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# NATURAL BOUNTY AND ARTIFICIAL SCARCITY :

## Population And India's Water Resources

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# H I G H L I G H T S

* India is one of the wettest nations in the world. On an average, about 120cms of rain (or snow) fall every year over India's landmass -- though it varies widely over time and space.

* **Is this water enough to provide for India's expected climax population of 1700 million people in the next century? The answer is no, if we continue to use water as we do at present.**

* Detailed calculations show that present use patterns will (i) not be able to adequately feed us, (ii) will lead to horrendous pollution of our rivers and other water bodies and create massive social and political conflicts.

* There is an urgent need for a radically new approach to water resources management, based on conservationist ethos. This will require minimizing non-irrigation demands and shifting the emphasis towards low water-consuming crops and rainfed agriculture.

* **Recognizing that water is a dispersed resource in nature, water resources management must emphasize optimal use of water where it falls -- moving away from the present focus on big irrigation projects and intensive-use to harnessing rainwater and soil moisture. Extending the use of water in rainfed areas is essential since an estimated 80 per cent of the people below to poverty line live there.**

* The new approach requires an alternative economic and political framework based on meeting the basic needs of people, ecological sustainability, decentralization and social justice.

# Natural Bounty and Artificial Scarcity: Water Resources

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The sub-title of this paper suggests a question: Does India have enough water to meet the needs of its rapidly growing population? This specific inquiry is part of a wider concern, at home and abroad, about the capacity of India's natural resources to sustain its population.

A serious analysis of the adequacy of the resource base requires (i) a knowledge of the size of the dependent population, (ii) the extent of the resources, or the land's carrying capacity; and (iii) the consumption patterns. Unfortunately, most people who talk about "population pressure" are usually only aware of the growth of population. Few people have knowledge of the country's carrying capacity. Comprehensive and reliable estimates of the carrying capacities of nations are rare because such projections are extremely complicated and uncertain. When such analyses are made, however, the results can be quite surprising.

The most comprehensive study of India's carrying capacity, with particular reference to food needs, is contained in a report "Potential Population Supporting Capacities Of Lands In The Developing World" prepared by the Food & Agriculture Organisation (FAO).[1] These estimates were made using a complex methodology of dividing the country into units on the basis of soil quality, slope, climate and availability of irrigation.

In the case of India, the FAO study concluded that in 2000 AD, assuming low levels of inputs—low-yielding varieties, no chemical inputs, long fallow periods, no long - term soil conservation measures, declining soil productivity, high labour and low energy intensity, subsistence production and fragmented land holdings—it will be able to support 1038 million people, against a projected population of 1036 million. At an intermediate level of inputs, the population supporting capacity in 2000 will be 1800 million persons. With high levels of inputs, it shoots upto 2621 million.

The sustainability of the high inputs scenario of the FAO study for India is debatable. The intermediate inputs scenario may be achieved through sustainable practices. Nevertheless, the FAO study succeeds in highlighting the fact that India's population problem, in terms of food needs, is not an insurmountable one. The real problem lies in our ability to manage two basic productive resources — soils and water.

It will be shown in this paper that India's water resources are capable of supporting the maximum number of people at which our population will stabilise, provided we use these resources intelligently. The choices we need to make and the scientific support these choices require are also discussed.

## Stationary population

According to current population projections, India's population is expected to stabilise at around 1700 million people.[2] Unfortunately, the time when the population will stabilise is not defined, though it is sometime after 2050, when India's population is expected to be about 1500 million.[3]

Again, the division between urban and rural areas is not available. Predicting the growth rate of India's urban population has been further complicated by trends in the last two decades. Between 1971 and 1981, the urban population grew at a decadal rate of 49 percent. But, between 1981 and 1991, the corresponding figure was only 34 percent. Hence it is not clear whether the urban population growth will be as rapid as expected earlier.

For purposes of calculation in this paper, India's projected stationary population of 1700 million has been divided into 700 million urban-dwellers (41.1 percent) and 1000 million rural folks (58.9 percent).

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## India's water resources

India is one of the wettest countries in the world. On an average each year, about 120 cms of rain (or snow) fall on every bit of India's landmass. The actual distribution of the rainfall, however, varies widely over space and time. The spatial extremes are represented by Cherrapunji in the northeast receiving over 1000 cm a year and Jaisalmer in the Thar desert receiving a mere 16 cm annually. Again, most of the rain comes from the Southwest monsoons during June to September. These spatial and temporal variations make regional and seasonal water shortages (and floods) an annual feature. When the prevailing political, social and economic disparities within the population are superimposed on the natural water distribution pattern, the result is an even more unjust and unfair access to water resources.

In addition to the 400 million hectare-metres (Mha-m) of rain and snow annually, we receive another 20 Mha-m from rivers flowing in from other countries. The primary distribution of the 420 Mha-m is as follows: [4]

| | | |
|---|---|---|
| Immediate evaporation from the soil | 70 | Mha-m |
| To soil moisture | 165 | Mha-m |
| To groundwater | 50 | Mha-m |
| To surface flows | 135 | Mha-m |
| Total | 420 | Mha-m |

Surface and ground water are hydrologically interlinked. Surface water at one place may become groundwater in another area and then re-emerge as surface water at yet another location. The total surface flow and groundwater availability also increases due to re-use.

