FOOD SECURITY AND SUSTAINABLE AGRICULTURE IN INDIA: THE WATER MANAGEMENT CHALLENGE

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ABSTRACT

Managing water for securing food security means needs a multi-pronged approach. At the aggregate level the irrigation water supplies and the demand for irrigation need to be balanced. This offers two challenges: of water supply management and inter-sectoral water allocation. At the next level, greater equity needs to be ensured in accessing and controlling water from aquifers and public systems. At the third level, farmers should maximize production from available land and water resources with least environmental consequences such as land degradation and groundwater depletion, through efficient resource use. The existing water resource development technologies have great bias towards the rich. In water abundant regions such as Bihar and Orissa, the poor still depend on water purchased at prohibitive prices for irrigation. In this paper, the author shows that under the current pricing system for electricity in farm sector, the conventional water saving technologies favours the rich with greater opportunities.

The author argues that emerging technologies such as treadle pumps, can not only change the trajectory of water resource development, but also increase the ability of the poor in water rich regions to invest in irrigation, boost productivity and production and secure food security. Micro irrigation technologies can greatly enhance the ability of the poor to maximise production from limited water supplies they would have access to. Integrated land and water management practices such as organic farming, agronomical practices would be key to enhancing land and water use productivity on a sustainable basis; but small and marginal holders would face severe constraints in adopting them. Subsidies are needed for poor farmers to adopt technologies that would reduce their dependence on biomass, increase biomass use efficiencies, and invest in integrated land and water management techniques to improve land and water use productivity.

Allocation of tradable private property rights in water will lead to overall enhancement in the economic efficiency of water use and higher productivity in agriculture. Enforcement of tradable private property rights will ensure equitable access to water in water scarce regions, for agriculture and also across classes. This is critical from the point of view of local and domestic food security. Where as in water abundant regions, it can also provide the landless farmers with sufficient incentives to invest in development and transfer water to high valued uses elsewhere, and generate income. Volumetric pricing of water from public canals and unit pricing of electricity in the farm sector with carefully designed structures, along with properly enforced water rights, can not only improve the physical efficiencies of water use in agriculture, but also provide the rich and poor farmers with equal opportunities for income earning from farming.

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1 INTRODUCTION

Though the world has been changing remarkably over the past 25 years, food security still remains an unfulfilled dream for more than 800 million people living in the developing countries (Leisinger 2000). But the fact that the number of undernourished people has come down from the 1971 figure of 890 million, and that there has been an addition of 1.5 billion people to the population since 1971 show remarkable achievements in food security (FAO 1996 as cited in Leisinger 2000).

In Asia, where nearly 73% of the population of the less developed world live (source: World Population Data Sheet 1996, as cited in Leisinger 2000), the number of undernourished people reduced from 701 in 1969-71 to 512 in 1990-92. What is more notable is that the percentage of undernourished people in the region has fallen dramatically from 37 to 16 (based on FAO 1996), while the region's population is growing at a rate of 2% per annum.

India wants to be self-sufficient in food and "food secured". Therefore, it is imperative for national food security that we need to grow sufficient food within the country. At the same time, for domestic food security, we need to sustain economic growth to raise the income levels and purchasing power of the poor people. These apart, agricultural regulations, through fixation of foodgrain procurement prices, regulation of consumer prices and public distribution, have an important role to play in ensuring food security at the domestic level, even if self sufficiency is achieved in food grain at the national level (Banik 1997; Goyal 2002). Governments intervene and control a large proportion of the marketed food supply in order to safeguard the farmers against low and unpredictable price for produce. But, often inefficient pricing leads to undesirable consequences on access to food supplies. However, this dimension of food security problem is beyond the scope of the paper (Banik 1997).

Irrigation has contributed significantly to boosting India's food production and creating grain surpluses, which is used as drought buffer. On the other hand, agriculture remains as the backbone of India's economic growth, in spite of the major structural changes that the economy is undergoing. Though differences of view exist over the impact of economic growth on poverty among scholars (see Janaiah *et al*. 2000), several studies in the past have indicated that agricultural growth, especially growth in food grain production negatively impacts on rural poverty (Ahluwalia 1978; Hazzle and Haggblade 1991; Rao 1994; Ghosh, 1996; Desai and Namboodri, 1998). After Ravallion (1998) and Dev and Ajit (1998), rural poverty has correlated with relative food prices, which is affected by fluctuations in food supply (Ravallion 1998; Dev and Ajit 1998).

Recent studies also show that in the 1990s, there was no change in rural poverty ratio, while urban poverty reduced by 10% as compared to 1980s. This coincided with the period, which recorded stagnation in growth of primary sector, especially the agricultural sector, at 3.2-3.4 per cent. The growth rate in production of food grains also dropped to 1.2 per cent during the 1990s from 2.3 per cent in the 80s (Datt 1999). All these lead to the unquestionable role that irrigation can play in stabilising food prices, and alleviating rural poverty, provided effective institutional interventions are in place. The growing need to manage water for agriculture in developing countries such as India has been muted by several researchers due to its ability to reduce the incidence of poverty, and achieving food sufficiency (for instance see Chaturvedi 2000).

Owning to the fact that the net area under cultivation and also area under food grains remains more or less saturated at the macro level (India's Planning Experience, Planning Commission, GOI 2002), irrigation is key to enhancing agricultural production. This leads us to the point that irrigation is the key to sustaining economic growth. The rural population (nearly 70%) depends on agriculture for subsistence and employment. Irrigated agriculture remains the largest absorber of rural labour force, and therefore impacts on the livelihoods of millions of rural households, while its impact on farmer households is more direct. Expansion in irrigation will be the key to sustaining the past growth in agricultural production and ensuring food security, at the national, regional and domestic levels. But, farming practices that involve intensive use of irrigation and land cause degradation of land and water resources. This, in turn, can threaten long-term sustainability of irrigated agriculture itself.

In order to ensure food security on a sustainable basis, three concerns need to be addressed. They are: adequate supplies of irrigation water to sustain the growth in agricultural production at the national level; water security for poor farmers to grow food for subsistence; and adequate economic incentives for farmers to maximise their production from the available land and water with least environmental consequences.

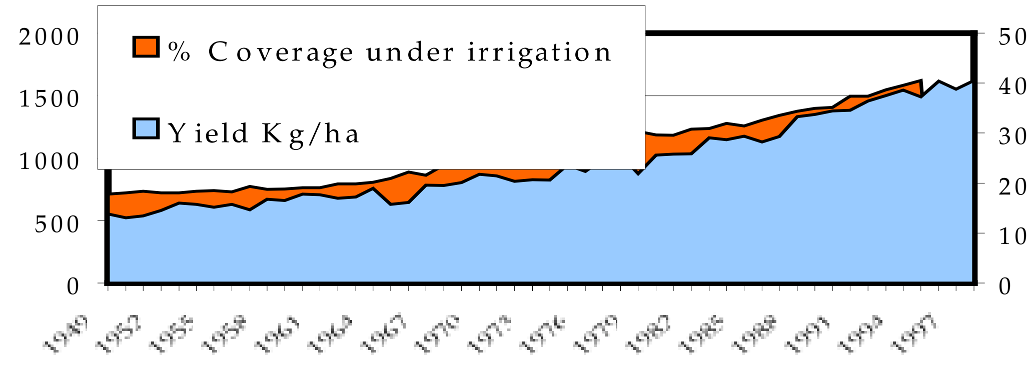
In India, lion's share of diverted water is used for irrigation (Xie *et al*. 1993; WRI 1996; GOI 1999). The capacity to augment the existing irrigation potential, through conventional technologies, is fast reaching the limits (Kumar 2001). The irrigated areas, especially command areas of surface irrigation schemes, are increasingly facing the threat of land degradation and productivity decline On the other hand, the demand of water from sectors, namely, urban domestic use, and industrial use, is growing leaps and bounds. This coupled with widening gap between overall demand and supplies would severely limit water availability for producing food for the growing population. On the other hand, the poor small and marginal farmers face several constraints in adopting agricultural technologies and agronomic practices, which are needed to maximise productivity of land and water. Shortage of biomass limits the ability of farmers to adopt organic farming practices that are more sustainable. These are some of the major concerns in the area of sustainable agriculture production and food security.

2 WATER, AGRICULTURE PRODUCTION AND ECONOMIC GROWTH

Since Independence, India has made substantial progress on the economic front with the per capita net national product recording a compounded growth rate of 1.7 percent (Datta 1997). Contribution of agricultural production to this progress in GDP growth during this period has been quite phenomenal, as its value grew 3.2 times in real terms (TERI 1998). Irrigation has been the key to enhancing grain production, and ensuring food security at the national level, with 2/3rd of the agriculture production comes from irrigated areas. The following figures illustrate this.

First: the growth in TFP contributed significantly to growth in crop outputs in India, i.e., 1.1 to 1.3 per cent per annum, while conventional inputs such as irrigation, fertilizers contributed 1.1 per cent. Irrigation investments also generated TFP growth apart from the output growth it makes as a conventional input through providing improved environment for crop technologies (Evenson et al. 1999). *Second*: the food grain production in the country saw a commendable growth from 50.8 million tonnes in 1950-51 to 203.04 million tonnes in 1998-99 (source: Indian Planning Experience, Planning Commission, GOI). The contribution of yield enhancements (average yield increased from 522 to 1620 kg/ha), which was the result of introduction of green revolution technologies and irrigation, to this growth, was more than the growth in cropped area (Evenson *et al*. 1999). Figure 1 shows that food grain yields increased almost consistently with percentage area under irrigation from 1949-50 to 1998-99.

Figure 1: Growth in area under food grains, yield, and production



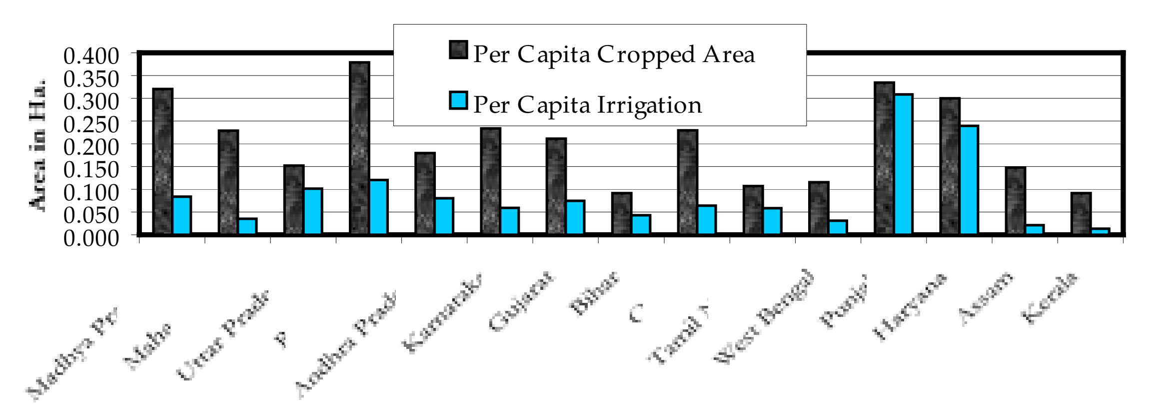
A large chunk of the growth in agricultural production in the country since Independence has come from the northern region, mainly Punjab, Haryana and Western UP, which reaped the benefits of Green Revolution rather fast (source: Table 21, Evenson *et al*. 1999). They achieved it by enhancing the use of conventional inputs such as irrigation and fertilizers, and by improving the total factor productivity through the adoption of new crop technologies. There has been significant expansion in irrigated agriculture in the region. Similarly, the annual growth in total factor productivity (TFP) during the period from 1956 to 1987 was 1.40% for northern region comprising Haryana, Punjab and UP, against a national average of 1.13% (Evenson *et al*. 1999).

