Chapter 11
Future Water Management: Myths in Indian Agriculture

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Abstract Water management in India in the coming years will have to take an entirely different trajectory from what was followed since Independence, if recent trends are any indication. At the national level, the trends are: rising per capita incomes and improving living standards; rapid urbanisation and higher population growth rates in large cities; fast changing structure of the national economy; changing consumption pattern, with increasing preference for high calorie food—milk and milk products, and meat; fast improving transportation, and information and communication networks in rural areas; ageing population, and rising rural farm wages. These trends would create new water management needs and priorities for the future. Along with technological, institutional and policy interventions for water demand management, large water projects would be an integral part of the future solution. But, a section of the civil society argues that 'viable alternatives' to large water projects exist by propagating certain myths. This chapter makes an objective assessment of these 'alternatives' and shows how they fail to meet the future 'water management needs' by confronting these myths. Accordingly, the trends that are most likely to emerge in future in the water management sector are deciphered.

Keywords India · Agriculture · Water demand management · Water scarcity
Soft paths · Civil society

11.1 Water and Agricultural Growth

In India since Independence, irrigation has been the key to enhancing grain production and ensuring food security at the national level, supporting nearly 60% of the country's population (Sharma 2011) in terms of food grains, pulses, fibre, oil seeds, vegetables and fruits. Though the contribution of agriculture to the national gross domestic product (GDP) has been declining fast since 1950–1951 (Fig. 11.1,

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A. K. Biswas et al. (eds.), *Assessing Global Water Megatrends*, Water Resources Development and Management, https://doi.org/10.1007/978-981-10-6695-5_11

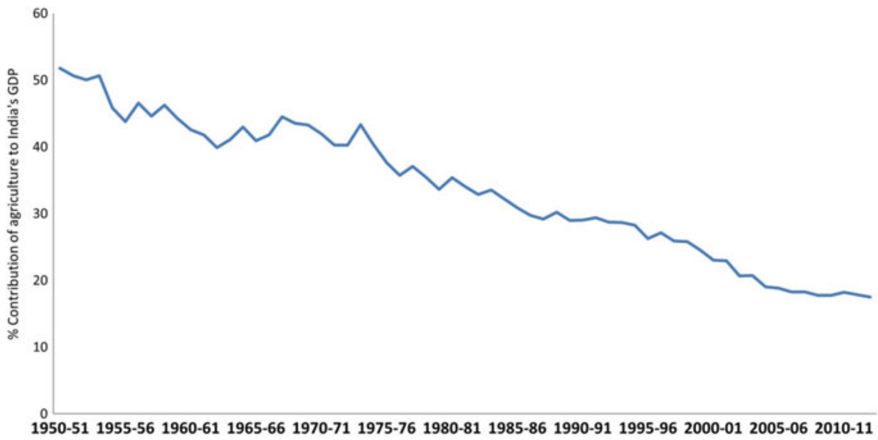

Fig. 11.1 Share of agriculture and allied sectors to India's GDP

based on GOI 2014) and now hovers around 17.6%, it still accounts for 49% of the employment in the country (KPMG 2016). But, this growth has not been uniform. A large chunk of the growth in agricultural production has come from the northern region, mainly Punjab, Haryana and Western Uttar Pradesh, which reaped the benefits of the Green Revolution rather rapidly (NRAA 2011).

The growth rate in TFP (Total Factor Productivity) is lowest for eastern region comprising Bihar, Odisha, Chhattisgarh, Jharkhand and West Bengal. Further, it has declined over three decades (1956–1987) from 1.5 during 1956–1965 to 0.70 during 1977–1987 (Evenson et al. 1999). During 1975–2005, the TFP growth in wheat has been lowest in Bihar and West Bengal, and that in paddy has been lowest in Bihar, Odisha and West Bengal (Chand et al. 2012). The grain yields are lowest in Bihar (Pathak et al. 2003). There are many reasons for the low agricultural productivity in this region. First is a low level of cultivation and use of irrigation. Irrigation, when compared with population size, is poorer in states such as Bihar and Odisha as compared to Punjab and Haryana, resulting in a very low per capita irrigated area (Kumar et al. 2012; NRAA 2011). The situation is Bihar is noteworthy due to it being one of the lowest per capita cropped areas (0.092 ha), and a high incidence of rural poverty. Nearly 32.6% of the people in the state live under poverty (Planning Commission, 2014) and the average per capita income of the state was a mere 40.6% of the national average (Biswas and Tortajada 2017). The constraints imposed by low per capita cropped area and irrigation are compounded by low yield levels (Kumar 2003).

Low levels of farm surplus, socio-economic deprivation, lack of public funds to invest in water resource development sector and poor availability of credit, which constrain technology adoption in agriculture, and poor political leadership act as three major challenges (based on Kumar et al. 2012; Kumar 2007; NRAA 2011).

In peninsular India, which has relatively high per capita agricultural GDP and TFP growth (Evenson et al. 1999), scarcity of irrigation water is becoming a major impediment to sustaining this growth. Inter-basin transfer of water from water abundant river basins to the water scarce ones could help augment the irrigation potential of these regions (Kumar and Singh 2005; Kumar et al. 2012), while augmenting the country's water supply potential by 200–250 Billion Cubic Metres (BCM). However, this must be followed by measures to improve the efficiency of water use in different sectors to achieve water demand management on a technological and institutional front. Particularly, greater attention should be paid to urban areas, with cities and towns claiming larger quanta of water (Kumar 2010, 2014a) and with non-revenue water (NRW) accounting for as high as 45% of the supplied water in certain cases (Kumar 2014a).

Demand for water in agriculture is growing due to increasing food grain needs of the growing population, and the growing preference for water-intensive cash crops. High pre- and post-harvest losses in food, which account for nearly 25% for cereals, oil seeds and pulses, nearly 40% for roots and tubers, and as high as 50% for fruits and vegetables (Gustavsson et al. 2011) are other factors that would increase the demand for water in agriculture in developing countries like India. In the urban and industrial sectors, the growth would be rather rapid, owing to the faster growth in urban population and rapid industrialisation. However, the scarcity is not going to hit all regions uniformly (Amarasinghe et al. 2008; Kumar 2010; Kumar et al. 2012). The naturally water-scarce regions, such as western India, south Indian peninsula (except Kerala), northwestern India and parts of central India, would be hit badly, as the demand for water from agriculture, industrial and urban sectors is high in these regions, while the renewable water resources available from within the region are low. This is compounded by the demand for water for reducing environmental water stress in the rivers. In the absence of proper legal regimes under which water can be allocated among the competing uses, water rights will be politically contested, leading to conflicts (Kumar 2010). Inefficient central and state water agencies and an absence of institutional arrangement for inter-state water allocation complicate further in most cases.