## Utilisable water resources

Over the years, estimates of the maximum amount of water available for use, also called the ultimate utilisable potential, have shown a steady increase (see Table 1). While most estimates of the ultimate utilisable potential for surface water remain around 70 Mha-m, the corresponding figure for groundwater has risen almost 40 percent from 26 Mha-m to 42 Mha-m. The earlier figures for groundwater potential were mathematical estimates. The most recent figure,



Table 1

Ultimate Utilizable Water Potential Estimates (Mha-m)

| Source | Ultimate utilizable potential | Ultimate surface water potential | Ultimate ground water potential | Ultimate irrigation potential (Gross area) | Remark |
|---|---|---|---|---|---|
| Second Irrigation Commission Report (1972) | 92.7 | 66.6 | 26.1 | | As reported by M.C. Chaturvedi, 1976 |
| National Commission on Agriculture (1976) | 105.0 | 70.0 | 35.0 | 113.5 | As reported by R. Ghosh, 1987 |
| Seventh Plan Document | 93.5 | 67 | 26.5 | 113.5 | Ultimate irrigation potential will increase to 148 Mha through inter-basin transfers |
| R.B. Shah (1987) | 110.26 | 68.41 (C.W.C.) | 41.85 (C.G.W.B) | 113.5 | |
| R. Ghosh (1987) | 116.0 | 74 | 42 | 113.5 | Ultimate irrigation potential increases to 153 Mha by inter-lining of rivers |
| | | Tentative Assessment (C.W.C., 1977) | (C.G.W.B., 84-85) | | |

*Notes* : CWC - Central Water Commission, CGWB - Central Ground Water Board, SW - Surface Water, GW - Ground Water

*Sources* : See Reference at the end.

determined by the Central Ground Water Board (CGWB), though provisional, is based on surveys conducted by it (macro-level) and by state-level groundwater organisations (micro-level). Besides, it is reasonable to assume that with technological development the exploitable resources can increase.

Though the recent estimates of official sources of the ultimate utilisable potential is higher (110-116 Mha-m), for purposes of planning, it is prudent to use a lower figure. We have, therefore, adopted the figure of 105 Mha-m for the ultimate utilisable potential, as proposed by the Second Irrigation Commission.

### Ultimate water demands

Estimating water demands is tricky. Variations exist not just across specific activities — e.g., domestic use, irrigation, industry, power generation — but also within each of these water-using activities. In agriculture, for example, the amount of water required to irrigate a particular crop varies with the climate and soil type. In industry, water requirements for a specific product can vary with the production process, the size of the production unit and the unit's in-house efficiency. Simplified assumptions, therefore, have to be made. Future demands are further complicated by uncertainties in the growth rates of different water-using activities. The value of long-range demand estimates lies not in their exactness but in the indications they provide for present policies and actions.

Data for water use are of two types: (i) water withdrawn and (ii) water consumed. Thus, a factory may withdraw a certain amount of water for use. The factory's wastewater may later drain into a nearby river or lake, or leach into the ground, or may be directly applied for irrigation. The difference between the water withdrawn and the wastewater released is the water consumed. The latter figure is a better measure of the actual water demand, whereas water withdrawal figures give a better indication of the likely conflicts arising out of competing demands for a given resource.

In the rest of this section, we first determine the non-irrigation demand largely following the analysis of Shah[5] and then work out the adequacy of water available for irrigation.

### Ultimate domestic demand

*Urban:* Against the recommended urban supply of 200 litres per capita daily (lpcd), by the World Health Organisation (WHO), the supply in urban India varies from 70 to 250 lpcd for an average of 140 lpcd. For projecting future requirements, Shah suggests enhancing the WHO figure by (i) 50 lpcd for non-domestic uses and (ii) another 25 percent extra to account for losses.[6] The per capita urban domestic demand is thus taken as 310 lpcd.

*Rural:* A major inequity is revealed by the figures of water availability for household consumption in rural areas. At present the availability can be as low as a few lpcd, as for example in the arid districts or during summer months, or in pollution-affected areas. The National Technology Mission for Drinking Water Supply had set a target of 40 lpcd for rural areas, and an additional 30 lpcd in desert areas for cattle.[7] Shah raises the rural demand to 90 lpcd accounting for non-domestic uses and wastage.[8] We assume a figure of 70 lpcd for the rural population, including livestock needs. Following Shah, we make allowances for non-domestic uses and wastage. The total rural demand for the human plus livestock population is 112.5 lpcd, say, 115 lpcd or 4.2 Mha-m per annum. Shah's figure for rural demand in 2025 is 4.05 Mha-m.

The above figures are for water withdrawals. Shah puts the consumptive use at 20 per cent of the withdrawals, while other estimates reach 50 per cent.[9] Even if present trends support the latter figure, water use efficiency can be expected to increase in the future, leading to a lower consumptive use. We have chosen to give the range from 20 to 50 percent consumptive use.

The ultimate domestic demand can now be computed as follows:

| | Withdrawal Mha-m | 20% Cons. Use Mha-m | 50% Cons. Use Mha-m |
|---|---|---|---|
| Urban Domestic Demand (700 M) | 7.9 | 1.6 | 4.0 |
| Rural Domestic Demand (1000 M) | 4.2 | 0.84 | 2.1 |
| Total (1700 M) | 12.1 | 2.44 | 6.1 |
| Say, | 12.0 | 2.4 | 6.0 |

### Ultimate industrial demand

Water demands for the whole country for domestic and industrial uses were estimated by the Second Irrigation Commission at 3.0 Mha-m and 5.0 Mha-m. This suggests a ratio of 1.66:1 for industrial to domestic requirements. The proportion of industry in the GNP having increased since the Second Irrigation Commission's determination, it should offset the savings due to better water-use efficiency. Hence, for determining the water demands of industry for a stationary population, we use the ratio of 1.66:1 for industrial to domestic withdrawals.