The growth rate in TFP is lowest for eastern region comprising Bihar, Orissa and West Bengal (0.75). Further, it has declined over three decades (1956-87) from 1.5 during 1956-65 to 0.70 during 1977-87 (Evenson *et al*. 1999). The grain yields are lowest in Bihar (source: Water and Related Statistics, CWC MOWR, July 1998 as cited in Table 3.21 of GOG 1999). There are many reasons for the low agricultural productivity in this region. First is low level of use of cultivation and irrigation. Irrigation, when compared with population size, is poorest in states like Bihar and Orissa as compared to states like Punjab and Haryana. In order to capture the population factor, the per capita cropped area and irrigated area were estimated. While the per capita irrigated area is 0.31 ha for Punjab, 0.24 ha for Haryana, 0.12 ha for Rajasthan and 0.10 ha for UP, it is only 0.043 ha for Bihar. Though there are some states, which have much lower per capita irrigated area such as Maharashtra and West Bengal, situation is Bihar is noteworthy because of the lowest per capita cropped area (0.092 ha) amongst all the twelve states selected. The other states having very low per capita irrigated area have high per capita cropped area (Source: author's own calculations based on agricultural census data (1998-99) and population census data 2001). The constraints imposed by low per capita cropped area and irrigation are compounded by low yield levels.

This means low levels of farm surpluses, due to which the farmers are not able to invest in irrigation sources, expand irrigation, increase cropping intensities and enhance crop yields, thereby pushing agricultural growth. Though irrigation potential of groundwater is very high, the pace at which development of groundwater resources takes place in the region is extremely low. The stage of development of groundwater in (erstwhile) Bihar, expressed as a ratio of the gross draft and the replenishable groundwater resources, is only 23.3% (GOI 1999: pp16). Poor irrigation also influences the level of use of inputs such as fertilizers, pesticides and hybrid variety of crops are some of the reasons adversely, resulting in low TFP.

Agricultural growth will be critical to reducing the region's high rates of unemployment and poverty and improving food security. Socio-economic deprivation is an important constraint in investing for irrigation development and increasing input use for maximizing agricultural outputs in regions falling in the water abundant Indo-Gangetic plains such as eastern UP, Bihar, and West Bengal (Shah 2000). The average, per capita income (indicated by the per capita consumption expenditure) in the states such as Bihar and UP are far below the national average (GOI 2002: pp35). The resource poor, small and marginal farmers in the region, instead, prefer buying water from well owners, at prohibitive prices to irrigate crops (Ballabh and Chaudhary 2002), though it makes least economic sense for them.

Figure 2: Per Capita Cropping and Irrigation in Different States



Having said that, I would like to add lack of financial resources available with the state or the National government to invest in the water resource development sector as a third challenge in fuelling the engines of economic growth. For instance, inter-basin transfer of water from water abundant river basins to the water scarce ones could help augment the country's water supply potential in the order of 200-250 BCM (Chaturvedi 1999). However, this would cost to the tune of 20-25 billion dollars. Availability of finance is going to be a major stumbling block in opting for such projects.

After Chaturvedi (2000), poor endowment of natural resources and environmental degradation are going to pose major challenges to sustainable economic growth in developing countries including India. Let us examine how far this argument is valid for India. First of all, the per capita availability of renewable fresh water in India, which is an important input for economic growth, is far less than many of the developed countries in the world (Glieck 1997). For instance, the per capita annual water resources (AWR) of India (2085 m^3) is less than $1/4^{th}$ of USA (8520 m^3), and only 2.2% of that of Canada, but more or less close to that of China and slightly less than that of Pakistan (Source: AWR figures are obtained from World Resource Institute (1996). The author's own calculation based on estimated population for the year 2000, using base population of 1995 obtained from WR T8.1 and annual growth figures of 1990-1995 as provided in WR T8.1).

Secondly, there are increasing evidences of environmental degradation from across the country. In spite of the increasing public consciousness, degradation is likely to continue, though at a slightly slower pace. This is because an important cause for environmental degradation is the poor efficiency of use of natural resources for economic production purposes. Poor efficiency of resource use is mainly due to the lack of economic power to invest in conservation technologies, which is a characteristic feature of developing countries like India. The per capita GNP of India is just $1/30^{th}$ of a developed country like the US. Poor economic conditions are likely to cause major hindrances to India's ability to make large-scale investments in resource conservation for many years to come.

While the demand for environmental resources such as water, land and biomass, and rate of environmental degradation in a cumulative sense are increasing (manifested by land salinization, groundwater pollution due to excessive leaching of fertilisers residues, pollution of surface water due to poor or lack of treatment of trade effluents disposed into natural water courses) due to the gradual rise in average income levels, the per capita income levels[2], the income levels are still not high enough for people to invest heavily in environmental management. This is compounded by the problem of increasing income disparity between those who are the richest and the poorest. Though the inequality in income distribution has declined over the past nearly 20 years[3], it is still very significant.

2.1 Water Scarcity and Its Implications for Agriculture and Food Security

Many researchers have argued that increasing water shortage would be a major challenge to achieving global food security (for example, see Leisinger 2000). Since Independence, there has been a remarkable increase in water supplies for irrigation, rendered through building of large and medium reservoir & diversion schemes, and rapid and widespread exploitation of groundwater. According to the Central Water Commission, Ministry of Water Resources, for 1993-94, irrigation contributed 52 per cent of the food grain production in the country (source: CWC, MOWR, July 1998 as cited in Table 3.21 of GOI 1999). But, most of the major schemes for irrigation had been planned and implemented much before major advancements in hydro sciences were made in the world. As a consequence, the efficiency of utilisation of water for irrigation has been extremely low in the country, like many other developing countries (Chaturvedi 2000).

Further, the approach to planning, development and management of water resources has been, by and large, centralised, sectoral and segmented. This approach has not only led to unsustainable development of water resources, but also caused several negative social, economic and environmental problems (Kumar and Ballabh, 2000; World Bank/GOI 1998). As a matter of fact, Sandra Postel argues that most of the environmental problems associated with large water resource development project are the result of poor water resource development and management, and not inherent in irrigation (Postel 1999). So far as adding to the existing capacity is concerned, the potential is fast reaching the limits. The reasons are many: viable sites for building new reservoirs are almost absent; the social and environmental costs of surface water resource development projects are prohibitively high; the storage of existing reservoirs is dwindling; and groundwater resources are showing increasing signs of depletion (Kumar and Ballabh 2000).

On the other hand, demand of water for agriculture is growing due to increasing food grain needs of the growing population, and the growing preference for growing water intensive cash crops. In the urban and industrial sectors, the growth is rather rapid, owing to the faster growth in urban population and rapid industrialisation. As water becomes scarce, the financial and environmental cost of its use

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2 The per capita income levels as captured by the monthly per capita consumption expenditure have increased significantly during 1983 to 1999-2000 from Rs. 78.90 to Rs. 98.50 in rural areas and Rs. 111 to Rs. 143.5 (National Human Development Report, Government of India 2001).

3 Inequality in distribution of income –as indicated by the consumption expenditure--has declined from 0.298 in 1983 to 1999-2000 (National Human Development Report, Government of India 2001).

increases enormously. However, demand management, the key to minimising the environmental stresses caused by water scarcity, has not received adequate attention.

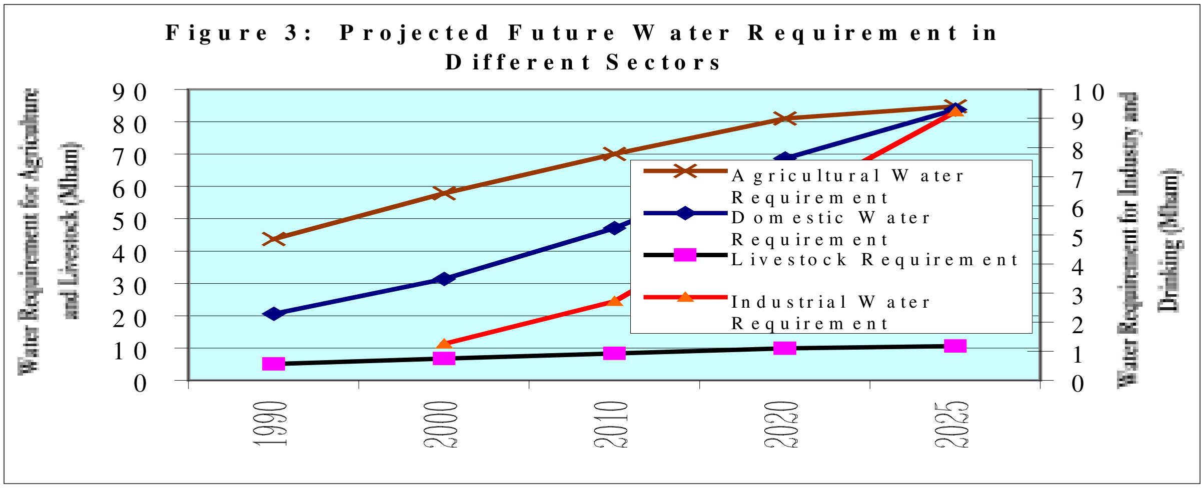
Several researchers and agencies have made projections of the future demand for water in India from all the four competitive use sectors, viz. agriculture, industry, domestic use and livestock drinking for the year 2025 (for eg., Seckler *et al*. (1998), GOI 1999; Ballabh *et al*. (1999) and Kumar (2001)). The estimates by Ballabh *et al*. (1999) and Kumar (2001) involve concerns of national food security and agricultural growth concerns. In their projections, the drivers of change are population growth, growth in per capita income levels, growth in industrial production and the change in food consumption levels. I would here use my own estimates (Kumar 2001) as the basis for further discussion on the emerging water scenario in India.