The large cities located in naturally water-scarce regions of India are heavily dependent on water imported from distant reservoirs (Mukherjee et al. 2010). The economically and politically powerful urban areas are likely to manage the huge additional supplies required from the rural areas with adverse implications for irrigated agriculture. Thus, agriculture in naturally water-scarce regions would be facing severe competition from other sectors such as industry, urban drinking and environment. The remarkable variations in the demand-supply balance across regions, and competing claims made by urban domestic, manufacturing and environmental sectors (Amarasinghe et al. 2004; Kumar et al. 2012) magnify the problem.

Approaches to water management in India in the coming years will have to take an entirely different trajectory from what was followed since Independence, including new water management models and innovative planning approaches, if recent trends are any indication (Biswas and Tortajada 2009). At the national level, the trends are: rising per capita incomes and improving living standards; rapid urbanisation and higher population growth rates in large cities; fast changing structure of the national economy; changing consumption pattern, with increasing preference for high protein diet—milk and milk products, and meat; changing composition of agricultural outputs, with greater contribution of horticulture, and dairy products; fast improving transportation, and information and communication networks in rural areas; and rising rural farm wages. These trends would create new needs and priorities in the water management sector for the future. As noted by Biswas and Tortajada (2009), ageing of the population, and retirement of the older generation with vast knowledge, experience and collective memory from the workforce, would pose new challenges.

However, a section of civil society has been demanding a new outlook on water management. The following views characterise this outlook: any water project that involve submergence of forests and human displacement should be completely avoided; rather than augmenting water supplies, water use efficiency in irrigated agriculture should be enhanced significantly to manage the demand for water in that sector and to allocate more water for other sectors; sufficient flows need to be maintained for environment in all rivers; the performance of new schemes should be assessed in relation to their ability to improve equity in access to water rather than augmenting water supplies; and new irrigation schemes, if at all required, should meet the growing needs of the farming enterprise, rather than contributing to the country's grain basket.

It is a well-articulated fact that large dams have a very important role to play in human development of developing countries, and there is really no other choice (Biswas and Tortajada 2001). Even in states such as Bihar, whose northern part is heavily prone to floods, trans-boundary water management in international rivers such as the Kosi, judicious water resources development for flood control and hydropower development can act as engines of economic development (Biswas and Tortajada 2017). While human displacement can be a major challenge to deal with, they can be made direct beneficiaries of the project for improving their lifestyles. In Brazil, upstream townships now receive 2% of the revenue from all electricity sales, in perpetuity. In Bhutan, each resettled family receives a certain amount of electricity free, in perpetuity. If they cannot use it all, they can trade that electricity at the market price. Such measures can significantly change the opposition to large water projects.

However, attempts were made by these interest groups to downplay the grave situation arising out of a scenario of not investing in large water infrastructure projects from the point of view of agricultural growth, rural development, food security and livelihoods. They propagated several myths to argue that viable alternatives to large water projects exist, or agriculture would not be a major claimant for water in future. These myths cripple healthy debate on water management solutions. In fact, the afore-mentioned 'outlook' on water management is part of a larger narrative to gain legitimacy for the 'alternatives'. In the process, what is ignored is that large dams are the best examples of rainwater harvesting, which they promote as 'alternative'. Therefore, large versus small is a wrong narrative for water debate in India. Rather, the discussion should focus on whether to go for 'large' or 'small'.

11.2 Where Would the Future Growth in Water Demand Come from?

Myth: When economy grows, more water would be used for domestic and manufacturing sector, and less for agriculture.

Reality: With growing population and rising income levels, India would require more food in the form of cereals, livestock products including milk, milk products and chicken, increasing the demand for water.

It is important to recognise the fact that the average calorie intake, which is one of the lowest in the developing World, is going to increase substantially in the coming years, with rising per capita income. Anyway, the demand for dairy products has been growing exponentially in India—from a low of 42 kg/capita/year in 1979–1981 to 71 kg/capita/year in 2005–2007 (Alexandratos and Bruinsma 2012) and is projected to reach 133 kg/capita/year by the year 2022 (Punjabi 2010) and this has major implications for water use, as dry regions are producing maximum milk. The perceptible change in food habits of the people and the preference for finer varieties of grains would further increase the demand for water for agricultural production.

Some researchers argue that when the country becomes developed and with nearly 50% of the population living in urban centres, there would be more demand for water from manufacturing and urban sector and agriculture would be less important in India's economic landscape (see Amarasinghe et al. 2008). Some of them argue further that with income from the non-farm sector becoming important, fewer numbers of people from rural areas would be dependent on agriculture for their livelihoods with the result that the average farm size would increase and those who operate the land would be in a position to use modern farming equipment with a resultant positive impact on water use efficiency. They do not foresee national food security as a concern for investment decisions in the water sector, as they believe that food and feed can be imported. Along with food security, energy security is also essential. There is no thinking on how food and energy security can be concurrently achieved.

The situation in some developed countries, where manufacturing and domestic sectors account for a large share of the total water use (UN 2009) is often cited to support these arguments. Such optimisms are highly misplaced, and can lead to dangerous consequences for the country's food security, rural livelihoods and overall social fabric, resulting from widespread water shortages in rural areas owing to lack of investment for irrigation. The reasons are many:

First: India has a very large rural population and a very large workforce, and the potential of manufacturing and service sectors to absorb this population is very limited. The possibility of population stabilising before 2050 is impossible. As a combined effect, a significant chunk of the rural population would continue to depend on farming and allied sectors as one of the occupations for many decades to come. While there is no extra arable land available for cultivation, this would only lead to intensive use of the land that is under crop production by making more irrigation facilities. We also have to make big allowances for food waste, unless major reductions in pre- and post-harvest losses of agricultural produce are achieved in coming years. As global experience suggests, a major increase in farm size that is sufficient to make a significant impact on modernisation is unlikely to happen in the near future in India (Eastwood et al. 2010).