Estimates of consumptive water use by industry range from 10 percent of withdrawals to 30 percent.[10] The Central Board for Prevention and Control of Water Pollution (CBPCWP) has given figures ranging from 14 to 33 percent consumption by different industries.[11] It may therefore be useful to set a range corresponding to high and low consumptive factors.

The ultimate industrial demand for water is:

| | Withdrawal Mha-m | Consumption 10% | (Mha-m) 30% |
|---|---|---|---|
| Industrial demand = 1.66 (Domestic demand) | 20.0 | 2.0 | 6.0 |

### Ultimate power generation demand

Power generating stations require copious amounts of water for cooling purposes. Shah has estimated future water withdrawals for power generation at almost twice the industrial demand. Estimates of consumptive use by this sector range from one percent to 10 percent.[12] The CBPCWP reports much higher consumption figures.[13] Once again, it is worthwhile to take a range covering the best and worst case scenarios. The future demand for water by power stations can now be assessed as:

| | Withdrawal Mha-m | Consumption 10% | (Mha-m) 25% |
|---|---|---|---|
| Power demand = 2 (Industrial demand) | 40.0 | 4.0 | 10.0 |

The total demand for non-irrigation purposes for a stationary population of 1700 M, therefore, is

| Non-irrigation use | Withdrawal Mha-m | Consumption Mha-m |
|---|---|---|
| Domestic demand (inc. livestock) | 12.0 | 2.4 – 6.0 |
| Industry | 20.0 | 2.0 – 6.0 |
| Power generation | 40.0 | 4.0 –10.0 |
| Total non-irrigation demand | 72.0 | 8.4 –22.0 |
| Say | 72 | 8.0 –22 |



A comparison of estimates of the non-irrigation water demand is shown in Table 2. Our estimates are higher for two reasons: (1) We are reporting figures for a higher population and (2) we have considered higher estimates of consumptive use.

Three significant inferences can be drawn from the above figures:

(1) With nearly three-quarters of the total available water (105 Mha-m) being withdrawn for non-irrigation purposes, the conflicts between rural and urban areas and between states will increase manifold. (See box: WHO IS USING INDIA'S WATER?) Hence there is need to limit the water demands through conservationist policies, to evolve clear-cut and binding rules on water apportionment between states and public education to limit water use.

(2) Efficient resource use can reduce the consumptive demand for non-irrigation uses to a third of the maximum value. This can also mitigate the conflicts mentioned above.

(3) The wastewater flow from human settlements and industrial units will increase enormously. The need for stringent pollution control measures is thus obvious. What is less obvious is that more flowing water will be needed in our rivers to help dilute the pollution loads and protect the water quality.

### Ultimate irrigable area

The total water available for irrigation will range from 83 Mha-m (105 - 22 Mha-m) to 97 Mha-m (105 - 8 Mha-m). For estimating irrigation needs, we choose to work with the worst-case scenario using the lower figure. This is an optimistic figure considering that Shah's figure for 2025 AD is only slightly higher at 85.5 Mha-m. The obvious question is: What is the level of agricultural production that can be sustained with 83 Mha-m of water available for irrigation? In the following analysis, we will estimate only the more critical foodgrains production potential by assuming that 75 percent of the total irrigated area is under foodgrains cultivation.

The availability of surface and groundwater for irrigation purposes now needs to be computed. The Second Irrigation Commission has estimated the utilisable surface and ground water resources at 70 Mha-m and 35 Mha-m, respectively. Of the latter, 15 percent (5.25 Mha-m) may be allocated to non-irrigation uses, following the Central Ground Water Board's recommendation.[14] Thus the ground

Table 2

**Estimated Sectoral Demands (Mha-m)**

| Author [a] | Domestic Demand | Industrial Demand | Power Gen. DEMAND | Livestock Demand | Total Non-Irrigation | Others | Irrigation Withdrawals | Remark |
|---|---|---|---|---|---|---|---|---|
| 4(1975) | 5.0[b] | 12.0 | 16.0 | — | 33 | — | 77 | Water withdrawal figures for 2055 AD |
| 9(1979)[d] | 3.1 | 1.0 | 0.5 | 0.9 | 5.8 | — | 77.4 | Water requirement for 2000 AD |
| 5(1986)[d] | 1.64 | 0.82 | 1.5 | 1.18 | 5.14 | 5[c] | 85.54 | Water requirement for 2025 AD |
| Ours (1991)[d] | 2.4-6.0[b] | 2.0-6.0 | 4.0-10.0 | — | 8.4-22.0 | — | 83-97 | Water requirement for 1700 M population |

*Notes* : (a)Reference number in text (b) livestock included (c) including fisheries and recreation (d) consumption figure.



water quantum available for irrigation is 29.75 Mha-m. The surface water allocations work out to be 53.25 Mha-m for irrigation and 16.75 Mha-m for non-irrigation uses.

