in analyzing WP changes the way we assess agricultural WP improvements. While new windows of opportunity for WP improvement are created, it also creates some new limits. For instance, taking the basin as a unit for WP enhancement measures leaves us with the opportunity for improving WP using the climatic advantage, as within the same basin, climate often varies remarkably. It then summarizes various interventions for WP enhancement in rain-fed and irrigated agriculture, which are discussed in various papers. This is followed by a discussion of various macro-constraints in enhancing agricultural WP in rain-fed agriculture that are social, economic and financial in nature. In the case of irrigated agriculture, the constraints are physical, technological and infrastructural, institutional, and market- and policy-related. Finally, the scale at which various WP improvement measures could be adopted in India and their potential impact on future growth in agricultural water demand is assessed.

Why Is WP Improvement in Agriculture Crucial for India?

Many of India's agriculturally prosperous regions are water-scarce, where the natural endowment of water is poor (Amarasinghe et al. 2005), while the demand for water in agriculture alone far exceeds the utilizable renewable water resources (Kumar et al. 2008b). The common features of these regions are excessive withdrawal of groundwater and excessive diversion of water from rivers, which cause environmental water stress. Agriculture is the major user of water in these regions, particularly for irrigated crops, with very high per capita water use in irrigation (Kumar et al. 2008c). Agriculture is in direct conflict with other sectors of the water economy and environment. The scope for augmenting the utilizable water resources in these regions is extremely limited. While there are many regions in India where water resources are abundant, most of them have limited potential for increasing agricultural production due to the limitations imposed by land and ecological constraints. So, improving WP in agriculture, wherever possible, holds the key not only to sustaining agricultural production and rural livelihoods but also to making more water available for other sectors including the environment.

The world over, agriculture has very low water use efficiency when compared to manufacturing (Xie et al. 1993; Turner et al. 2004), and the situation is no different in India. Agriculture continues to be the largest user of diverted water in the country (Amarasinghe et al. 2008a; GOI 1999). Moreover, productivity of water use in India is very low for major crops in terms of the amount of biomass produced per unit of water depleted in crop production. The reasons are many.

First, India has some of the lowest yields in cereal crops viz., wheat and rice (Amarasinghe and Sharma, paper 2, this book). They consume large quantities of irrigation water in aggregate terms (Amarasinghe et al. 2005), compared to what is biologically possible to consume by these crops for a given variety, in the given temperature and solar radiation The factors responsible for this could be lack of irrigation, deficit irrigation or excessive irrigation, or lack of soil-nutrient management through optimal dosage of fertilizers and micro-nutrients, poor on-farm water management or farm management. Furthermore, what is biologically possible may not be economically viable or in other words optimal. It is particularly true in areas where the soils are degraded with poor micro- and macro-nutrients, which demands application of huge quantities of nutrients to achieve the maximum yield. The latter increases the input costs, reducing the net income. Also, many crops are grown in regions where the climate is not fully favorable for realizing good yields.

Second, irrigation water use efficiencies are poor in India (GOI 1999) due to inefficient irrigation practices or unfavorable soil conditions. Flood irrigation, level border irrigation and, to an extent, furrow irrigation are generally practiced by Indian farmers for agricultural crops. The adoption of water-efficient irrigation technologies has been by and large very poor to date. One example of an unfavorable soil condition is the practice of growing irrigated paddy in light soils. Excessive deep percolation would require frequent watering of the crop to keep the ponding of water in the field. Another important issue is the adoption of short-duration food crops, which are inherently inefficient in water use in terms of amount of grain yield per unit of water consumed (ET), but survive on rains, in vast regions of India, owing to lack of irrigation facilities.

Improving WP in agriculture can bring about many positive outcomes. While in some regions WP improvement would result in increased crop production with no increase in consumptive use of water, in some others it would result in reduced use of surface water or groundwater draft. Both would protect the environment. On the other hand, there are certain regions in India where yields are very poor as the crops are purely rain-fed in spite of having a sufficient amount of unutilized water resources. Augmenting water resources and increasing irrigation in such regions can result in enhanced yield and income returns, as well as water productivity improvements. Hence, such strategies have the potential to reduce poverty in these regions.