Second: a decline in food grain and agricultural production, with a simultaneous increase in per capita income can cause food price inflation, and there is also an inverse relationship between growth rate in food grain production and agricultural price index (Sasmal 2015). These relationships imply serious consequences of any future reduction in agricultural production for food security, hunger and poverty, because of two major reasons. (1) there are large regions in India, especially in the eastern Gangetic basin where the poverty rate is very high, and the population in that region is increasing much faster than the rest of the country, with an increase in absolute number of people living in abject poverty. (2) the purchasing power of an average person would be adversely affected by rising food prices. The combined effect would be that hunger would increase due to insufficient access to food (based on FAO 2009).

Third: unlike many developed countries, which have very good agricultural production technologies, large-sized operational holdings, very small fraction of the population engaged in farming with high average income of individual farmers and a lot of the agricultural outputs produced for export, in India, farmers who have very small average holdings and low average income, have very little leverage to reduce the area under production and reduce water use (Eastwood et al. 2010, based on 1990 and 2000 rounds of FAO farm measures; Wichelns 2003).

Some recent projections show growth in aggregate water demand in agriculture by the year 2025 (for details, see Amarasinghe et al. 2008; Kumar 2010). In many developed countries, the agricultural water withdrawal has increased over the years, in spite of water use efficiency improvements. An example is the USA (based on Kenny et al. 2009). In all probability, a similar trend in water use would be witnessed in India, which is most likely to experience large-scale adoption of water-saving technologies in water-scarce regions, owing to the presence of extensive well irrigation and the presence of large areas under crops that are amenable to micro-irrigation technologies. A major reason for this likely trend is that only 30–40% of the arable land in these areas is currently under irrigation and there is strong incentive among farmers to expand the area, using the saved water. Hence, due to excessive increases in irrigated areas, eventually consumptive water use would either remain the same, or even increase.

While these can be the probable trends of agricultural water demand in India, water demands in domestic and industrial sectors are going to increase at a very high rate, given the high rate of urban population growth and industrialisation. In future, domestic and industrial sectors would claim a greater proportion of the available water than at present. There would be great competition for the limited water resources from these sectors. Problems of food shortage and water scarcity are likely consequences, unless we increase crop yields substantially through technology innovations, improve efficiency of use of water Kilogram of biomass per unit volume of water consumed in evapotranspiration (kg/ET), and reduce the colossal wastage of agricultural produce, during and after the harvest. The need for promoting this three-pronged approach is as follows. First: in regions where there is enough water, there is huge scarcity of land. Second: in regions with plenty of arable land lying un-irrigated, water is a major constraint for crop intensification. Third: reducing food wastage would reduce the domestic demand for cereals at the aggregate level. Therefore, we would require an integrated approach to addressing the water-land-environment related issues. We are already seeing enormous investments in genetically modified (GM) crops, salt-tolerant crops, drought and flood resistant crops and high yielding seed varieties.

11.3 Can Water-Scarce Regions Adopt a Soft Water Path to Development?

Myth: Water-scarce regions can abandon intensive agriculture, and look for soft water path to development.

Reality: Water-scarce regions are agriculturally most prosperous regions, and water-rich regions are agriculturally backward. Also, number of people engaged in farming is more in the water-scarce regions. This is also true for countries such as the USA, Mexico and China.

Among the water demanding sectors of the economy, agriculture is still the largest user (Amarasinghe et al. 2008; Kumar 2010). Given the fact that our economy is still a developing one, with low average incomes, the size of agricultural GDP and the number of people engaged in agriculture in a region could determine whether agriculture is important for the region's economy or not. Figure 11.2 shows that per capita agricultural GDP is very high in regions that are naturally water scarce.

Historically, these states have seen irrigation expansion through both surface water development and groundwater development. Gujarat, which currently has low agricultural NSDP (Net State Domestic Product), is now experiencing a high degree of agrarian growth with the introduction of SSP (Sardar Sarovar Project) waters for irrigation. Whereas, the agricultural component of net state domestic product in per capita terms is very low for some of the water-rich states such as Bihar, Uttar Pradesh, Kerala, Assam, West Bengal, and many of the northeastern States (with the exception of Himachal Pradesh and Arunachal Pradesh). This is in spite of the fact that, there, states have a high degree of irrigation development. The reason for this dichotomy is that the marginal returns from the use of irrigation water are much higher in water-scarce regions, compared to water-rich regions Kumar et al. (2008a).

As regards agricultural labour, we do not find a similar trend, though. The number of persons employed in agriculture as a fraction of the total population of the state (Fig. 11.3), either in own farming or as agricultural wage labourers, is not high in the water-scarce states, except Madhya Pradesh and Andhra Pradesh. Most importantly,

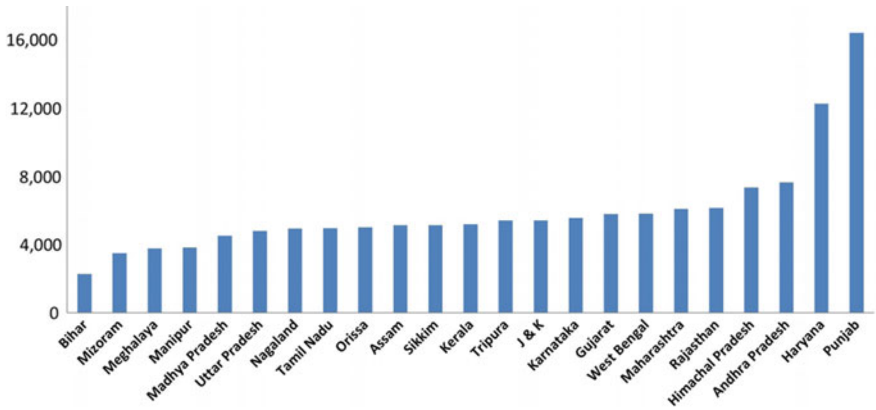

Fig. 11.2 Per capita agricultural GDP of selected states

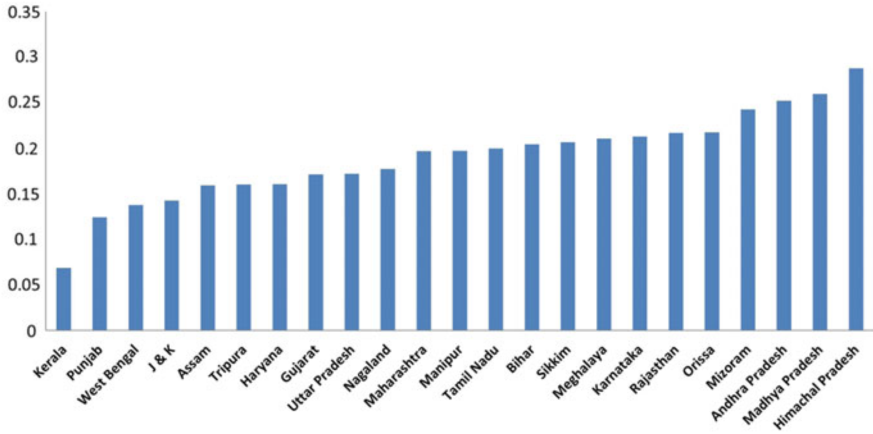

Fig. 11.3 Population engaged in agriculture as a fraction of total (2001)