The potential gross area that can be irrigated with 53.25 Mha-m surface water and 29.75 Mha-m of groundwater can be calculated by using a figure for the depth of irrigation, i.e., the irrigation delta. Dhawan has analysed irrigation performance in 10 canal command areas across the country. [15] Using his data, we have determined an average irrigation delta of 0.63 m for all crops in these commands. Dhawan has also cited an Indian Agricultural Research Institute (IARI) study in which recommended average irrigation deltas for all crops are given for 11 major states. [16] This averages to 0.54m. The IARI averages are aimed at maximising production by enhancing irrigated area rather than maximising yields. Shah has used irrigation delta values of 0.83 m for surface irrigation and 0.62 m for groundwater irrigation.[17]

We assume 0.63 m as an average depth of irrigation for all sources of irrigation. Thus, the potential gross irrigated area is 84.5 Mha by surface water sources and 47.2 Mha by ground water. It is well known, however, that there are conveyance and other losses in irrigation systems. Field studies of surface irrigation systems performance suggest 40 percent losses in major and medium systems. [18] The Planning Commission reports 93 percent and 94 percent utilisation for minor surface irrigation systems and ground water respectively. Assuming that the present ratio of surface irrigated areas for major and medium versus minor schemes remains unchanged, the actual irrigated area can be calculated. The results are:

| Irrigation source | Estimated ultimate actual irrigated area (Mha) |
|---|---|
| Major & Medium Surface Irrigation | 40.6 |
| Minor Surface Irrigation | 15.7 |
| Groundwater | 44.4 |
| Total | 100.7 |
| Say | 101 |

Our estimate of 101 Mha as the actual ultimate irrigable area is about 10 percent less than the standard official figure of 113 Mha (see Table 1). While we have taken the figures of water losses from field data, the official calculations are based on more optimistic estimates. Assuming an irrigation intensity of 1.3, the gross irrigated area of 101 Mha roughly corresponds to a net irrigated area of 78 Mha, leaving an area of 65 Mha under rainfed agriculture.

### Water availability

At present, about 83 percent of the irrigation water is used for foodgrain crops and the rest for non-foodgrain crops. We assume that, in the future, the ratio will remain more or less the same, say, 80:20 in favour of foodgrains. Thus the water available for irrigating lands under grains is only 66.4 Mha-m. This is a gross value. The net value, after deducting the usual losses for the different irrigation sources, is only 50.4 Mha-m. With inter-basin transfers, the corresponding figures are 84 Mha-m and 63.8 Mha-m, respectively.

## FOODGRAINS PRODUCTION POTENTIAL

### Present production patterns

We first try to estimate the ultimate production under present conditions. Currently, 75 percent of the gross irrigated area is under foodgrains while 72 percent of the rainfed area is under foodgrain crops. [19] The gross cultivated area is assumed to be 180 Mha. [20] Thus, the ultimate area under foodgrains can be calculated as:

| | | |
|---|---|---|
| Ultimate irrigated gross area under foodgrains | = | 76 Mha |
| Ultimate rainfed gross area under foodgrains | = | 57 Mha |
| Total ultimate gross area under foodgrains | = | 133 Mha |

The source-wise distribution of irrigated area in 1980-81 was 38.8 percent under canal irrigation, 46.4 percent under wells and 14.8 percent under minor or other sources. [21] Dhawan has given relative average productivities of all crops for canal, wells and tank irrigated areas for eight different states.[22] Taking account of the relative area under each source, the yield for the different sources can be expressed in terms of the yield for canal irrigation. Thus:

($\bar{y}$ wells) all crops = 1.31 ($\bar{y}$ canals) all crops average

($\bar{y}$ tanks) all crops = 0.82 ($\bar{y}$ canals) all crops average



Taking Dhawan's figures to be true for foodgrains, we have estimated the ultimate foodgrains production potential from irrigated areas at 210 MT. Assuming an average yield of 0.85 T/ha for foodgrains from rainfed areas, the ultimate foodgrains output from rainfed areas will be about 48 MT.

The total ultimate foodgrain production potential, under present production patterns of area, productivities, water use efficiency, etc — is only 258 MT. A similar calculation using productivity figures from the Bureau of Ecomomics and Statistics gives an even lower figure.

What will be the foodgrain requirements of India's stationary population ? At the 1988-89 level of foodgrains production, about 204 kg per capita annually, we will require 347 MT to feed 1700 M persons.[23] It is well known, however, that food consumption increases with economic development. The average Chinese calorific intake in 1986-88 was 2637 calories per capita daily against 2104 Cpcd for India.[24] Though Korea and Brazil have higher per capita calorific intakes, let us assume the Chinese figure to be a desirable target. It is close to the present average of 2600 Cpcd for India's high income population. In 1989, the annual per capita foodgrains consumption in China was about 279 kg.[25] To meet this target we would be required to produce 474 MT foodgrains for our stationary population.

Thus, if we continue to use our land and water resources as we do at present, we will simply not be able to meet the food needs of our climax (stationary) population.

### Enhancing land productivities

In the analyses of most officials, the ultimate irrigable area is calculated to be about 113 Mha, from surface and ground water sources (Table 1). It is then assumed that in the future field productivities will be much higher, 4 to 5 T/ha — because many other countries have achieved such levels (Table 3). The future foodgrains production potential is then placed at some desirable level. Another desired element in such strategies is the interlinking of river basins.[26] It is estimated that this will add about 26 Mha of actual irrigated lands, deducting losses for the different irrigation sources as done earlier.

The official strategy thus seems to be: more of the same. More water (through interbasin transfers), more HYV seeds, fertilisers

Table 3
**Agricultural Productivities in Different Countries (T/ha)**

| | Rice | Total Cereals | Pulses | Groundnut | Sugarcane |
|---|---|---|---|---|---|
| World | 2.3 | 2.5 | 0.8 | 1.2 | 60.4 |
| Egypt | 4.7 | 4.7 | 3.2 | — | — |
| U.S.A. | 2.3 | 3.7 | 1.7 | 2.8 | 80.6 |
| Brazil | — | 1.8 | 0.5 | 1.7 | 62.7 |
| China | 3.0 | 3.9 | 1.3 | 1.8 | 52.7 |
| India | 2.0 | 1.7 | 0.5 | 1.1 | 60.7 |

*Source:* Area & Production of Principal Crops in India 1988-89
Directorate of Economics & Statistics
Ministry of Agriculture
Govt. of India, New Delhi 1989

and pesticides. But how realistic are these guesstimates ? This can be determined by checking the water required to obtain a desired production level. This is done below.