The estimates showed that the total water requirement for human and animal uses, industrial production and irrigated agriculture would be 104.50M ha m in the year 2025. As per the estimates, agriculture would continue to be the major user of water in the year 2025 with 81.13 per cent. The domestic water requirement is expected to grow from 4.70 per cent in 1990 to 8.9 per cent in 2025 and industrial water requirement from a mere 2 per cent in 2000 to 8.83 per cent in 2025 (Figure 2) (Source: Kumar, 2001). The total water utilisation potential in 2025 was estimated as 78.3M ha m, with an annual growth of 0.74M ham. The estimates involved three important considerations: [1] the past growth trends in water development; and [2] the growing public concerns about the social and environmental costs of water development projects.

Comparison of water requirement and utilisable supplies showed that, by the year 2025, the magnitude of scarcity would be 26.20M ham. In that case, there will be greater competition between various sectors for the scarce water. In the absence of proper legal and institutional regimes under which water rights can be allocated among the competing, rights will be politically contested, leading to conflicts. Let us have a closer look at the emerging scenario.

The urban water utilities are largely dependent on rural water resources for the supplies. Urban areas being economically and politically powerful (Banik 2000), it is very likely that they manage the huge additional supplies required from the rural areas. This can have major implications for irrigated agriculture, especially for the economically weaker groups. Already conflicts exist over diversion of water from irrigation reservoirs to urban areas for drinking in the water scarce regions of Gujarat, Rajasthan and Maharashtra. Growing industrial water use can also come into conflict with irrigation. With the enormous increase in the financial and environmental costs of water use, in future, there will be greater pressure to reallocate the available water for the more efficient industrial uses. Over and above, the current political economy of growth based on industrialization and urbanization encourages re-allocation of available water in favour of industries and urban areas. This will deprive the people in the rural areas of the precious water needed to meet food production requirements.

Another major source of threat to agriculture is pollution. Very few industries and municipal areas treat their effluents to safe levels. They use natural water bodies such as rivers and lakes as “sink” for



untreated and partially treated effluents. This deprives the communities living in those areas of the water for agriculture and domestic purpose. As industrial and municipal water use goes up, the effluent load also increases, thereby the magnitude of the threat. Therefore, at the macro level, there are major threats to food security posed by growing water scarcity and pollution. The problems will be acute in the semi arid Gujarat, Rajasthan, Tamil Nadu and Maharashtra, which experience ever-increasing demand for water from all sectors.

Apart from the lack of availability of sufficient water for agriculture, two important concerns, which have implications for food security are: [1] how much of the irrigation water is allocated or used for producing food grains; and [2] the efficiency of use of irrigation water in growing food crops. The first concern originates from the fact that with shrinking water availability in both physical and economic sense, the rich farmers would allocate larger share of their land to crops that yield higher cash returns per every piece, but are capital-intensive such as cash crops, horticultural crops and floriculture.

The best example is north Gujarat region. With the rising cost of pumping groundwater, and with limited access to irrigation water owing to the regulated power supply and shared pumping hours, the farmers of north Gujarat region have made major crop shifts. They are now growing cash crops such as castor, cotton and mustard and fodder crops, while they earlier used to grow more of food crops such as wheat, bajra and jowar. The farmers who purchase irrigation water are now allocating a significant share of the irrigation water for growing fodder as a survival strategy, as only dairying is viable. Such patterns of changes are likely to adversely affect the prospects for movement of grain surpluses from rural areas to urban areas. Further, given the differences in consumption pattern between rich and the poor, the dairy products and fruits are likely to feed the rich, especially those in urban areas. Decline in production of food crops would push up the grain prices in the local markets, resulting in problems of food security for the rural masses.

Another example is Chennai. With increasing groundwater scarcity and farming increasingly becoming un-viable, farmers in the region surrounding Chennai had started diverting water for urban uses, where in they could fetch a price of up to Rs.50 per cubic metre of water.

The second concern stems from the fact that productivity of irrigation is very poor in India. India diverted or used 569 m^3 of water per capita for irrigation in 1990, while China used only 401 m^3 of irrigation water per capita. The figures are far higher for countries USA (see Table 1). At the same time, the per capita cereal production achieved in the country was only 221 kg, against 328 kg for China. The per capita irrigation withdrawal figures are far lower for Canada, while it produces 1674 kg of cereals per capita. The net result the cereal production per unit volume of irrigation water used is second lowest for India, after Pakistan amongst the five countries.

Table 1: Irrigation Withdrawals and Cereal Production in Five Countries including India

Name of Country	Withdrawal of irrigation water per capita (m^3)/year	Irrigation withdrawal on Crop Land	Irrigation Withdrawal on NIA (m)	Irrigation Withdrawa l on GIA (m)	Average Per Capita Cereal production (Kg)	Cereal per m^3 of Irrigation Water (Kg)
India	569	0.31	1.07	0.74	221	0.39
USA	785	0.11	0.94	0.58	1227	1.56
Canada	192	0.01	0.74	0.74	1674	8.72
China	401	0.51	0.97	0.53	328	0.82
Pakistan	1226	0.81	0.88		162	0.13

Note on Table 2: The irrigation water withdrawal per cropland was estimated using, the figures of per capita cropland (Table 4 of Chaturvedi 2000) and per capita irrigation water withdrawals (Seckler et al. 1998). The figures of cereal production per cubic metre of irrigation water used were estimated by using per capita cereal production figures (Table 4 of Chaturvedi 2000) and per capita irrigation water use figures (Seckler et al. 1998). The irrigation water withdrawal figures for USA, Canada and Pakistan were estimated using per capita irrigation water withdrawal provided for that country in Seckler et al. 1998 and the population figures of those countries for the year 1990.

While China produces 0.82 kg of cereal for every cubic metre of water used in irrigation, India produces only less than half. The difference cannot be simply attributed to differential productivity in irrigated agriculture through scientific planning of water use alone. There could be many reasons for higher cereal production in the case of China such as increased allocation of available irrigation water to growing food grains, and higher crop production from rain fed areas. But, given the fact that the cropland is much less in China as compared to India (95.98 M ha against 169 M ha), "higher production from rain fed areas" can happen only if the rain fed yield in China is significantly higher, and can therefore be ruled out. Therefore, if we assume that water allocation pattern remains same for both the countries, the higher cereal production comes from better water use planning. What is done in the China is to spread the available irrigation water in larger area, and to use for irrigating different seasons. As a matter of fact, the gross irrigated area in China is much higher than India, and the irrigation water diversion on gross irrigated area is 0.53 for China against 0.74 for India.

- Therefore, in sum, China seems to be tackling its food security problems through better planning of water use in irrigation, in spite of the lesser availability of irrigation water, while India manages to produce much less with higher level of use of irrigation water

2.2 Water Resource Degradation Problems and Impacts on Food Security

2.2.1 Groundwater Depletion and Its Impact on Food Security

Groundwater accounts for more than 50 per cent of the net irrigated area, and nearly 80 per cent of the agriculture production from irrigated areas in the country. Its contribution to the nation's food basket is quite major. Over and above, groundwater is a de-centralised and democratic resource. This is unlike canal irrigation, where in investment is mainly from the State, and access is restricted by topographic constraints. By virtue of this unique characteristic of groundwater, its contribution to local food security is great. In arid and semi-arid areas, the increased demand for water for agriculture and other uses is being met by excessive withdrawal of groundwater leading to its depletion and quality deterioration. Table 2 provides the figures of number of over-exploited talukas/blocks/mandals/watersheds[4] in eight states, which experience problems of excessive withdrawal as on 1995.

Table 2: Groundwater Over-exploited Blocks in India

Name of State	Total Number of Blocks	Number of Over-exploited Blocks	Overall Status of Groundwater Development (%)
Punjab	118	62	94
Haryana	108	45	84
Rajasthan	236	45	51
Tamil Nadu	384	54	61
Gujarat	218	14	42
Karnataka	175	06	31
Uttar Pradesh	895	19	38
Andhra Pradesh	309	02	24
Total	2722	247	

Source: Ground Water Resources of India, CGWB, 1995.

Problems of groundwater depletion are encountered in both alluvial areas and hard rock areas. Examples are alluvial areas of Punjab, Haryana, and Gujarat mainland, and hard rock areas of Tamil Nadu, Karnataka and Saurashtra region of Gujarat. As shown by the table, the extent and degree of over-development is most severe in Punjab, with nearly 53% of the talukas affected by over-exploitation, and the overall stage of development touching 94%. In view of the fact that several blocks in Punjab are facing the problems of rising groundwater levels[5] and water logging, the degree of over-draft would be very high in the areas of over-exploitation[6]. With secular decline in water levels, shallow wells dry up. As the investment for drilling tube wells reaches astronomical heights, the poor farmers lose out in the race of chasing water table. They are either forced to purchase water from the rich well owners at prohibitive prices or shift to rain-fed farming practices. For instance, the

4 Mandal is the unit for assessment of groundwater development in Andhra Pradesh, while watershed is the unit in Maharashtra, it is Taluka in Gujarat, and block in other states.

5 The total area, which experienced rises in water levels during 1979-99, is 13,903 sq. km, i.e., 27.6% of the geographical area. Of these, in a total of 5628 sq. km area, the rise in water level is above 5m during the 20-year period (source: Gulati 2002, Table VIII).

6 During the period from 1979-99, nearly 31% of the area of Punjab experienced a water level drop in the range of 0-3m, 21% in the range of 3-5 m, 20.1% in the range of 5-10m, and 0.21% above 10m (Gulati 2002).

tube well owners of Mehsana in north Gujarat charge as high as Rs.70- Rs.100 for an hour of irrigation service. In the first case, the economics of farming itself is adversely affected due to the rise in cost of production, affecting the livelihood security.

In the second case, crops become highly vulnerable to vagaries of monsoon with very high incidence of failure during droughts. High inter-annual variability in rainfall, and frequent droughts are characteristic features of this low-medium rainfall region (IRMA/UNICEF 2001; Kumar 2002b). As a result, agriculture and rural economy become more and more vulnerable to droughts. The rich farmers are able to sustain tube well irrigation because of the flat rate mode of pricing electricity. Under the flat rate system, since the marginal cost of pumping is zero, the well-owning farmers can pump out excess water and provide irrigation services to the neighbouring farmers. By doing this, they can even earn profits, after recovering the high capital investment for well construction, and the high fixed operating costs.

Again, when groundwater resources deplete and the cost of well construction and pumping increases, the system of trading water provides greater economic opportunities to well owners having large holdings, and lesser opportunities to well owners having smaller holdings and water buyers. This is due to the fact that for a large farmer, the implicit unit cost of water is much lower as compared to small farmers. At the same time, a small farmer will not be able to raise the water charges to match with the implicit cost of pumping, as the prices are determined by the market forces (Kumar *et al*., 2001).