the number of people engaged in agriculture as a ratio of the total population is very low in Punjab and Haryana in spite of these states having large irrigated areas, because farms in Punjab and Haryana attract a large number of migrant labourers from Bihar. For instance, in the case of Punjab, paddy cultivation alone attracts nearly 55.75 million person-days of migrant labour from Bihar (Kumar and van Dam 2013). Hence, the actual number of people that these states can absorb as agricultural labourers, is high. Whereas, in many of the water-rich states, such as Kerala, a small fraction of the population is engaged in farming, with the ratio below 0.07, meaning only 7 out of the 100 persons in the state are engaged in agriculture. In states, such as Bihar, where the percentage of people engaged in agricultural labour appears high, the actual figure could be much lower if we factor out migrant labourers who work in other states. While Bihar has highly fertile soils and abundance of water, what it lacks is sufficient amount of arable land in relation to its high population, and the per capita arable land in the state is very low (0.07 ha).

If water-scarce states such as Punjab, Haryana, Gujarat, Rajasthan and Madhya Pradesh moved out of agriculture, it could have serious consequences for rural employment and livelihood. In the case of states such as Punjab and Haryana, such diversification would also affect in the neighbouring poor state of Bihar, which exports labour. Whereas Kerala can still afford to move out of agriculture and has been able to do so through investments in education and human resource export to other parts of the country and the world, Kerala has also been successful in replacing traditional paddy with plantation crops (like coconut, arecanut, rubber) that require labour spread over the whole year, rather than seasonal labour, thereby avoiding peak labour demands. A significant chunk of Kerala's State Domestic Product comes from foreign remittances. The relatively high per capita incomes and the relatively low contribution of agriculture to the state NSDP, make such a shift easier. In summary, it would be impossible for naturally water-scarce regions of India to move rural people out of agriculture, and adopt a softer path to development.

11.4 Can Supplementary Irrigation with Rainwater Harvesting Enhance Water Productivity of Rain-Fed Crops?

Myth: In water-scarce regions, supplementary irrigation supported by local rainwater harvesting can enhance crop water productivity remarkably.

Reality: In India, supplementary irrigation is required mainly for kharif crops when monsoon fails.

Creating infrastructure for supplementary irrigation is too expensive. However, supplementary irrigation is already happening by default wherever technical feasibility exists. Alluvial Punjab, Haryana and alluvial tracts of Gujarat are examples. In other places (especially in the hard rock areas), there is a shortage of water in aquifers and local catchments for harnessing to provide for supplementary irrigation when it actually becomes critical for plant protection. Yield and water productivity of crops in physical terms may go up with supplementary irrigation, but outcomes *vis-à-vis* net return and water productivity in economic terms are open to question due to the high cost of harvesting water in situ for supplementary irrigation. The research from other parts of the world is rather skewed and largely ignores the economic viability aspects (Kumar and van Dam 2013).

This idea, however, has found many takers in India, who have extended it to the rain-fed areas of the country, where productivity of rain-fed crops is low (see Iyer 2011; Phansalkar and Verma 2005). Such skewed analysis has limited application when the farmers are concerned more with maximising the net income returns from a unit area of the farm or unit volume of water rather than the total grain yield from unit volume of water. The reason is that the cost of providing supplementary irrigation would be so substantial that it would significantly reduce the net returns and therefore water productivity in economic terms (Kumar and van Dam 2013).

To begin with, there are two types of rain-fed areas in the country. The first is high rainfall regions, where the monsoon rains alone can support the growth of kharif crops. Examples are high rainfall areas of Kerala, Jharkhand, Assam, Orissa and West Bengal and the eastern parts of Madhya Pradesh. Here, the dominant kharif crop, i.e. paddy, is fully grown under rain-fed conditions. The second is areas where the kharif crop is grown under dry conditions, just using soil moisture available from the rainfall. We would therefore deal with the second type of areas.

In water-scarce regions, supplementary irrigation to enhance crop water productivity would make sense if the incremental (net) economic returns from yield enhancement exceed the opportunity cost of depriving the downstream users of equal amount of water. So, there are two aspects to it: (1) the cost of providing supplementary irrigation against the incremental return farmers can secure through yield enhancement; and (2) the opportunity cost of using water for supplementary irrigation (Kumar and van Dam 2013).

If we leave aside alluvial areas such as Punjab and Haryana where water intensive crops are grown with supplementary irrigation resulting in high crop yields, everywhere supplementary irrigation is required when the monsoon fails, as farmers are already growing crops that are of short duration and that transpire less amounts of water. It is in this low to medium rainfall regions where monsoon rains experience high variability (Droogers et al. 2001). These regions also experience high aridity, and a significant part of the potential evaporation is during the monsoon season itself. As a result, in years of meteorological drought, the reduction in runoff would be disproportionately higher than that of the rainfall, leading to hydrological droughts. A close look at these regions shows that they fully coincide with those regions where groundwater resources are either scarce due to hard rock geology or are over exploited (Kumar et al. 2006). In the hard rock regions, the local groundwater supply being a function of rainfall, in drought years, water availability in the wells during monsoon would be poor. While supply of local runoff and groundwater would be extremely poor and unreliable, use of exogenous water is not going to make economic sense, as both the direct cost and opportunity cost would be too high.

Some advocate rainwater harvesting as an alternative to large water resource systems such as large reservoirs and canals (Dharmadhikary 2005; Iyer 2011). A recent work in India argues that the cost of water-harvesting systems would be enormous, and reliability of supplies from it very poor in arid and semi-arid regions of India, which are characterised by low mean annual rainfalls, very few rainy days, high inter-annual variability in rainfall and rainy days, and high potential evaporation leading to a much higher variability in runoff between good rainfall years and poor rainfall years (Kumar et al. 2006, 2008c), and are also very expensive. Comparison between the unit cost of water harvesting and recharge schemes, and net return from unit volume of water obtained in irrigated crop shows, incremental returns due to yield benefits may not exceed the cost of the system (Kumar et al. 2008c).