*Productivity:* We begin by assuming three different levels of land productivities : (1) low (2) moderate and (3) high.

1) Low levels : These are the average yields already achieved in the rainfed and irrigated areas (see Table 4). For calculating production figures, we have used weighted averages for all irrigation sources, using Dhawan's data of canal commands and the relative yield relations for other irrigation sources cited earlier.
2) Moderate level: The rainfed and irrigated areas yields for rice, wheat, coarse cereals and pulses are the maximum statewide yields reported from field data at present. [27] These are shown in Table 4.
3) High level: The irrigated yields correspond to the best values achieved on experimental farms in India so far. [28] The rainfed yields are enhanced proportionately over the moderate yield levels for rainfed areas. The rainfed and irrigated productivities for different foodgrains are shown in Table 4.

*Areas:* We assume that the relative areas allocated for the different foodgrains remain the same as at present. The relative allocations are:



| | Rainfed Areas (%) | Irrigated Areas (%) |
|---|---|---|
| Rice | 27 | 43 |
| Wheat | 6 | 45 |
| Coarse Cereals | 42 | 8 |
| Pulses | 25 | 5 |
| Total | 100 | 100 |

The gross irrigated area without inter-basin transfers for foodgrains is 76 Mha, with inter-basin transfers it is supposed to go up to 95 Mha.

*Production:* The production levels attainable under different levels of productivity and total irrigation are summarised later.

*Water demand:* We have followed so far the method of official experts in calculating the production potential on the basis of the irrigable area. To check on how realistic these figures are, we calculate the corresponding water demands. The results are shown on next page:

Table 4:
**Yields for different Crops in India (T/ha)**

| | Average Actual Yield (1984-89) Rainfed | Irrigated | Farm Maximum Achieved (1984-89) Rainfed | Irrigated* | Potential Yield (Experimental Plots) irrigated |
|---|---|---|---|---|---|
| Rice | 1.1 | 2.9 | 2.6 | 3.3 | 5.8 |
| Wheat | 1.0 | 2.3 | 2.0 | 3.6 | 6.8 |
| Coarse Cereals | 0.8 | 1.7 | 1.5 | 2.6 | 4.9 |
| Pulses | 0.6 | 1.0 | 0.9 | 1.4 | 2.5 |

*Notes* : *Average yields of crops in 10 canal command areas across the country. (Source 1)

*Sources:* 1. B.D. Dhawan *Studies in Irrigation Management*, Commonwealth Publishers, New Delhi 1989
2. Area & Production of Principal Crops in India 1988-89, Directorate of Economics & Statistics, Ministry of Agriculture, GOI, New Delhi, 1989.
3. Basic Statistics, All India, Vol. I, Centre for Monitoring Indian Economy, Bombay, 1988.

Total foodgrains production potential (MT)

| | Non-Interlinked Basins | | | Interlinked Basins | | |
|---|---|---|---|---|---|---|
| | Low yield level | Mod yield level | High yield level | Low yield level | Mod yield level | High yield level |
| Rainfed Prod. | 48 | 95 | 171 | 32 | 63 | 115 |
| Irr. Prod. | 210 | 251 | 460 | 259 | 310 | 568 |
| Total | 258 | 346 | 631 | 291 | 373 | 683 |
| Water Demand (Mha-m) | 64 | 74 | 135 | 79 | 92 | 168 |
| Net Water Available (Mha-m) | 50.4 | 50.4 | 50.4 | 63.8 | 63.8 | 63.8 |

**Note:** Rainfed area is less under interlinked basins.

The above table reveals that in each production scenario, the irrigation water demand exceeds the net irrigation water available. Thus under present conditions of foodgrain yields per hectare and water use efficiency, India will not be able to meet the above production potentials of the land, since the water available for irrigating food growing farms is simply not enough. The limiting factor for achieving desired foodgrains production, from a minimum of 347 MT to a maximum of 474 MT, is thus water, not land.( See also Figure 1a and 1b)