Recent analysis has shown that in deep tube well areas, if the State Electricity Boards start charging the full cost of electricity for pumping, irrigated production of many crops would be un-viable (IRMA/UNICEF 2001). This means that from a larger societal point of view, groundwater irrigation in such situations does not contribute to economic growth. On the other hand, it also has negative ecological impacts.

In the case of hard rock areas, one of the immediate consequences of over-development has been the increase in incidence of well failures. In such cases, the farmers are forced to deepen their wells or dig new wells, to sustain access to irrigation water. Here as well, the poor farmers, who do not have sufficient resources, lose out in the race. This has led to widespread emergence of groundwater markets. As hard rock areas have limited groundwater potential, water markets become monopolistic in nature (Janakarajan 2002). Gradually, irrigated farming itself becomes un-viable for water buyers.

As groundwater contributes 1/3rd of the agricultural GDP, it is a truism that depletion will have long-term impacts on the country's economic growth. But, recent evidences suggest that the impacts will be visible in the short term rather. Severe problems of groundwater depletion are mainly being experienced in hard rock regions of India[7], which cover 2/3rd of India's geographical area. These hard rock areas have very poor groundwater storage. Most of this is concentrated in the upper weathered zones. Excessive withdrawal leads to lowering of water levels and drying up of groundwater in the weathered zone. This also seems to cause reductions in the natural recharge occurring from annual rainfall. The farmers in these regions are forced to drill bore wells to chase the water, which move towards the deeper formations and get trapped in the cracks and fissures. Changing from large open wells to bore wells significantly reduce the ability to extract this renewable portion of groundwater.

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[7] Exceptions are the alluvial areas of north Gujarat and Punjab.

The net result will be sudden, sharp and permanent reductions in the irrigation potential. However, this is not going to be compensated by a growth in well irrigation from the areas with under-utilized potential such as Chhattisgarh, Orissa and Madhya Pradesh. There are two key reasons: the demand (economic) for groundwater for irrigation is extremely poor due to a dominance of farmers with extremely poor economic conditions, and low irrigation requirements due to ecological reasons.

2.2.2 Water logging and Salinity

The twin problems of water logging and salinity pose serious threat to sustainability of agriculture in command areas. According to the report of the working group on Water logging and Salinity, MOWR, GOI, nearly 2.46 million hectares of land in command areas are affected by water logging due to rising groundwater levels. This trend is caused by excessive irrigation from canal water and under-utilisation of groundwater. The underlying cause is the incredibly low water rates and the poor control over water delivery. The problem of water logging is most severe in Haryana, followed by Punjab (see Table 4).

Water logging leads to salinity of groundwater and soils, causing permanent degradation of land and sharp productivity declines. Yield declines are reported from the canal-irrigated areas of Punjab, Uttar Pradesh and Haryana.

Whereas in coastal areas, salinity is caused by salinity ingress and seawater intrusion, in inland areas, it is mainly due to rising groundwater levels (GOI 1999: pp 94). For instance, a large tract of coastal area is affected by salinity in Saurashtra area of Gujarat due to intrusion of seawater in the coastal aquifers and seawater ingress. At the same time, rising groundwater levels in command area of Mahi irrigation scheme cause soil salinity problems in South Gujarat (Kumar 2002b).

. The area affected by salts, in the form of either salinity or alkalinity, is reported to be as high as 3.3 million hectares in the country. Most of it is caused by salinity in groundwater in the command areas (GOI 1999).

2.3 Land Degradation and Food Security Impacts

Land is an important resource for food production. Until recently, policy makers and policy analysts have not perceived land degradation as a threat to global food security. It has been widely assumed that at the global level, land is in abundance, and is less important than other factors in determining agricultural productivity (de Vries *et al*. 2002). Though the second statement has been not been true in the case of India[8], the problems posed by land degradation in irrigated lands other than those covered by canal commands has not yet become a central theme for policy discourses on food security. The water logging and salinity problems are concentrated in canal command areas of the alluvial plains of Punjab, Haryana and Uttar Pradesh. Whereas the problem of land degradation in well-irrigated areas, caused by irrigation with saline water or excessive use of fertilizers, is larger as it can affect larger area and is less apparent.

The current farming practices, which involve excessive use of chemical fertilizers and irrigation water, lead to salinization of soils and their consequent degradation. This is particularly important in

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8 The issue of stagnation faced in the growth of cultivated lands has been raised by many researchers in the past. Also, the issue of land degradation caused by water logging and salinity in canal command areas has been in the fore for quite some time.

the high production and productivity areas of Punjab, western UP and Haryana. These changes had major imperatives for irrigation water requirement of crops, as farmers have to apply more water to maintain yield rates.

It is already established that the growth rate in food grain production has declined over the last few years (Katyal 1998). As regards agricultural production, the study by Evenson *et al*. (1999) shows that the contribution of TFP growth to growth in agricultural output, which was highest (1.39%) during early green revolution (1966-77), had declined to 1.05% during 1977-87. It further argues that the contribution of inputs such as irrigation, fertilizers and research to raising TFP declined after the early green revolution period. For instance, the study shows that the elasticity of marginal TFP due to irrigation decreased from 0.28 during 1956 to 0.20 during 1977-87 (Evenson *et al*. 1999: Table 30, pp 61). This phenomenon, which is popularly known as the fatigue of Green Revolution, is attributed to the steady decline in the fertility (nutrient availability) of land, and general decline in soil health in the well-endowed areas. Since the basic resources have been used in an unsustainable manner, even to maintain the same level of production, larger inputs will have to be used For example, 1 kg of fertilizer nutrient was sufficient to produce 15 kg of wheat in the seventies, where as at present, 1.5 kg is required (Gadgil *et al*. 1999).

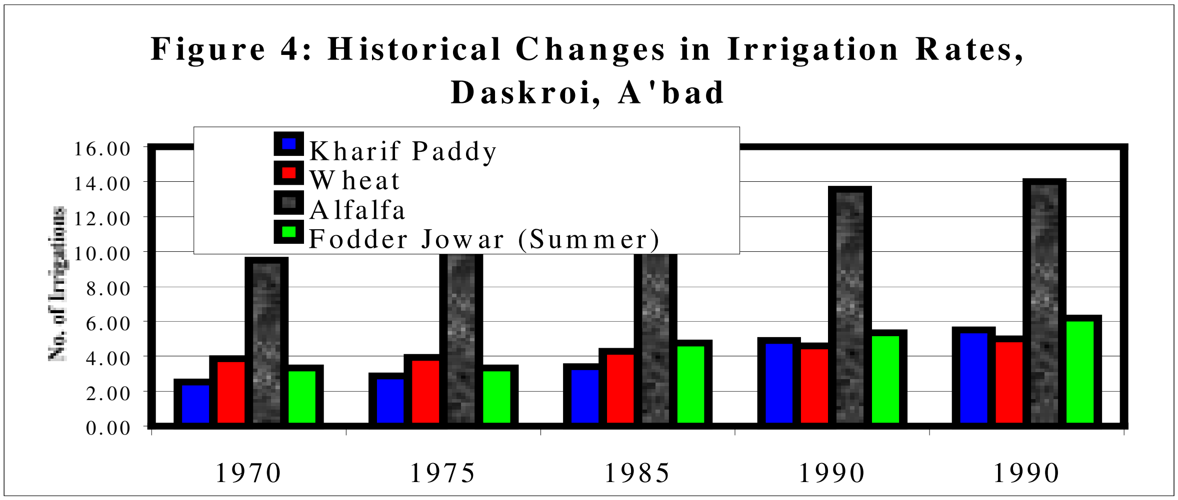
The following paragraphs illustrate the process of degradation of land through irrigation. One immediate consequence of energisation of wells and tube well revolution was the remarkable increase the intensity of irrigation. The land, which used to receive irrigation water only once in a year, started getting water in most of the cases in two seasons, and in a few cases in three seasons.

Excessive irrigation results in leaching of minerals and organic matter in to the soil. As irrigated area increased, availability of organic manure per unit area of cultivated land got reduced substantially. Chemical fertilizers had to be used in greater quantities. This, in a way, substituted for the organic, bio-fertilizers, which fell far short of the requirements. The chemical fertilizers enhanced the secondary productivity of the soils. On the other hand, the organic fertilizers were necessary to maintain the soil structure; provide necessary soil nutrients; and maintain the primary productivity of the soils. Increased fertiliser use also became necessary for modern farming using green revolution, hybrid varieties.

Studies carried out in Daskroi taluka of Ahmedabad district showed remarkable increase in the rate of application of chemical fertilisers for crops, namely, paddy, wheat, jowar and alfalfa, with the highest increase reported in the case of paddy, from 137 kg/ha in 1970 to 404 kg/ha in 2000. This results in breaking of soil structure. In a nutshell, three major changes in land use seriously impacts on land productivity: increase in cropping and irrigation intensity; increased rate of water application for each of the irrigated crops; and increased rate of application of fertilizers.

Irrigation with saline groundwater also leads to soil salinity. A study carried out by GUIDE (Singh *et al*. 2000) cites groundwater over-exploitation as one of the major causes of inland salinity in Gujarat, like increased use of fertilizers, and lack of soil nutrient management practices. In many arid and semi-arid areas, farmers use high TDS groundwater for irrigation. This leads to increase in soil salinity causing hardening of soil surface and lump formation. In order to break the soil lumps to enable better growth of crops, the farmers had to increase the water application rates. Thus, over a period of time, more salts get accumulated on the soil surface and the soils become saline. Excessive irrigation to leach the salts causes faster loss of organic matter and nutrients. All these ultimately result in soil degradation. This leads to decline in water productivity and land use productivity. As a consequence, the farmers are forced to increase irrigation for maintaining the yields. In Daskroi taluka, the average number of waterings for kharif paddy went up steadily from 2.5 in 1970 to 5.5 in 2000 (see Figure 4). Similar differences were found in the case of wheat and summer jowar also. The average number of waterings for jowar went up steadily from 3.3 in 1970 to 4.75 in 1985 to 6.2 in 2000. For wheat, the increase in the number of waterings was only one over a period of 30 years. This reduces the economic returns from farming. The poor will be worst affected, as economic constraints would limit their ability to invest more in farming.

The land resources that can be put to cultivation are shrinking due a variety of reasons, the most important of which is urbanization. India is experiencing high rates of urbanization, like many Asian countries. The urban population growth is pitched at 3.0% against an overall growth in population of 1.2%. With the fast pace of urbanization, more and more agricultural land is being converted into non-agricultural uses. Under such a scenario, increased food grain production to meet



the needs of growing population can be achieved only through intensified land use, with greater cropping intensity and greater use of agricultural inputs. This is owing to the fact that the contribution of yield enhancement in raising the total agricultural output will become less and less significant in the years to come. Yield increase in the important production areas, which offer very high levels of productivity, such as Punjab, is on the recession, as increasing water shortages, salinization, and bleaching out present enormous problems (WRI 1995; Leisinger 2000).