More importantly, since the basins in such regions are ‘closed’, the water-harvesting systems cause negative impacts downstream (Glendenning and Vervoort 2011; Kumar et al. 2008c; Ray and Bijarnia 2006). Due to high inter-annual variability in rainfall and runoff, the economic viability of water harvesting reduces with increasing system capacity (Kumar et al. 2006, 2008c).

11.5 Are Rain-Fed Crops Alone Sufficient to Boost Agriculture Production in the Future?

Myth: A lot can be done in the rain-fed areas to enhance agricultural production, merely by focusing on new rain-fed varieties.

Reality: Yes, but to a limited extent. Irrigation has been the key to enhancing grain production, and ensuring food security at the national level, with two-thirds of the agriculture production coming from irrigated areas. The following analysis supports this.

Analysis of data on state-wide per capita irrigated area and an agricultural component of per capita net state domestic product in India show that the agricultural GDP is strongly related to the irrigated area (the regression equation is $Y = 3457 + 40862 \times X$, where X is the area in hectares, and Y is the agricultural GDP in Rupees). The R^2 value was 0.75 here, meaning irrigation explains agricultural GDP to an extent of 74%. Such a strong relationship (in spite of the sample states having wide variations in agro climate from hot and semi-arid and arid climates to hot sub-humid climate and cold and sub-humid climate, and major variations exist in the percentage contribution of rain-fed area to total cropped area across states) shows the high impact of irrigation in driving agricultural growth irrespective of the climate. On the other hand, the very small Y intercept of the curve (3514), indicates limited contribution of rain-fed production to agricultural GDP. While the rain-fed area in relation to population size is very high in high rainfall regions of India such as Kerala, Bihar, Uttar Pradesh, West Bengal and Assam, the agricultural GDP per capita is very low in these states, which make the curve steep and its ‘Y intercept’ small. The very low per capita arable land in these states reduces the overall scope for enhancing rain-fed component of agricultural surplus.

The rain-fed yields in India are quite low, with a large difference between potential yields and actual yields realised in farmers’ fields (Rockström et al. 2007). The extent to which they could actually contribute to boosting India’s agricultural outputs in value terms needs to be thoroughly examined against the amount of water taken from the hydrological system. A study carried out in Narmada river basin showed that rain-fed crops accounted for nearly 79% of the total water used from the hydrological system for crop production (17.52 BCM against a total of 22.05 BCM), but contributed only 61.7% of the surplus value product from agriculture. Whereas blue water accounted for only 21% of the total water use, and constituted 38.3% of surplus water product from agriculture. The overall water productivity for blue water use was Rs. 2.5/m^3 while it was only Rs. 1.03/m^3 for green water use (Kumar 2010).

Droogers et al. (2001) show that the rain-fed yield potential in India is very low to moderate in the regions where the mean annual rainfall is the range of low to high. It is only in the very high to excessively high rainfall regions where the rain-fed yield potential is high. Kumar (2014a) shows that improving the yield and water productivity in rain-fed agriculture in central Indian belt and peninsular India would require supplementary irrigation along with improvements in other farm inputs, in the central Indian belt and parts of peninsular India, where the yield potential is very low to moderate. However, it was further argued that, in many cases, there are hydrological and geo-hydrological constraints in ensuring supplementary irrigation through small water harvesting systems in these regions.

In water-scarce regions, such comparisons of economic surplus generated from blue water and green water are extremely important. What is often not appreciated is that when basins are 'closed', expansion in rain-fed areas means reducing the stream-flows and natural recharge to groundwater, which could be made available for diversion into irrigated production that generate higher value surpluses (Falkenmark 2004). In other words, so long as there is an opportunity cost of using moisture in the soil profile for growing rain-fed crops, this trade-offs need to be fully understood (Kumar 2010).

Under such circumstances, to enhance agricultural outputs we should choose from each region, those rain-fed crops that yield highest water productivity (Rs/m^3), and also identify regions where a particular rain-fed crop gives highest water productivity. It would result in more water being available in the hydrological system as blue water, and take some land out of cultivation. Comparison of water productivity estimates for two rain-fed crops namely, soya bean and black gram, from nine districts representing seven agro climatic sub-zones in Madhya Pradesh shows that water productivity of Soya bean varies across agro climates from 0.68 Rs/m^3 to 2.68 kg/m^3 in a normal year to 0.85–1.83 Rs/m^3 in a drought year. Also, there was significant difference in water productivity between black gram and soya bean, with the former showing higher water productivity in the two zones where both the crops are grown—Rs. 3.55/m^3 against Rs. 2.08/m^3 in Hoshangabad and Rs. 1.34/m^3 against Rs. 0.68/m^3 in Narsinghpur (Kumar 2010). Conversely, if the basins are still 'open', we need to identify crops which, if provided with supplementary irrigation, can give higher net return from every unit of land, and devise strategies for supplementary irrigation.

11.6 Can Micro-irrigation Systems and Water-Efficient Crops Solve Irrigation Water Scarcity Problems?

Myth: Micro-irrigation (MI) can help expand the irrigated area manifold and can substitute investments in large water development projects. In water scarce regions, significant water saving in agriculture would be possible through shift in cropping pattern to highly water-efficient crops.

Reality: There are major limitations to expanding area under MI systems, induced by cropping pattern, soils, geo-hydrology and climate. There are also limits to expanding area under water-efficient crops, induced by concerns of farming risk; national and regional food security and labour absorption in agriculture.

The real water saving benefits of MI come from reduction in non-beneficial evaporation and non-beneficial, non-recoverable percolation (Allen et al. 1998). The reduction in non-beneficial evaporation through the use of MI systems would be significant only in the case of distantly spaced crops, and for arid and semi-arid climates. Increases in spacing and aridity increase this component of the total water depleted from irrigated land in the case of conventional flood or small border irrigation (Kumar et al. 2008b; Kumar and van Dam 2013). The non-beneficial non-recoverable deep percolation becomes major when the unsaturated zone is deep, and the climate is hot and arid (Todd and Mays 2005). In hot and arid climates, the groundwater table is generally deep with thick vadoze zone. From an economic perspective, the cost of the MI system reduces with increase in spacing of plants, and economic viability of MI system generally reduces for closely spaced crops. Finally, the conventional MI systems require pressurising devices to run. The MI systems become technically feasible under pressurised irrigation.