Opportunities and Constraints for WP Improvements

As various papers included in this book show, there are several opportunities for improving the WP of crops. They include

- providing irrigation to crops that are currently rain-fed so as to meet the full crop evapotranspirative demand for realizing the yield potential (Amarasinghe and Sharma, paper 2, this book);
- adopting long-duration food crops, which have higher water use efficiency, and replacing short-duration ones, which have low efficiency, again possible through the availability of irrigation water (Amarasinghe and Sharma, paper 2, this book);
- growing certain crops in regions where their yields are higher due to climatic advantages (high solar radiation and temperature for instance), better soil nutrient regimes or lower ET demand (high humidity for instance)—(Abdulleev and Molden 2004; Loomis and Connor 1996);
- improving quality and reliability of irrigation water (Kumar, Trivedi and Singh, paper 3, this book; Palanisami et al. 2008); managing irrigation for certain crops, which could mean controlling allocation or increasing allocation to the said crops (Kumar and van Dam, paper 6, this book);
- adopting high-yielding varieties without increasing the crop consumptive use (Amarasinghe and Sharma, paper 2, this book);
- providing optimal dosage of nutrients, such as artificial fertilizier, and improving farming systems with changes in crop and livestock compositions (Singh and Kumar, paper 5; Kumar and van Dam, paper 6, this book).

But, there are constraints to improving WP for irrigated crops induced by land availability (Amarasinghe and Sharma, paper 2, this book; Singh and Kumar, paper 5, this book), food security concerning regional economic growth (Kumar and van Dam, paper 6, this book) and existing institutional and policy frameworks. For instance, in many situations, improvement in WP in kg/ET or Rs/ET does not guarantee better returns for the farmers due to inefficient pricing of water and electricity, and absence of well-defined property rights in water

(Kumar and van Dam, paper 6, this book; Kumar et al. 2008a). Cereals such as wheat and paddy, growing of which is important for meeting national food-security needs, have much lower water use efficiency, as compared to cash crops such as cotton, castor and groundnut (Kumar and van Dam, Paper 6, this book). In the case of rain-fed crops, many communities lack the knowledge and wherewithal to adopt technologies and practices to improve WP in agriculture. Finances required for investing in water harvesting systems for supplementary irrigation for rain-fed crops, and its economic viability are critical issues (Kumar, Paper 7, this book).

In a nutshell, while there seem to be great opportunities for improving WP in agriculture, to what extent these can be achieved in real practice depends on the scale at which the above-mentioned constraints operate. Also, as we have discussed earlier, to what extent the improvement in WP can be leveraged to reduce the demand for additional storage, for India depends on the source of WP improvement. It is quite clear that though we can avert the need for new development of water resources for irrigation to a great extent through WP improvements, some interregional transfers of water saved from the committed releases in certain regions, resulting from improved WP of crops in these regions, might still be required.

Institutional and Policy Measures for WP Improvements

The policy constraints concern the pricing of water used in canal irrigation and electricity used in well irrigation, whereas the institutional constraint comes from the lack of well-defined water rights for both surface water (Kumar and Singh 2001) and groundwater (Kumar 2005). Both these factors leave minimum incentives for farmers to invest in measures for improving crop WP as such measures do not lead to improved income in most situations (Zekri 2008; Kumar et al. 2008a). The electricity supplied for groundwater pumping needs to be metered and charged on a pro-rata basis in regions where well irrigation is intensive. The State of Gujarat, one of the most agriculturally prosperous states in the country, has already started doing this, where nearly 40% of the agricultural connections are now metered and farmers pay electricity charges on the basis of actual consumption.

The other measures that can be taken up in the short term are improving the quality of irrigation water supplies from canal systems, including provision for intermediate storage systems like the ‘diggies’ in Rajasthan (Amarasinghe et al. 2008b); improving quality of power supply in agriculture in regions that have intensive groundwater irrigation, with longer-duration supplies along with an improved tariff structure; improving electricity infrastructure in rural areas of eastern India; and provision of targeted subsidies for micro-irrigation systems in regions where their use results in major social benefits. This would help maximize the scale for adoption of micro-irrigation systems, and potential impacts in terms of WP improvements. On the other hand, investment in irrigation infrastructure for supplemental or full irrigation would significantly enhance crop yields in many areas and WP in some rain-fed areas. This would be a medium-term measure.

Future Research

The concept of WP improvements in agriculture is relatively new. The amount of scientific assessment of WP available from research studies is heavily skewed in terms of geographical coverage, the scale of analysis, crop types, and the determinants used in assessments. These assessments mainly covered wheat, paddy and maize among food grain crops; and cotton among cash crops. Most of the assessments, which are for developed countries in the west, look at biomass output per unit of water depleted or applied and are done at the field scale looking at individual crops (Zwart and Bastiaanssen 2004; Kumar and van Dam 2008). There are quite a few unknowns in the field of WP, which can hinder making the right kind of policy decisions for managing water demand in agriculture that does not cause any undesirable consequences for the farming communities and society. Next, we discuss a few of these unknowns that require further research.