2.4 Food Security Situation in India

The Food Insecurity Atlas of India prepared by the UN World Food Programme and M. S. Swaminathan Research Foundation on the basis of a food insecurity index[9] shows that Bihar and Jharkhand are two "extremely food insecure" states in India (source: as cited in Agricultural Issues on India Together and de Vries *et al*. 2002, Figure 5, page 21). The poor agricultural productivity and production, and low level of food grain outputs resulting from low level of introduction of agricultural/crop technologies; poor rural infrastructure; high vulnerability of crop production to natural disasters such as floods and droughts; and high rates of unemployment and poverty, are some of the reasons for the high degree of food insecurity.

[9] The Food insecurity index calculated for each state of India is a composite index taking into account five indicators for food availability, six indicators for access to food, and six indicators for food absorption.

For instance, annual growth rate of per capita Gross State Domestic Product (GSDP) is lowest (1.2% during 1991-92 to 1997-98) in Bihar among all Indian states, against 7.57% in Gujarat. It is 1.24% in UP and 1.64% in Orissa (SDP and population data obtained from the CSO as quoted in Ahluwalia 2000). Similarly, the poverty ratio is highest (54.96%) in Bihar, against the second lowest of 24.21% in Gujarat (source: Planning Commission as quoted in Ahluwalia 2000).

On the other hand, Gujarat, according to the Atlas, is "severely food insecure". Serious groundwater depletion, land degradation, and the high degree of vulnerability of most parts of the State to droughts, increasing allocation of scarce water from rural areas for industrial production and municipal uses are two important factors causing agricultural output losses, and food insecurity problems in the State. In fact, groundwater depletion has increased the vulnerability of most parts of the State, which do not have access to water supplies from surface sources and subjected to highly variable rainfall conditions, to droughts (Kumar 2002b).

This is in spite of the high rate of economic growth achieved mainly through rapid industrialization (8.87% annual growth) and low percentage of people living below poverty line. It is also important to note that the State recorded a very low growth rate in the agricultural sector, with the agricultural component of GDP growing at a slow rate of 1.42% during 1980-81 to 1997-98 (source: EPW Research Foundation, as quoted in Hirway and Mahadevia 1999). This once again reinforces the fact unless we maintain steady growth in agricultural sector, and food grain production, it is difficult to achieve food security, even with high levels of GDP growth and high average per capita incomes.

As per the atlas, Madhya Pradesh, Rajasthan, Uttar Pradesh, Chhattisgarh, Orissa and Uttaranchal are also "severely food insecure" states. At the same time, states such as Andhra Pradesh, Maharashtra, Karnataka and West Bengal are "moderately food insecure" states, Kerala and Tamil Nadu are "moderately food secure" and Punjab and Himachal Pradesh "food secure" (source: as cited in de Vries 2002: figure 5, page 21).

3 IRRIGATION TECHNOLOGIES IN THE HANDS OF THE POOR

3.1 Technologies to Change the Trajectory of Irrigation Development

Though several arid and semi-arid parts of the country are facing groundwater depletion problems, there are several other regions, which do have abundant groundwater supplies, and in some cases surface water supplies too. Examples are the north eastern and eastern parts of the country such as eastern Uttar Pradesh, Bihar, North Bengal, Orissa and Assam. This region accommodates the largest number of poor people in the country (Shah et al. 2000). The groundwater resources in these regions largely remain under-utilized in spite of the fact that public irrigation facilities are very poor. High rates of illiteracy, poor economic conditions, lack of adequate rural infrastructure and lack of experience with irrigated agriculture are the major constraints for the people in these regions in tapping groundwater for wealth creating agriculture. Poor access to credit facilities for procuring modern water extraction mechanisms is another factor (Shah 2000).

With the conventional abstraction structures and mechanisms, the trajectory of development of groundwater resources in the region is most likely to be same as the projections made by the author. In order to change the trajectory of development, these regions need simple technologies that involve very little capital investment, and that can absorb the surplus labour force. This way, India can boost the rate of growth in groundwater development, which otherwise would remain slow, if conventional technologies are pursued due to economic constraints.

Treadle pump, a manually operated pump, require very low capital investments, while being much more energy efficient than traditional water lifting devises such as Denkul and Shena. The pump, which costs in the range of Rs.1000-Rs. 1400, is highly suitable for millions of poor farmers in the region who have postal stamp sized holdings. It can provide them the water security, essential for their livelihoods. Treadle pump has already changed the face of rural economy in Bangladesh, where an estimated one million pumps are in use. Recent studies carried out in Eastern India show that adoption of treadle pumps lead to expansion in irrigated area, cropping intensities, enhanced crop outputs and yields, and significant rise in income from farming, while farmers move from subsistence agriculture to wealth creating irrigated farming practices (Shah et al. 2000; Kumar 2000b). Shah et al. (2000) therefore argues that the pump can create millions of micro-economies.

Studies conducted in Orissa also throw enough hard empirical evidences to show that pump adopter households enjoy greater food and nutritional security (see Kumar 2001 for details). Treadle pump irrigation ensured increased output from irrigated agriculture, more importantly vegetables. The surplus production, which is sold in the market, brings in cash income from farming. This enables the households to purchase other essential commodities, which ensured better access to food supplies both in terms of quantity and variety.

To have a broad understanding of the food security impact of TP adoption, the data on the transaction of these essential commodities[10] are analysed for different categories of farming households. The results show that the percentage of households engaged in buying is third lowest in the case of TP. adopters, (69%) and highest for rain-fed farmers (73%). Also, the average number of commodities purchased is highest for rain-fed farmers (6.57), and third smallest for TP adopters (6.17), though the differences being marginal. On the contrary, the percentage of households engaged in selling is highest for TP adopters (19.8% against 5% for rain-fed farmers, 12.8% for Tenda owners, 15.5% for water buyers, and 4.8% for landless sharecroppers) and the differences are wide. Further, the average number of commodities sold is highest for TP adopters (1.8 against 0.45, 1.15, 1.4 and 0.4) and the differences are sharp. On an average, the number of commodities being transacted (either selling or buying) is, therefore, largest for TP adopters (8.0 against 7.02, 7.38, 7.42 and 6.13) including kerosene, which every household purchases (Kumar 2000b).

The percentage of households engaged in transaction (buying and selling) of all essential commodities is highest in the case of TP adopters (88.4) as compared to rain-fed farmers (78), *Tenda* owners (82), water buyers (82.4) and landless sharecroppers (68). This means that the percentage of households who have access to all essential commodities is significantly higher for TP adopters than all their counterparts, especially rain-fed farmers and landless sharecroppers. An average TP adopter is able to access more of essential commodities as compared to all his counterparts. The improvement in income levels has also influenced the type of food, as many adopter families started taking meat and eggs frequently, while it was a rare event prior to adoption (Kumar 2000b).

A comparative analyses of the quantum of purchase and sale of different commodities showed that average per capita transaction of six of the essential commodities (rice, meat, fish, milk, kerosene, and vegetables) was higher for TP adopters as compared to rain-fed farmers and landless sharecroppers. Further, the average per capita transaction of rice and vegetables is the highest for TP adopters and the average per capita transaction of fish, milk and kerosene is the second highest. This led to the conclusion that the adopter families enjoy greater access to food supplies than their

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[10] The commodities selected are rice, dal, egg, meat, edible oil, milk, vegetables and kerosene.

counterparts having no irrigation facilities in terms of both the number of food items and the quantity (Kumar 2000b).

Another aspect of household food security is the nutritional value of the food consumed. As the study Kumar (2000b) found that introduction of TP has directly contributed to rise in both vegetable production from farms and intake of vegetables by households.

3.2 Technologies to Increase Crop per Drop

So far as harnessing more and more water from the natural systems is concerned, technologies have their limits. The next option available to enhance food production is to improve the efficiency of use of water.

World wide, micro irrigation technologies, conceptualised and developed in the early 1970s, are promoted to save water and get increased efficiency of water use in agriculture. There are several technologies, which help farmers not only save irrigation water (the water saving is up to an extent of 75% over flood irrigation, but also obtain 20-30 per cent higher yields apart from saving labour. While micro irrigation systems have seen a relatively rapid adoption rate over the past one-decade in India, the overall adoption level is still quite. Drip and sprinkler irrigation systems cover less than 6% of the global irrigated area, and in the case of India, they cover only 2,00,000 ha or less than half the per cent of the net irrigated area of the country low (Behr and Naik (nd.)) as cited in *www.ideorg.org/ techgallery-library/ techinfor/ china1.htm)*.

But, these technologies have great bias. For farmers to take full advantage of them in terms of water saving, they should install them for large fields. However, this depends on the mode of charging of electricity in the farm sector. In areas (states) where power pricing is dependent on the pump horsepower, both the capital cost of the pumping per unit per unit area and the operating cost per unit area will be higher for resource poor farmers who adopt the system for smaller areas. The farmers who adopt the system for larger area can bring down the cost per unit area significantly (Please see Kumar 2002c for details). This is because of two facts: the capacity of the pumping unit is not dependent on the area under coverage by the pressurised irrigation system, but the discharge of the pump; and 2) the electricity charge is not dependent on the energy consumed which will be high in the case of farmers who adopt the system in larger area.

These systems involve high capital investments. Further, installing these systems for small fields would increase the cost per unit area. Also, the maintenance requirements for these irrigation systems are quite high. The drip system, which is the most water efficient of these technologies, is most suitable for horticultural plantations from the point of view of cost effectiveness. Thus, they are best suited to resource rich, large farmers, who can spare part of their land for horticultural crops, and can wait for 3-4 years for returns.

Another important issue involved in the adoption of pressurised irrigation systems is the lack of enough economic incentives. In many Indian states, where depletion problems are encountered, groundwater resources are abundant, only power supply is limiting the farmers' access to groundwater. Examples are alluvial areas of north Gujarat, Punjab, western UP and Haryana. These are situation where the groundwater supply potential is higher than what the available power supply could deliver.

The large static storage of the aquifers[11] permits the farmers to keep pumping water, even though it is at the cost of excessive draw down. The factors like overall physical availability of utilisable groundwater, and economic viable pumping depths do not have any influence on the pumping behaviour. This is owing to two major facts. First: either cost of electricity for pumping unit volume of water is extremely low (under subsidised unit pricing system) or the marginal cost of energy for pumping is zero (under flat rate system of pricing electricity). Second: there are no limits on the volumetric pumping by well owners, and well owners do not pay for water.