Analysis by Kumar et al. (2008b) shows that the crops which are amenable to MI irrigation India cover only 7.93 million ha from 15 major Indian states, and from this only 5.84 million ha is where the MI systems can make significant impact on water saving. The empirical basis for estimating this is: (1) the gross irrigated area under crops that are amenable to MI systems; (2) the percentage of net irrigated area under well irrigation in the respective states; and (3) basins where adoption of MI systems for crops would lead to real water saving by virtue of the geo-hydrology and climate.

Kumar et al. (2008b) analysed the impact of MI devices on aggregate water requirement for crop production in India. A total of six crops, for which country-level data on irrigated crop area are available (namely, sugarcane, cotton, castor, potato, groundnut and onion), were considered for estimating the future water-saving benefits of MI systems. The data on aggregate output from these crops were then obtained. Assuming that the same output for the respective crops is to be maintained in future, the future water requirement for growing the crops could be estimated by dividing the improved water use efficiency figures by the crop output.

The aggregate reduction in crop water requirement due to the adoption of drip systems was estimated to be 44.46 BCM. It can also be seen that highest water-saving could come from the use of drips in sugarcane, followed by cotton. This is the maximum area that can be covered under the crops listed in well-irrigated areas, provided all the constraints facing adoption are overcome through appropriate institutional and policy environments. What is important is that the estimated total water saving (44.46 BCM or 4.44 Million Hectare Metre (M ham)) is only 17% of the total water demand-supply gap (26.2 M ham) estimated for the year 2025. This figure would undergo upward revision as the area under high-value crops (fruits, vegetables and flowers) increases as a result of market pull.

As regards introduction of water-efficient crops (in terms of Rs/m^3 of water depleted), at the farm-level, replacement of traditional cereals (paddy and wheat) by water-efficient vegetables, fruits and cash crops would induce constraints from the perspective of farming system resilience, as raising these crops involves production and market risks, apart from being capital intensive (Kumar and van Dam 2013). In composite farming systems, dairying, which is dependent on crop by-products yield high water productivity (Amede et al. 2011) and replacement of cereals by fruits, vegetables and cash crops would affect dairy farming (Kumar and van Dam 2013).

At the regional level, attempts to adopt water-efficient crops or crop-dairy based farming to enhance agricultural water productivity might face several constraints from a socio-economic side. First, is the food security constraint (based on Amarasinghe et al. 2004; Ganesh-Kumar et al. 2007). However, this constraint would soon disappear with Madhya Pradesh emerging as a major supplier of cereals to the national grain bank.

Labour absorption capacity of irrigated agriculture and market prices of fruits are other considerations. Replacing paddy, which is highly labour intensive, by cash crops would mean reduction in farm employment opportunities. On the other hand, the labour and fodder scarcity would be constraints for intensive dairy farming to maximise farming system water productivity at the regional level, though some farmers might be able to adopt the system. Large-scale production of fruits might lead to price crashes on the market, and farmers losing revenue unless sufficient processing mechanisms are established. Hence, the number of farmers who can adopt such crops is extremely limited (Kumar and van Dam 2013).

11.7 Can Groundwater-Intensive Use Be the Panacea for Water Problems in India?

Myth: In future, India's irrigation will be entirely from groundwater, in lieu of the pathetic performance of public surface irrigation system, manifested by the zero growth in canal irrigated areas, despite the sector witnessing continued investments (Mukherji et al. 2013; Shah 2009). Though groundwater resources are over-exploited in some arid and semi-arid regions, these problems can be tackled through local recharge initiatives, and MI systems.

Reality: The crisis of the groundwater sector is far more serious than in the surface water sector. It is an institutional and governance crisis.

India faces the problem of excessive use of groundwater for agriculture in the semi-arid and arid regions, with many millions of small holders pumping groundwater through wells and pump sets (Kumar 2007; Kemper 2007). Groundwater overdraft problems are experienced in hard rock as well as alluvial areas (Anantha 2009; Narayanamoorthy 2015; Kumar 2007).

However, political economic considerations guided policies in the water and energy sector that had implications for sustainability of groundwater use for agriculture in rural areas. Farmers constituting a major share of the rural vote bank, the politicians' views are largely myopic. They consider measures such as raising power tariff and regulating energy supply in the farm sector as highly unpopular and suicidal, despite growing evidence to the effect that farmers prefer good quality power that is sensibly priced than free power, which is available over short duration (World Bank 2001). Instead, they prefer popular schemes such as 'small-scale rainwater harvesting' for villages, and frame policies and legislations to favour investment in such schemes.

The arguments that shaped public policies in the agricultural groundwater sector in India are: high density of farm wells in remote areas increases the transaction cost of metering and charging for electricity on pro rata basis, as a tool to control groundwater draft; groundwater economy is controlled by millions of small and marginal farmers, and that any attempts to regulate it would threaten their livelihoods and therefore are politically sensitive (Mukherji et al. 2012; Shah 2009); and, eastern Gangetic plains, which have abundant groundwater resources, can kick-start a second Green Revolution if electricity supply in the rural areas is improved and free power connections are offered to farmers, by intensifying groundwater use for irrigation (Mukherji et al. 2012).

The politicians and policymakers are also encouraged by some highly pervasive arguments from researchers such as: (a) free power and subsidised diesel benefit for poor small and marginal farmers who do not own wells, by lowering irrigation water charges in the market; (b) transaction cost of metering and introducing metered tariff would be so high that it, if passed on to the consumers in the form of an electricity tariff, would reduce the overall welfare benefits of groundwater irrigation, while substantially reducing farm incomes (Shah 2009); (c) raising the power tariff would adversely affect the poor water buyer farmers, by raising the selling price of water (Mukherji et al. 2012); (d) small water harvesting systems are cost effective, and improve water security in villages if built in large numbers, and have no negative social environmental effects (see for instance, Shah et al. 2009).

Large amounts of public funds are being pumped every year into integrated watershed management, dug well recharging, and community-based water harvesting in naturally water-scarce regions, without any hydrological considerations, and with no visible positive outcomes (Kumar 2007; Kumar et al. 2008b). However, there are no attempts to introduce market instruments such as electricity pricing or groundwater taxes or water rights.