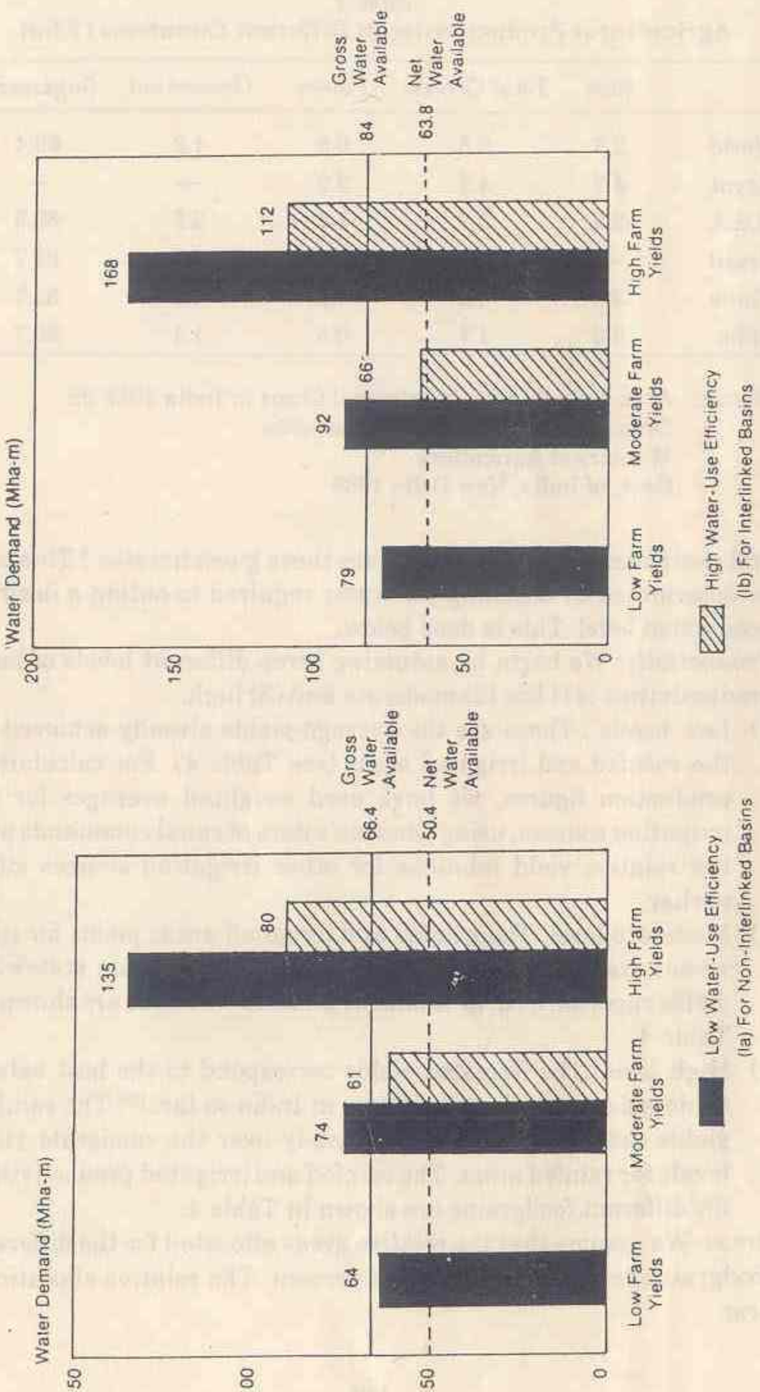
## Impact of water-use efficiencies

A better assumption, however, will be that along with increases in farm productivities, water-use efficiencies will also be enhanced. Accordingly, we assume that moderate level yields can be reached with an irrigation depth of 75 cm against the earlier assumed value of 63 cm.[29] The increase in water-use efficiencies (reflected by this assumption) for different crops are: rice 10 percent, wheat 36 percent, coarse cereals 18 percent and pulses 45 percent. The new water demands are shown in figures 1a and 1b for the moderate-yield levels.

We can assume further enhancements in water use efficiencies by the time high yields are reached, say, a uniform increase of 50 per cent in water use for all foodgrains. The final demands are shown for high productivity levels, in figures 1a and 1b.



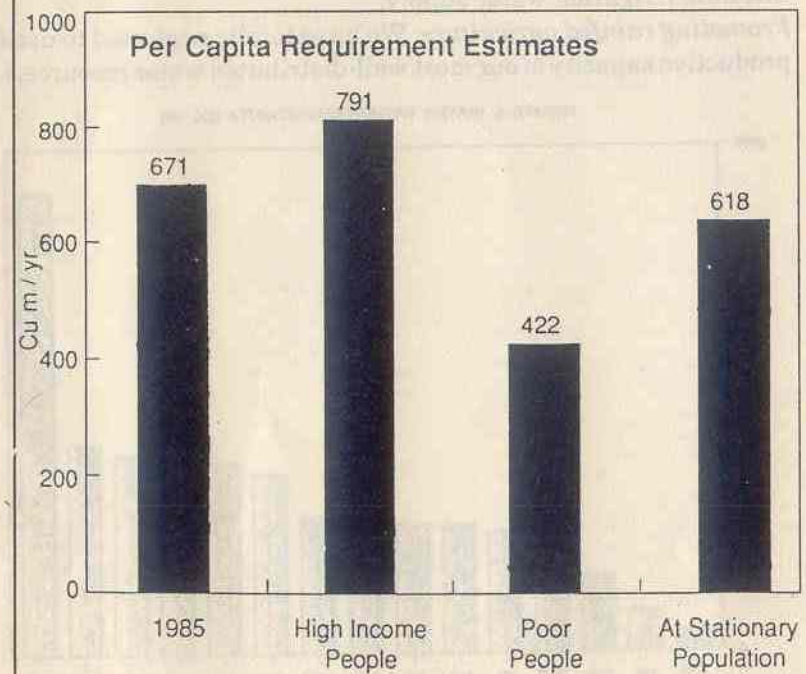
FIGURE 1. WATER DEMAND SCENARIOS



## Who is Using India's Water

Each time the flush handle is yanked in an average urban Indian home, the cntire daily consumption of an arid zone dweller in India goes down the drain. In general, an urban high-income person (HIP) eats more food (calorific intake 2600 kcpcd), uses more industrial products, more power and more water during a day than a poor person (calorific intake 2000 kcpcd). We have estimated the per capita water demand to provide for food intakes and assumed the consumptive water requirement (50%) of withdrawal) for domestic consumption at 155 lpcd for the urban HIP and 20 lpcd for the poor person. Allocations of water for industrial and power demands are proportionately made, as in the text. The annual demands are in the ratio of nearly 2:1 for the HIP to the poor person (see figure below).