Since pressurised irrigation systems need extra power to run, the well output could drop with the installation of the system. As the farmer is already utilising the power supply fully, the total water output from the well would drop. Though farmers could manipulate the well output by choosing a higher capacity pump, he/she will not do so due to the power tariff implications. Thus, the farmer will not be able to cash in on the benefit due to water saving in the form of increased area under irrigation. Therefore, the only economic opportunity available with pressurised irrigation technologies is yield increase. However, ability to secure higher yield through water saving devises depends heavily on the management practices, including agronomic practices.

Nevertheless, the situation would be drastically different in hard rock areas facing depletion problems. These are situations where power supply is in abundance and groundwater is scarce. In those areas, currently farmers are not able to utilise power supply fully due to shortage of water in wells. In such situations, pressurised irrigation systems could benefit the farmers by enabling him/her to run the pump for longer hours, maintain the same level of total well output and irrigate larger area.

Water saving technologies had recently been developed to suit the requirements of many millions of the poor, small and marginal farmers in the country. They are the mini sprinkler systems and micro tube drip systems being promoted by the International Development Enterprises. While mini sprinklers require energised pump sets, micro tube drips can work under very low-pressure head, with as little as a bucket full of water. These systems are adaptable to postal stamp sized holdings. It enables the poorest of farmers with very little access to irrigation water to grow crops and earn their livelihood. Such technologies can attract even the landless farmers, who can cultivate vegetables in their backyards. The investment is as low as US D 300 per acre, while the conventional sprinklers and drips cost around USD 1200 and Rs.15,00 per acre, respectively. These systems require much less maintenance as compared to the conventional pressurized irrigation systems. The easiness in maintenance is more significant in the case of micro tube drip systems. However, the adoption of these technologies by poor farmers would depend heavily on the supply of information, materials and services for installation.

4 NRM TECHNOLOGIES FOR SUSTAINABLE AGRICULTURE PRODUCTION

The ability to improve the water productivity and land use productivity depends on the way we manage the primary productivity of land (Kumar 2002a). There are several on-farm management practices that the Indian farmers can practice. Such practices are particularly important for the semi

[11] Western UP and Haryana are underlain by deep alluvial aquifers with have a vertical extent of nearly 2000 metres. Most parts of north Gujarat are underlain by multi-aquifer system of alluvial nature, which have a vertical extent of up to 600 metres in many parts. Most of Punjab is underlain by alluvial deposit of the Indus valley.

arid regions, which have already taken to intensive farming using irrigation water, both from canals and aquifers, such as Punjab, western UP, Haryana, Gujarat, Rajasthan and Tamil Nadu.

These practices, if carried out consistently, can progressively reduce water requirement of the existing crops, along with improving primary productivity of the cultivated land. They are increased use of organic manure with gradual reduction in the use of chemical fertilizers, vermin-culture, and agronomic practices such as mulching, crop rotation and use of bio-pest control measures. Organic manure can help regain structure and texture of soils and enhance their moisture retention capacity along with improving soil nutrients. Use of farm management practices such as mulching can reduce the evaporation from soil surface thereby increasing the efficiency of utilisation of irrigation water. A recent study of organic farming practices adopted by nearly 250 farmers in Gujarat showed that over a period of three years, the irrigation water requirement of the crops in the organically farmed field, had reduced by half (Kumar 2002a).

There are several scientific studies carried out in Gujarat, which show the yield and water productivity impacts organic manures and mulching (Sadhu *et al*. 1996; Singh *et al*. 1990; Dudhat *et al*. 1996). In a study carried out on the effect of mulching on yield and water productivity of mustard crop in south Saurashtra, the pooled yield of seeds went up from 1004 to 1087 kg/ha and pooled stover yield went up from 2751 to 2962 kg/ha with the application of mulch at the rate of 10t/ha, over a two-year period. Further, the agronomic efficiency of water use went also increased significantly from 4.56 kg/ha/mm to 5.43 kg/ha/mm (Table 1; Sadhu *et al*. 1996). The study carried out by Dudhat *et al*. (1996) showed positive effect of organic manures such as FYM and castor cake on grain and straw yield of wheat with significant impact on B/C ratio. The yield of wheat went up from 4.30 t/ha to 4.683 t/ha with the application of FYM (15t/ha), and from 4.3 to 5.038 t/ha with the application of castor cake (source: Table 1; Dudhat *et al*. 1996). The B.C ratio was 1.94 with the combined doze of FYM and FRD of fertilizers against 1.72 with FRD of fertilizers (Table 2; Dudhat *et al*. 1996).

In a nutshell, in order to increase the water productivity in agriculture, the primary productivity of land needs to be increased. This requires nutrient management measures. The biomass inputs have to be proportionally increased to increase the efficiency of utilisation of irrigation water. In order to increase overall productivity of land, the moisture retention capacity of soil needs to be enhanced along with increasing the biomass inputs. Thus, there is a need to manage land, water and biomass in an integrated manner (Kumar 2002a).

But, the Indian farmers would face several constraints in adopting more sustainable agriculture based on organic farming practices. They use cattle dung and straw for preparing Farm Yard Manure. However, the practice followed for this is highly unscientific and the efficiency of utilisation of biomass is extremely low. This is the first constraint. Studies show that if scientific methods of composting are practised, the efficiency of production of FYM can be substantially increased.

The second constraint is the availability of biomass for preparation of organic manure and mulching. For a farmer, the availability of surplus biomass for best farming heavily depends on how he/she is positioned with respect to cattle vis. a. vis. land holding, his ability to invest for efficient compost making practices; and find alternative sources of cooking fuel.

This means that small and marginal farmers, who own cattle, are likely to face severe constraints in shifting to more sustainable ways of farming. The farmers having large holdings along with cattle are likely to experience relatively lower stress in managing their biomass needs. One main reason for this is the fact that the size of cattle holding is not proportional to the land holding size. The families having large holdings, and irrigation facilities try and minimize cattle holdings, while those with poor holdings and irrigation facilities utilize surplus family labour for rearing cattle. As a matter of fact, livestock keeping and dairy have become the most important source of livelihood for the small and marginal farmers of "water stressed" regions like Gujarat and Rajasthan where the farmers' ability to generate sufficient income from irrigated farming is reducing. A study carried out in 30 villages in Banaskantha district, which fall in one of the most water scarce regions in India, shows that the per capita cattle holding is inversely proportional to the per capita irrigation (see Figure 5; source: the author's own analysis).

This issue of biomass availability is pertinent in the Indian context owning to the reason that small and marginal holdings account for a lion's share of the total operational holdings in India. According to 1990-91 agricultural Census, 78.2% of the holdings belong to small (18.8%) and marginal (59.4%) farmers, who controlled a total of only 29 % of the area under cultivation. The number of small and marginal holdings in the country has been on the rise over the years, while the number of medium and large farmers has been on the decline (source: Agricultural Census 1985-86 and 1990-91).

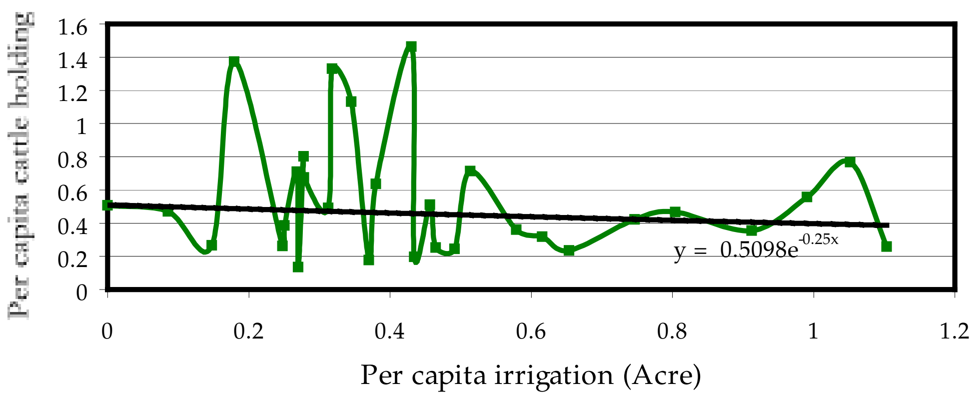
The challenge is to produce surplus biomass that can be used as input for farming, without causing any increase in the dependence on exogenous water for producing biomass in the form of fodder and leafy biomass.

Rainwater is the only endogenous source of water. Many arid and semi arid regions of the country which receive low to medium rainfalls, are characterized by high year to year variation in the monsoon rains, with years of high and low rainfalls. In high rainfall years, the number of rainy days is also high. During these years, the farmers can take up plantation of trees in common land as well as private land. The resistance of trees to moisture stresses is high, by virtue of which they would survive even during years of low rainfalls and droughts. In the absence of moisture in the soil moisture zone of the sub-surface strata, the deep-rooted trees can suck the water in the vadose zone, which is also known as the hygroscopic water. Once matured, the trees will provide biomass throughout the year.

Farmers with relatively large holdings can adopt block plantation and those with smaller holdings can adopt peripheral plantation on private land. On-farm water conservation practices such as construction of "farm bunds" and "farm ponds" can also be taken up to ensure availability of moisture and water, necessary for the growth of trees. Another way to produce surplus biomass is to go for rain-fed crops in large areas that would yield sufficient green fodder during Kharif and dry fodder during other seasons, and crop residues for mulching and compost making. However, this is viable only in the case of farmers having large holdings.

Community plantation is another viable alternative. In the case of common land, soil moisture conservation measures can be adopted. Indian villages have sufficient amount of wasteland under the control of the local governments. These lands can be transferred to the village institutions, which are

Figure 5: Irrigation vs Cattle holding



legally recognised, for taking up plantation and soil moisture conservation activities. These local institutions can take up plantation of tree crops, grasses and some of the green fodder. They can evolve norms to ensure equitable distribution of the returns. If the farmers practice scientific methods of composting, the effective availability of biomass will increase. Adoption of biogas plants would reduce the pressure on crop residues and cattle dung for cooking fuel.

5 INSTITUTIONAL CHANGES FOR CHANGING THE TRAJECTORY OF WATER USE AND PRODUCTIVITY IN AGRICULTURE

The strategy to increase agriculture production and economic outputs, without causing any increase in the overall demand for water, is to increase the economic efficiency of water use. Demand management strategies have two components: [1] transfer of water for economically more efficient uses; and [2] encouraging efficient use of water in the present use. But to ensure food security at the house level there should be greater equity in access to and control over water allocated for agriculture.

5.1 Promoting Equity and Productivity in Water Use

The growing competition and concomitant conflicts between different sectors are major issues that need to be addressed in water allocation. The fundamental challenges are: promotion of economically efficient uses, while adequately compensating the agriculturists for the losses they suffer due to transfer of water to other efficient use sectors; and, equitable access to water from canals and groundwater within agriculture sector. This is important for regions with good natural endowment of water like Bihar, Orissa, and eastern UP--as well as those, which face physical shortage of water and scarcity and where demand exceeds supply like Gujarat.