Two decades of research in the groundwater sector also show that: (1) the regions with high well density do not experience intensive groundwater use; (2) the groundwater economy is mainly controlled by large farm; (3) in water abundant areas of eastern India, subsidised power does not reduce monopoly power of water-sellers (Kumar 2007); (4) in the eastern Gangetic plains, there is too little scope for raising cropping intensity from current levels through intensive groundwater use, as future growth in irrigation demand is unlikely owing to lack of uncultivated arable land, and free power connections will only benefit resource-rich diesel well owners, who sell water to the poor non-well owning farmers (Kumar et al. 2014); (5) in water-scarce regions, as the selling price of water reflects its scarcity value, increases in power tariff would have only marginal effect on the selling price of water (Kumar 2007); and (6) in semi-arid regions, raising farm power tariffs will not only result in improved efficiency, equity and sustainability in groundwater use, but will also be socio-economically viable (Kumar et al. 2013).

These studies further concluded that India would require strong institutions and instruments to check groundwater over-exploitation and to achieve greater equity of access to the resource and efficiency and sustainability of resource use. These can be in the form of water rights systems, and energy pricing and energy rationing, complemented by local institutional development for resource management, including monitoring of resource use (Kumar 2007; Kumar et al. 2013).

11.8 What Is Likely to Be the Future Trend in the Water Management Sector in India?

Even as the structure of Indian economy changes and per capita income rises, contrary to widespread belief, only a slight shift in the pattern of water use towards manufacturing and urban sector would be possible over the next few decades in India as per some projections (Alexandratos and Bruinsma 2012; Amarasinghe et al. 2008; Kumar 2010). This shift is not going to result in an aggregate reduction in water demand in agriculture, while urban and industrial water demands will grow manifold. On the other hand, with increasing remittance from cities and better access to knowledge and information through improved communication networks, the farm households might be able to invest more in agricultural technologies. This would be supported by the growing public expenditure in the farm sector, especially on subsidies for agricultural technologies that promote water use efficiency, crop protection and irrigation pump efficiency.

Keeping the foregoing analyses at the backdrop, the following are the mega trends that one would expect for India's water sector in the coming three to four decades, towards averting an impending water crisis and food shortage: (1) increasing state level regulation of water development in river basins; (2) greater number of inter-state water sharing agreements, and execution of large projects for transfer of water from water-rich basins to water-scarce basins; (3) large-scale adoption of micro–irrigation equipment, precision farming and plastics in agriculture for drastically improving water use efficiency, driven by the pressures of water scarcity and rising price of water; (4) adoption of new-age crop varieties—high yield seed varieties, salt-tolerant, and drought and flood resistant and GM crops; (5) greater regulation of groundwater over-draft through institutional development and application of market instruments; (6) large-scale investment in infrastructure and administration for demand management in urban areas, including leakage reduction, and water metering, pricing and rationing of water supplies; and (7) emergence of new institutional models for investment in wastewater treatment systems in cities. We will discuss these trends in the subsequent paragraphs.

With increased use of irrigation technologies, at the aggregate level, there would be reduction in demand for water in crop production (per unit area) as a result of improved water use efficiency. But, this is unlikely to result in water resource conservation and arresting of groundwater depletion in a majority of cases, as most regions that are likely to witness large-scale adoption of such technologies experience a relative scarcity of water when compared to land, with the result that the farmers would only expand the area under irrigation post-adoption, often called the 'rebound effect' of efficient irrigation technologies (Molle et al. 2004; Sanchis-Ibor et al. 2015).

Groundwater resources in India are already under severe stress due to abstraction exceeding utilisable groundwater recharge in most semi-arid and arid regions where it is the major source of water for irrigation and other uses (GOI 2012). The fact that the water-rich eastern India faces acute scarcity of arable land places additional pressure on land-rich regions to produce surplus for the former, while the latter have limited renewable groundwater resources. As regards surface water resources, in western and northwestern India and most basins of the South Indian peninsula (except Godavari basin), it is already over-appropriated, with some untapped potential in the central Indian basin of Narmada, which is considered in the ongoing plans.

The future development of water resources in India for irrigation expansion and other uses therefore cannot be driven by groundwater, but by surface water resources, mostly involving inter-basin water transfers. On the other hand, bringing about institutional reforms in the groundwater sector with the institution of water rights, and introduction of a resource fee and electricity pricing will be crucial for achieving sustainability, equity and efficiency in groundwater use.

These two steps would be crucial to enhance agricultural production, and to sustain the livelihoods of people in the rural areas of these regions. Gravity irrigation from surface schemes supported by large reservoirs is also essential to revitalise the over-exploited aquifers in these regions. The agreement is already signed between Uttar Pradesh and Madhya Pradesh for the Ken-Betwa link. Six links are under consideration from the Godavari river in Andhra Pradesh, to transfer water to Krishna and then to the Pennar basin areas.

Inter-basin water transfer is likely to gain prominence as it is one of the two strategic means for survival of the large cities located in the water-scarce regions (Mukherjee et al. 2010), the other being water demand management (Kumar et al. 2014). The situation appears grave when we consider that population growth in these large cities is far higher than in small towns (Kundu 2006). Apart from problems of quantity, many cities such as Chennai, Bangalore, Hyderabad, Pune, Bhopal, Delhi, Rajkot and Jaipur are facing acute shortage of good quality water for domestic and commercial uses. There are many Class I cities in south and western India with population in excess of 10 million, which are growing fast. The groundwater, which is used by residences and commercial establishments without treatment, to meet the deficit in public water supply, is heavily contaminated with minerals, and, in some cases, domestic and industrial effluent from cities and their outskirts. Hence, urban water utilities are left with no choice but to go for bulk transfer of surface water from water-rich areas.

While, in the past, measures to reduce urban water demand have been extremely limited. However, given the fact that new sources of supply are going to be highly expensive, there would be increasing efforts to go for technological solutions and institutional and policy interventions to achieve demand reduction, including leakage detection and reduction; metering and volumetric water pricing of water; and water rationing. Studies indicate that higher economic value would be realised through such transfers. But, such water transfers face social, political, financial, environmental, ecological, engineering and scientific issues (Kumar et al. 2008a), the most important being political in nature (Iyer 2008). The institutional regimes such as the inter-state water disputes tribunals are sufficient only for allocation of water of trans-boundary river basins.

But, as noted by Biswas et al. (2017), there are also several problems with the existing tribunal system for inter-state water allocation. First, there are no uniform, logical and common processes. They have considerable discretions in terms of processes to arrive at settlements as also underlying concepts under which settlements are made. Also, there were significant variations noticed in the fundamental assumptions used in working out allocations from one tribunal to other. Second, tribunal results are non-binding to the states. Third, the Central governments have been reluctant to establish institutions for implementing the awards. Fourth, there is no fixed timeframe for negotiations and adjudications (Biswas et al. 2017).