It is ironic that our planners are struggling to find 10 or 20 or 30 ipcd extra water for rural areas. The bulk of the human need is for growing good. If our diet shifts from the present average diet to the more nutritious diet (Table 5) the per capita water saving is 400 litres per day.






The results in figures 1a and 1b show that the high land productivity scenario is unrealistic, due to inadequacy of irrigation water. The moderate land productivity scenario is feasible only if the irrigation water losses are lower than today, i.e., the net irrigation water for foodgrain crops is more than the levels shown in figures 1a and 1b, or by combining it with high water use efficiencies.

The actual foodgrain production that can be achieved, within the constraints of available water, from interlinked and non-interlinked river basins are shown in figures 2a and 2b. Figure 2b makes clear the attraction of the interlinked basins strategy for our irrigation planners.

The results shown in Figures 1a, 1b, 2a and 2b lead to the following conclusions:

(1) At current farm yield levels, we cannot expect to provide even the presently available amounts of food to India's stationary population in the next century.

(2) We need to attain at least moderate land productivity goals (equal to the best statewide productivities today) to provide the present levels of foodgrains to India's climax population. This must be combined with moderate enhancements in water use efficiencies and lower conveyance losses in irrigation, or there will not be adequate carry-over stocks to tide over poor rainfall years.

(3) None of the above scenarios enable us to reach the nutritional levels available to the Chinese population today.

(4) Ultimately, the maximum output we obtain from our land is limited by the amount of water available for irrigation.

(5) We have to pay more attention to the rainfed areas. Significantly higher yields have to be obtained from rainfed areas to achieve the levels in figures 2a and 2b.

(6) The additional gains from river basin transfers are unlikely to be worth the cost.

(7) Even the above levels of production may be difficult to reach due to the non-sustainable aspects of present irrigation practices. Thus, for example, (i) a quarter to half of all the irrigated areas may become permanently uncultivable due to soil salinity and water-logging;[30] (ii) several Mha-m of groundwater may be lost due to overexploitation of acquifers and (iii) loss of soil fertiliity due to shift away from fertility-building crops like moong beans and chickpeas.[31]

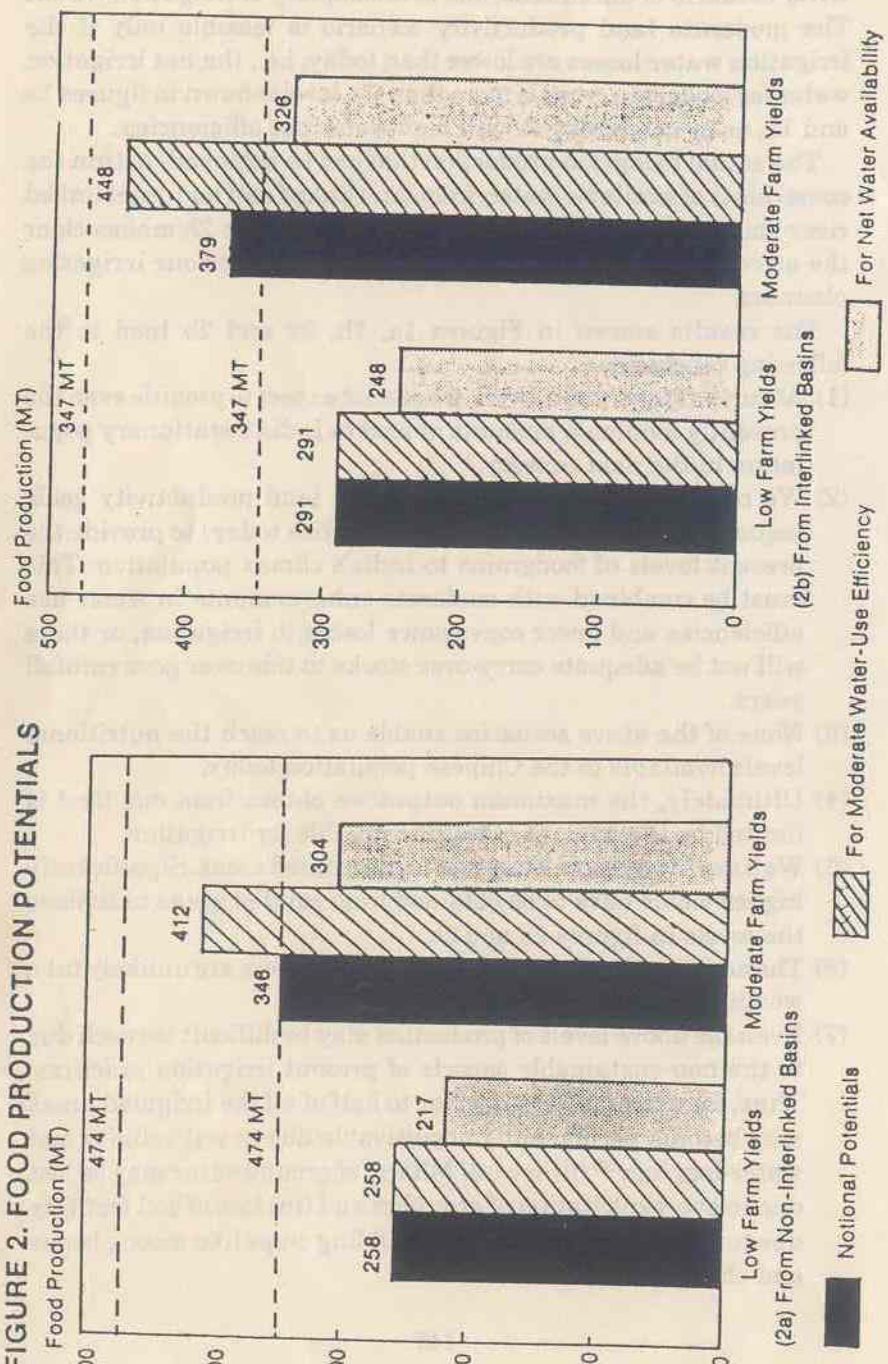



FIGURE 2. FOOD PRODUCTION POTENTIALS



If a quarter of the irrigated lands go out of cultivation, providing today's per capita food availability will become difficult.