Saleth and Dinar (1999) in their paper titled Water Challenge and Institutional Responses (A Cross Country Perspective) prepared for the Rural Development, Development Research Group and Rural Development Department, World Bank, say that concerns in the water sector, which once revolved around water development (and quantity), now revolve around water allocation (and quality) (Saleth and Dinar 1999).

Markets and regulations can be sought as instruments for water allocation (Frederick 1993; Howe *et al*. 1986). Howe and co-authors (1986) suggest six criteria for comparing alternative institutional arrangements to allocate water: (a) flexibility in allocating supplies in response to both short-term and long-term changes; (b) security of tenure to encourage investment in and maintenance of water-using system while allowing for users to respond voluntarily to incentives to reallocate supplies; (c) whether the user is confronted with the real opportunity costs of the resource; (d) predictability of the outcome of the transfer; (e) equity impacts; and (f) whether public values are adequately reflected in the process. Frederick (1993) lists low-transaction costs of moving water from one use to another to this list.

But, both markets and regulatory approaches are likely to fall short of satisfying all these criteria for efficient and effective water allocation (Frederick 1993). Let us take the case of maintaining in-stream flows in natural watercourses and rivers, which is an important demand management objective to be achieved through water transfers. This being a public good and the users of in-stream flows having no incentive to pay for the services it provides. As a result, markets are likely to fail in this sector. The enormous geographic and temporal diversity in water supply and demand situations suggest that no single institutional arrangement is likely to be preferred in all instances (Frederick 1993). Howe *et al*. (1986) have argued that markets meet all the criteria for effective water allocation better than any likely alternative in many situations. Saleth and Dinar (1999) based on their cross-country evaluation of the institutional responses in the water sector shows that "the old paradigm focused on centralized decision making, administrative regulation, and bureaucratic allocation is fast giving way to a focus on decentralized allocation, economic instruments, and stakeholder participation" (Saleth and Dinar 1999).

This argument, by and large, is valid in the Indian context. The spatial and temporal variation in water availability is very high in India, caused by heterogeneity in hydrology and geo-hydrology and high inter-annual variability in rainfall. For instance, 62% of India's water resources are concentrated in the Indo-Gangetic basin (page 21: GOI 1999). There are significant variations in the per capita renewable freshwater availability across regions. The author's own estimate shows that it is as high as 1,210 m^3 per annum in erstwhile Bihar and 1,362 in UP where the withdrawals are very low, while it is as low as 427 m^3 per annum in north Gujarat where the annual water withdrawal is 448 m^3 per capita (Kumar and Singh 2001).

So is the variability in demand situation. In socially and economically regions such as Bihar and Eastern Uttar Pradesh, irrigation demand is very low, though water resources are abundant, and problems of water logging due to rising groundwater levels caused by flooding and excessive irrigation from canals are encountered (Shah 2000). The demand for water for industrial and urban uses also remains very low in these regions. Demand management challenge here is to create increased demand for groundwater through market institutions, as investment in public tube wells has not been very effective.

On the other hand, demand for water is extremely high in arid and semi arid regions of Gujarat, Rajasthan, Tamil Nadu and Maharashtra where water resources are very scarce, and groundwater is the major source of water for all purposes. Pumping regulations in areas facing over-development problems through groundwater legislation, control of institutional financing for well development and restrictions on power connections for pumps has been by and large ineffective in these regions (Kumar 1995; Kumar 1999/2000; Janakarajan 2002). Further, large distances involved in conveyance of water between regions of abundance and shortage reduces the ability of the government to invest in public water systems for supply of water in bulk as it has serious financial and environmental imperatives. Inadequate finance is also a constraint in public investments in large-scale inter basin transfer projects, as discussed early (see Chaturvedi 1999).

The absence of well-defined property rights regimes is a major source of uncertainty about the negative environmental impacts of resource use, leading to inefficient and sustainable use (Pearce and Warford 1993; Kay *et al*. 1997). This has been apparent in the case of both groundwater and canal water supplied for irrigation.

In the Indian context, many researchers in the recent past have suggested establishment of property rights as a means to build institutional capability to ensure equity in allocation and efficiency in use of water across sectors (Singh 1995; Chaudhary 1996; Kumar 1997; Saleth 1996; Kumar *et al*. 1999, Kumar 1999/2000). But, again if the rights are allocated only to use water, it can create incentives to use it even when there is no good use of it (Frederick 1993). Therefore, water rights have to be tradable (IRMA/UNICEF 2001; Kumar and Singh 2001). Establishing privately-owned, property rights that are tradable is critical to establishing conditions under which individuals will have opportunities and incentives to develop and use the resource efficiently, or transfer it to more efficient uses (Frederick 1993).

The volumetric use right of individuals or "entitlements" can be defined and established by the government agency concerned by using a variety of social and economic parameters. A user who needs more water than the actual entitlement can purchase the water rights from another user, by paying prices that are determined by the supply–demand interactions. The price of water will reflect the opportunity cost for using water. The markets and market determined prices could work in two ways: [1] farmers can shift to alternative uses that provide higher economic returns than the price of water; or [2] they continue the existing uses with more efficient practices or resort to selling (Frederick 1993). Such transfers can promote access equity and efficiency in use (Kumar 1997; Kumar et al. 1999; Kumar 1999/2000).

Empirical evidences collected on the functioning of groundwater irrigation institutions in north Gujarat show that under a system of fixed volumetric water use rights, farmers prefer to grow mustard, which is less water intensive, in larger area as compared to wheat, though the earlier one has much lower land use productivity than wheat, but getting same water use productivity (see Kumar 2000a for details).

Tradable private property rights need to be enforced for groundwater and water supplied from public reservoirs for irrigation. In the case of groundwater and canal water supplied for irrigation, as individuals enjoy access to the resource, private property rights for individual users are envisioned.

For markets to function efficiently, the full benefits and costs of transfer should be borne by the seller and buyer. Generally, this is not possible due to the third party effects of water transfer. Allowing the user to transfer only the consumptive portion of the water he/she uses can reduce the third party effects in regions that are dry. The government will have to play a great role in reducing the third party effects of water transfers. Similarly, government has to invest in protecting the ecological and environmental services that are affected by water transfers (Frederick 1993).

Fixing norms for allocation of volumetric water rights across individual sectors, viz., agriculture, industry and domestic use, should involve considerations such as physical sustainability of the water resource system and environmental sustainability. The total water allocated from any region/basin, therefore, should not exceed the difference between annual renewable freshwater and the ecological demand, or the utilizable freshwater whichever is less. Going by such norms, the regions, where water resources are abundant by nature such as the eastern part of UP, Bihar, Orissa and West Bengal, the volumetric water rights of individual sectors and users, especially farmers would be very high.

In these regions, the potential for enhancing water productivity is low, though there are opportunities for increasing output through increased use of irrigation input. At the same time, land availability would continue to be an important factor in deciding returns from agriculture. The farmers will, therefore, have to choose crops, which are more water intensive and which would encourage intensive use of the same piece of land. In states such as UP and Bihar, land reforms could not be implemented so far. Hence, water right would not mean much for a large number of cultivators, who have marginal holdings or no land. But, allocating and enforcing water rights would be easier in these regions as compared to land ownership rights in view of the fact that water is in surplus.

In such situations, the allocation norms in agriculture need to be carefully designed, if equal opportunities are to be given to all types of cultivators to improve their own farm economies. In water allocation, the food security needs of the families could be given priority rather than the farm size. This will result in disproportionate allocation of rights in favour of small and marginal farmers. This way, we can delineate water rights from landownership rights, and the landless will also get rights to use water. Since the chances of increasing water productivity through improvements in physical efficiency are low, the rich farmers would then try and intensify land use to enhance land use productivity by going for highly water intensive, short duration crops. This would mean increase in water requirement.

$$\text{Total productivity or production} = \text{water use productivity} * \text{volume of water use}$$

This can induce interlocked land, pump and water markets, where in the rich well owning farmers will offer pump services to farmers who do not have their own irrigation sources, and can, in return, use a portion of their water rights. This will force the rich well owners to charge less for their pump irrigation services they provide.

The rich will also enter into sharecropping arrangement with landless. A good economic opportunity lies for landless, small and marginal farmers in transferring water in bulk to water scarce regions, or cities and industrial areas, which are concentrated points of large demands for water, as they are likely to have excess water.

Physical conditions for transfer of water from rich areas to water scarce areas exist in many regions. For instance, great opportunities exist for transfer of water from South and Central Gujarat to north Gujarat region (Kumar and Singh 2001). There could as well be opportunities for transfer of water from the areas of Punjab showing rise in water levels to areas facing the crisis of overdraft. Once water rights are properly established, farmers will show the willingness to invest in infrastructure for transfer of large quantities of water to areas of high demand through group efforts.

In developing countries, carrying out institutional reforms for water management, including well-established water rights is going to be an ardous exercise and the transaction cost is going to be enormous. However, the opportunity costs of not investing in institutional reforms in water sector are going to be enormous due to the growing water scarcity and can exceed the transaction cost (Saleth and Dinar 1999). Therefore, in water stressed regions, investment in creating institutions could be justified to a great extent. Further, it is a phenomenon world over that when water becomes scarce, communities are increasingly found to be evolving and enforcing social institutions.

Efficient water markets are likely to come up more in intensively-irrigated (groundwater) areas due to the following reasons: extensive use of conduits for water conveyance increases the transferability of water and reduces the third party effects; ability to measure the rights purchased; and, relatively low distance of transfer, which reduces the transaction cost.

Well-established tradable property rights and well-developed water markets can bring about significant improvements in the water productivity in agriculture, and growth in agricultural outputs, thereby ensuring economic security. Allocation and enforcement of volumetric water use rights would be a Herculean task in Indian context, especially for groundwater, in view of the fact that there are millions of groundwater users in agriculture in rural parts of the country with very small land holdings.

Allocation and enforcement of water rights could be vested with River Basin Organizations. The powers to evolve norms on inter-sectoral water allocation and volumetric use rights of individual users within each sector in the basin could be vested with a professional body. This body can operate at the basin level. Volumetric water rights could be allocated by the basin level authority to the ultimate users through a hierarchy of institutions from sub-basin to watershed to village level. In the case of water supply agencies such as irrigation department and drinking water supply agency, the basin level body can directly allocate volumetric rights. The volumetric water use rights of a particular institution would be based on the constituency it represents. These lower level institutions could be vertically integrated at the basin level. The powers to enforce volumetric use rights of individual users and groups could be vested with these institutions through monitoring. Each one of them could be made responsible for monitoring water use at the next lower level. A village level institution can comprise representatives of local groundwater users, and can monitor water use by individuals, including farmers, households, and industries.