1. The possible trade-off between improving WP of individual crops and the entire farm level needs to be better understood under different socioeconomic environments. For instance, while shift from irrigated paddy and wheat to water-efficient fruits and vegetables might help achieve higher crop WP, it might affect the output of milk from the farm, thereby affecting the WP of the farming system as dairying under 'mixed farming' conditions was found to be highly water productive (Kumar and van Dam 2008). The unknown here is the overall value of WP in dairying under different farming conditions (Rs/m^3). Also, the risk involved in cultivation of some of the vegetables and fruits, is very high when compared to dairy farming and paddy cultivation. This is one reason why many farmers prefer to adopt the wheat-paddy system, which involves the least agronomical and market risk.

2. There is very little useful research available that can be used to estimate the WP (both physical and economic) of many perennial fruit crops. The most crucial piece of information needed here is the amount of water consumed annually by the crop (ET) with increase in age of the plant, the change in yield over the years, and the irrigation water requirements in different years under different agro-climatic conditions. The issue of water consumption by tree crops is quite complex. While many trees consume large quantities of water, depending on the foliage, a good portion of this water comes from deep soil strata. In deep water table areas, the moisture held up in the 'vadoze zone' (hygroscopic water), which is not available for recharge or consumption by smaller plants, would provide this water. Hence, the impact of the trees on the actual water balance needs better understanding.

3. The possible trade-offs between improving agricultural WP of an individual farm and an entire region needs more assessment. For instance, the introduction of certain cash crops might help raise the field- and farm-level WP, thereby benefiting the farmers who adopt it. But, extensive adoption of these crops by a large number of farmers in a region might result in increased market risk, resulting from over-production and price crash. The research question is, what should be the optimum level of adoption of such crops in different regions to save water as well as to sustain farm economy?

4. The general perception is that micro-irrigation (MI) systems help raise the WP of crops and that there is sufficient analytical work now available, to show that the extent of real water saving possible with MI is a function of the soil, climate, geohydrology, and type of technology used (Kumar et al. 2008a,). But, unfortunately, change in the quantity of water applied after adoption of the technology is often perceived as reduction in water use. When researchers proceed with their analyses of physical and economic impacts of MI systems using such assumptions, it leads to false policy prescriptions. Most of the available research on water saving and WP impacts of MI systems is based on the

estimation of change in applied water. What is important is to know how the consumptive fraction changes under different climates, soils, water table conditions, and how it affects different crops.

5. The WP and income improvements that are possible through the conversion of single use systems into multiple use systems under different multiple use combinations require better understanding. This is a very crucial area for research because there appears to be several limitations to maximizing WP and income returns through the conventional route in many regions due to physical, technological, financial and climatic constraints. For instance, in the wetlands of cold/hot and subhumid areas, paddy is a dominant crop. It is difficult to shift from paddy to high-valued crops here. The reasons are many. Paddy is not amenable to micro-irrigation systems. Wetlands are not suitable for growing fruits and vegetables. At the same time, if the same land is also used for growing fish or shrimp, the returns could be enhanced significantly. Also, growing tree crops might enhance the returns. The biggest research challenge would be proper accounting of the water used in farms that helps assess the marginal productivity of various farming systems such as tree crops, field crops, duck-rearing and fishery.

Conclusions

With increasing water scarcities, WP enhancement in agriculture is not only relevant, but also very crucial in meeting future water demands of the agriculture and other sectors. There are several constraints in enhancing WP in agriculture. But, there are several opportunities too. However, the constraints can be reduced and the opportunities enhanced through appropriate institutional and policy interventions. WP improvement would definitely reduce the need for future investments in the new development of water resources in some regions. But, due to regional variations of water supply and use, the extent of reduction in demand for additional water for meeting future needs will not be the same as the scale of aggregate savings of water achieved by enhancing WP. However, it might result in more water being available for environmental uses or reallocation to other sectors in some regions wich were earlier used for growing crops.

The other outcomes of WP improvement are: reduced poverty due to rise in farm income in the agriculturally backward regions; reduced environmental stresses caused by excessive pumping of groundwater or diversion of water from streams/rivers; and better availability of water from basins for allocation to environmental uses or freeing up of a large amount of cultivated land under rain-fed production, resulting in increased streamflow generation from catchments. They all help meet the future water demand of different water use sectors. In fact, WP improvements in agriculture can be a major component in a water-sector perspective plan in India.

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