For inter-basin water transfers to become a reality, the current legal regime with regard to utilisation of water resources within the administrative jurisdiction of states, which have abundant water resources, will have to change for them to be under the purview of national laws. This can only enable speedy decisions for development and utilisation of these water resources. However, with the growing realisation that the water-rich regions will not be able to achieve food self-sufficiency with the arable land, ecosystem and production technologies at their disposal, political consensus is likely to emerge in future between potential ‘donor states’ and ‘receiving states’ on sharing of water. We can also expect greater application of economic principles in water management in future.

Here, the amount of water transferred by the donor states, and the amount of water required for producing one unit weight of food can be used as the basis for deciding the amount of cereals to be supplied to the ‘donor’ states, which are currently food insecure, by those which receive the water (Kumar and Singh 2005). The economic value of the water that presently comes free under ‘inter-basin water transfers’ can be used to decide on those subsidies at which cereals should be offered to the donor states. The initiative of the Union government to formulate a National Framework Law on water, particularly to address inter-state water disputes, would help address the concerns relating to inter-basin water transfers.

The riparian states of major basins, which have been on a war-path over sharing of water, are now showing increasing signs of willingness to have mutual dialogue to arrive at agreements on sharing of water and benefits of basin development, with the latest example of Telangana and Maharashtra signing an agreement over sharing of water from the Godavari basin.

Large-scale transfer of water to the cities would increase the volume of wastewater generated from those cities. The future would witness stronger institutional regimes in the form of regulations and a water pollution tax for improved water quality management in rivers, along with the creation of new institutions to build transparency, accountability and incentive among various line agencies involved in management of water supply to various sectors. Therefore, unlike in the past the urban water utilities would be under enormous pressure to treat the wastewater they generate, and put the water purchased through bulk water purchase agreements to use more efficiently.

The fact is that the water losses in distribution systems are very high in many cities that are spread over large areas; sewage collection is poor and separate systems for collection of stormwater and sewage do not exist in many cities (Kumar 2014b). Hence, in coming years, there would be enormous investment by urban water utilities in: (1) improving urban water supply infrastructure to reduce leakages, through replacement of old distribution systems; and (2) increasing the density of stormwater and sewage collection networks to improve urban drainage and improve the collection of wastewater, respectively.

While growing economic power would enable large cities to invest in improved water infrastructure (water distribution systems, drainage networks and sewerage system) and wastewater treatment technologies, it is quite likely that the treated water would end up in the peri-urban areas for producing fruits, vegetables, flowers and forage crops, on a much larger scale than what is happening today around many cities. Most of the farm produce, which comes from these areas ends up in the nearest cities for urban consumers. In Delhi and Kanpur, the municipal corporations are supplying treated wastewater to farmers in peri-urban areas at a fee (Amerasinghe et al. 2013). With greater willingness on the part farmers in naturally water-scarce regions pay for treated wastewater for irrigating these high-value crops, financially viable models in wastewater treatment and reuse would emerge in the future.

Hence, the future is likely to see public-private partnership for investment in wastewater treatment. Emergence of new institutional models in tandem with the greater willingness on the part of the urban population to pay for environmental management services are likely, with the result that the water utilities would be able to levy sewage treatment charges. This, in turn, can be diverted for building wastewater treatment systems. With skyrocketing of real estate prices in urban areas, the construction industry is also likely to invest in such systems even without the help of financing models, as this would help increase the market value of land in the peri-urban areas through reclamation of land degraded by wastewater reuse and a better living environment.

India's water bureaucracy's fascination for small water harvesting and watershed development seems to have already died out, with growing evidence to the effect that, in most instances, construction of water harvesting structures causes negative impact on overall water balance, in the form of reduced inflows into downstream tanks, lakes and reservoirs. While in the initial years, the irrigation/water resources department went against building water harvesting systems in the upper catchment of the reservoirs maintained by them, more recently, farmers, especially those who are dependent on tanks for irrigation, have started raising concerns about indiscriminate building of such structures. The increasing pressure from India's growing tax-paying middle class to invest in permanent water infrastructure is another compelling reason for this change in mindset. The future would also witness some sort of regulatory framework emerging with regard to water resources development in river basins/catchments.

However, to realise the goal of building large water infrastructure, Indian water administration will be forced to make investments in building a cadre of highly talented water sector professionals, to plan, design, execute and run the sophisticated water and wastewater treatment systems. This is going to be an enormous task, as over the past couple of decades, Indian water administration at both state and central levels had witnessed continuous loss of the 'talent pool' as people with vast knowledge, experience and collective memory retired from services and were not substituted by the induction of young professionals. Failing to achieve this task would create a situation wherein the governments and quasi-governmental agencies would be increasingly forced to outsource most of the work related to investigation, planning, design and management of water resources projects, to agencies in the private sector.

On the other hand, India would witness large-scale adoption of MI systems and other water saving practices like mulching for almost all the irrigated crops, barring a few, in the arid and semi-arid water-scarce regions, which are also agriculturally prosperous. On the one hand, the adoption would be boosted by the increasing preference of farmers for high value fruits, vegetables and flowers, driven by growth in demand triggered by growing urbanisation, increasing per capita income, and improved transportation facilities. On the other hand, it would be driven by social pressures to make agriculture more water efficient. Adoption of new-age crop varieties would contribute to this trend. This would help boost crop yields and improve water productivity in hot arid and semi-arid areas, but would be unlikely to save significant amounts of water from agriculture, owing to the fact that the scarcity of water is more acute than that of land in these regions, and farmers would eventually expand the area under irrigation. Sprinkler systems would account for a large proportion of the area under MI, and this trend would be part of agricultural mechanisation owing to reducing numbers of younger people in the agricultural workforce and rising farm wage rates. The phenomenon will have less to do with irrigation water scarcity. This likely increase in area under sprinkler irrigation systems is unlikely to result in saving of water even at the field level, as there would be no significant reduction in non-beneficial consumptive use and non-recoverable non-consumptive use for field crops.

Rural areas in the agriculturally prosperous, water scarce regions would require an enormous amount of talent for design, assembly, installation and maintenance of MI systems, other water saving technologies such as mulching and precision farming system, and marketing of new-age seed varieties, including that of GM crops. The increased demand for talented people, on the one hand, and the growing ability among farmers to pay for such services, would attract skilled manpower to rural areas.

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