One of the fears associated with allocation of tradable water rights is the trade off between food security and economic efficiency: that it encourages farmers to increasingly allocate water for non-agricultural purposes such as industry, with adverse impacts on food grain production, though such a tendency is desirable in a drought year. Results from the study carried out by IFPRI on Maipo river basin shows that net profits in irrigated agriculture increased substantially compared to the case of proportional use rights without rights to trade water. More over, agricultural production did not decline significantly, when water was traded from agriculture. Farmers earned substantial benefits from selling their unused rights, during the months with little or no crop production (source: www. ifpri.cgiar.org/themes/mp10.htm).

5.2 Encouraging Efficient Use of Water in Agriculture

Irrigation is the largest user of water in India. Water conservation has three distinct components: a) conservation by preventing the loss of stored water; b) conservation by preventing the loss of water from the system during conveyance from supply source to the agricultural fields; and, c) on–farm water conservation by adopting efficient water use technologies. The scope of these three options in cutting down the demand needs to be analyzed.

In irrigation, storage losses are very high for surface reservoirs. The potential for saving this water is very high. Again, the conveyance or the network losses are very high for the surface irrigation systems in the country. It is believed to be in the order of 45-55 percent for many of the large surface irrigation systems with extensive distribution network consisting of several hundred kilometres of unlined channels.

In India, the farm level efficiencies in surface irrigation systems are very poor due to very high field evaporation, evapo-transpiration, percolation, and runoff losses due to flood irrigation and poor on-farm water management practices being adopted by farmers. There is enough empirical evidence to substantiate this. For instance, it was found that 70 percent water loss in rice fields was due to percolation through the sandy loam soils of Delhi and only 480 mm out of 1200 mm of water was actually used consumptively by rice. But, the use of irrigation technologies such as drips (for row crops) and sprinklers (for field crops) that can result in significant saving in water used for irrigation is just one percent of the total irrigated area.

There are no storage losses in groundwater irrigation. The conveyance losses are also very low due to the generally short conveyance systems used. The field efficiencies are also generally higher due to greater control over water and manageable discharges. However, uncertainties about time and duration of power supply create incentive among farmers to apply excess water when supply is available leading to inefficient use.

5.2.1 Pricing of Irrigation Water

The fact that water is a scarce economic input should be a major decisive factor in determining the price of water used in irrigation (Kay et al. 1997). As a general principle, price of water for competitive use sectors such as irrigation and water intensive industry, should be guided by economic efficiency consideration. This means pricing of water should be fixed in such a way that it discourages uses that are economically inefficient. In India, annual irrigation subsidies are estimated to be around 5,400 crore rupees Wolf and Hubener (1999). However, irrigation water pricing is complex due to the concerns relating to public policy apart from those, which are purely economic in nature (Rao 2000).

Financial health of irrigation agency is another important concern, which may run in conflict with the social welfare concerns. After independence, the Indian governments saw irrigation as welfare means, and were reluctant to raise irrigation fee charged to poor farmers. As irrigation services declined and agencies weakened, farmers became reluctant to pay the water charges.

India's food security policy, which has the objective of ensuring food grain availability at an affordable price, has been another compelling reason to provide subsidies for the agricultural inputs, namely, water for irrigation supplied from public systems, electricity used for groundwater pumping and fertilizers. This is because of the fact that the farmers are denied the option of fetching high price for the grains produced through free trading, due to the government restrictions on inter-state grain trading, and the only way to make food production remunerative was through cutting down on the input costs (Goyal 2002).

Provision of input subsidy as such is not a bad idea in the agriculture sector. Several countries around the word still resort to subsidies to allow farmers to grow food at low cost (Kay et al. 1997; Rao 2000). For instance, according to estimates compiled by the US bureau of reclamations, in 1986, 17 western states in the US received an irrigation subsidy of 534 million dollars, from the federal government, with an average of US$ 54 per acre of irrigated land. As Rao (2000) points out "To the extent that large subsidies can alter the potential efficiency patterns of water use, water subsidies can cause long term irreversible effects-environmental, physical, geographic, economic" (Rao 2000).

While, a properly formulated and targeted pricing policy can bring about the desired outcome of subsidy, there are significant policy failures in pricing of irrigation water, owning mainly to the inappropriate pricing structure.

Due to the incredibly low water rates for the crops, and zero cost of marginal increase in irrigation water use, the farmers have tendency to grow crops that are highly water intensive. In the canal-irrigated South and Central Gujarat, out of the total 6,177 MCM of water used for agriculture, 4,614 MCM is used up by sugarcane and paddy alone (IRMA/UNICEF 2001). These crops yield very low return per unit volume of water. Adoption of such crops leads to shrinkage in the command (Kumar and Singh 2001). Such system of pricing perpetuates inequity in access to water and the distribution of the benefits of subsidy. Inappropriate pricing structure and lack of agency capability to recover water charges and penalise free riders create incentive for wasteful practices.

In spite of the recommendations of the second Irrigation Commission, state irrigation bureaucracies have failed to hike water charges that make economic sense. The failure has its roots in the absence of institutional capability to improve the quality of irrigation services and correctly monitor the water use, lack of institutional arrangements at the lowest level to recover water charges from the individual farmers, and enforce penalties on free riders (Brewer et al. 1999).

An appropriate pricing structure, with volumetric mode, followed by volumetric water rights could create incentive for introducing conservation measures and efficient use practices in irrigation. But, water pricing for irrigation can impact poor farmers adversely, if pitched at higher levels. One of the ways to reduce the negative impacts on access equity is to introduce progressive pricing system (Kay et al. 1997). The low levels of use can be priced at low rates and higher levels of use at higher rates. In any case, the prices have to reflect the scarcity value of the resource. This can motivate the farmers to allocate water for the most efficient uses or to adopt efficient water use technologies for the existing use and sell the excess water at the market rates to those who need it. Though the rights of individual users will be a function of overall water availability and will change with respect to rainfall and other climatic factors, there will be assurance of rights to meet the basic needs in all the years. But, pricing changes and rights reforms will have to be accompanied by modernisation of irrigation schemes. It involves technological innovations in the infrastructure for greater control over and measurement of water delivery, and institutional changes for greater involvement of user groups in irrigation management right from the main system.

5.2.2 Pricing of Electricity in the Farm Sector

Most Indian states follow flat rate system of pricing electricity supplied for the farm sector based on the premise that the management costs involved in metering electricity are high. Flat rate system of pricing electricity creates incentives for farmers to over-pump groundwater. It also leads to disproportionate distribution of benefits of subsidies in favour of farmers who enjoy greater access to groundwater, either by virtue of their resource availability or by virtue of the yield potentials of wells in particular geo-hydrologic environments (IRMA/UNICEF 2001).

Many researchers have suggested rational pricing of electricity as a potential fiscal tool for sustainable groundwater use in India (Moench 1995; Saleth 1997). Many argue that flat rate based pricing structure in the farm sector creates incentive for farmers to over-extract it, as the marginal cost of extraction is zero. However, empirical evidence does not seem to suggest any impact of the cost of extraction on the use of groundwater for irrigation in water scarce areas (Kumar and Patel 1995), and in areas where water charges reflect the scarce value of the commodity (Mohanty and Ebrahim 1995). Diametrically opposite views about the impact of electricity pricing on groundwater use also exist. For instance, Shah argues that flat rate pricing will induce positive impact on access equity in groundwater (Shah 1993). Others have argued that power tariff fixation based on diesel prices would have some positive impact on equity as well as efficiency (for instance see Saleth 1997).

Going by the conventional wisdom, if pricing structure is designed in such a way that it reflects the actual volume of water and unit of electricity consumed, with progressive increase in unit rates, it can induce incentives among farmers to use water more efficiently. But, such measures have not been attempted in any of the states where groundwater depletion problems actually exist, due to their social and political ramifications. The influential farm lobby is likely to protest against any move by the government to change the tariff structure due to the fear that it would affect the prospects of irrigated farming adversely.

The studies on economic returns from farming in diesel and electric well commands show that diesel well commands yield higher returns, due to the greater control over irrigation water enjoyed by diesel well owners (Kumar and Patel 1995). The results thus indicate that returns from farming are more elastic to reliability of irrigation than its cost. This proves an important point that power tariffs can be raised to substantially high levels to achieve efficient use of water, without causing negative impacts on the farmers. This, however, also reinforces the fact that the desired impacts of pricing changes can be brought about if we provide high quality power supply in rural areas and meter its use, levy the charges without default, prevent thefts, and penalise free riders (Kumar and Singh 2001). Private sector participation in power transmission and distribution will be an important part of the reform process. Engaging user-group organizations for distribution and metering of electricity at the village level, and bulk metering of electricity at the user group level could be another step (Kumar and Singh 2001; Panda 2002).

Geo-hydrological environment will be an important factor, which would decide as to what level the unit rates for electricity use in the farm sector could be raised against the reference to the actual cost of production of energy, keeping aside the socio-political and institutional factors. This is owing to the fact that the actual consumption of electricity (in units) for pumping unit volume of water would vary according to geo-hydrological situation. The feasibility of charging full cost of electricity would be extremely poor in deep pumping areas. Subsidies are imminent in deep water table areas. At the same time, full cost of electricity would be possible in high water table areas. The following example would illustrate this.

6 CONCLUDING REMARKS

Promotion of low cost, energy efficient water harnessing technologies such as treadle pumps, through supply of information, materials and services, can not only change the trajectory of water resource development in the country, but also enable poor farmers in the agriculturally backward eastern and north- eastern parts of our country, access irrigation water. This will create millions of micro economies with sustainable utilisation of water resources in the water abundant regions. Low cost, water saving technologies will enable the poorest sections of the communities to practice irrigated agriculture with very limited water in water scarce regions.

The policies and programmes need to be designed and operationalized to encourage sustainable farming practices with increased use of bio-fertilisers. Subsidies can be introduced for small and marginal farmers to adopt biogas plants and scientific compost making. Community-based programmes for increased production of biomass from common property wastelands can be introduced. Extension activities on efficient compost making practices, organic farming practices, biogas, and low-cost water saving technologies need to be taken up. The agriculture research should shift from a supply driven system to one that takes into account the demand side variables such as the local physical and socio-economic conditions, in order to increase the scope of the research.

Institutional reforms in the water sector, covering enforcement of establishment of private and tradable water rights in groundwater and water supplied from public reservoirs, can together bring about significant increase in farm outputs with reduction in aggregate demand for water in agriculture. It will also bring about more equitable access to and control over the water available from canals and groundwater for producing food and to ensure household level food security. This has to be complimented by volumetric pricing of can water, and unit rate based pricing of electricity in the farm sector with due considerations to the energy requirement for pumping water. In order to realize the desired outcomes demand management and efficiency enhancement through pricing changes, quality of power supply and irrigation need to be enhanced.

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