Hence a radically different approach to water resources management becomes imperative.

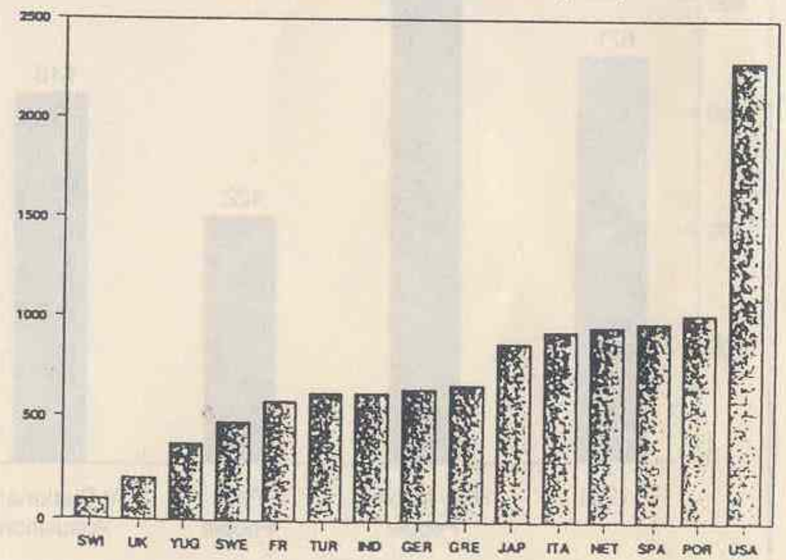
## A desirable approach

*Reducing non-irrigation demands:* India is among the more profligate water users in the world today (see figure 3). Major savings can be effected in the industrial and power generation sectors. There is enough evidence to show that Indian industries use water very inefficiently. For example, water use per tonne of paper produced in India is estimated to be more than two times as much as in the USA.[32] A rough indication of the relative water-use inefficiency in Indian industries is evident in figure 4.

The estimates for non-irrigation consumptive water use show that more efficient water utilisation in these sectors can increase the available water by upto 14 Mha-m, a 17 percent increase in the ultimate irrigation water supply.

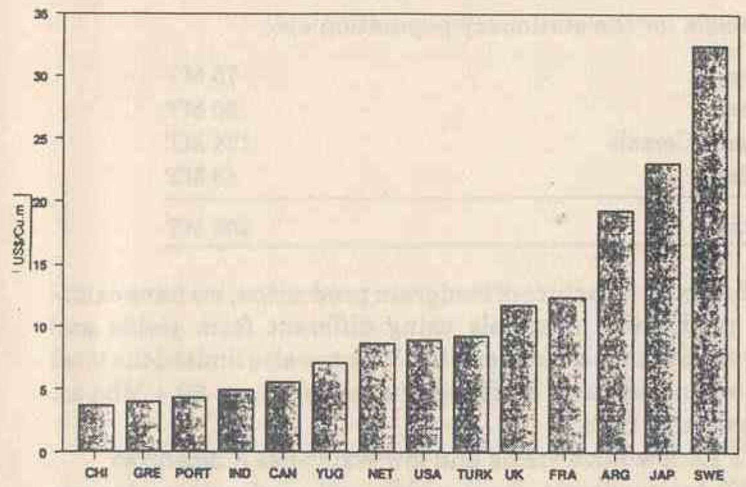
*Promoting rainfed agriculture:* We have totally neglected to use the productive capacity of our most well-distributed water resource, i.e.,

FIGURE 3. WATER WITHDRAWAL/CAPITA (Cu. m)




SOURCE : World Resources 1987, World Resources Institute, New York.
For India — R. B. SHAH : Water Resources Development, Scenario for India, in commemorative Volume, CBIP, New Delhi, 1987.

FIGURE 4. INDUST. GDP/UNIT IND. WATER WITHDRAWAL




SOURCE : For Indust. GDP (1) *World Development Report 1984*, The World Bank, Washington, Table 3, pp 222 (2) *World Development Report 1988*, The World Bank Washington, Table 3, pp 226.
For Indust. Water Withdrawal (3) *World Resources, 1988-89*, World Resources Institute, New York, Table 21.1, pp 318-319.
For India (4) R. B. 3 SHAH : Water Resources Development Scenario for India, In Commemorative Volume, CBIP, New Delhi, 1987

soil moisture. Nearly 120 Mha-m out of the annual rainfall of 400 Mha-m is locked up as soil moisture.[33] Maximising water use where it falls saves enormous amounts of energy and money. Future production increases must come from rainfed areas, where an estimated 80 percent of the population below the poverty line live.[34]

Developing rainfed lands on a watershed basis appears to be the most useful approach to enhancing their yields. Special attention needs to be given to rainfed areas with high rainfall, since their yield potential is as high as in the irrigated areas. A review of the results obtained by the Central Soil & Water Conservation Research & Training Institute's stations in different parts of the country reveals the high potential of water harvesting and good farm management practices.[35] Among the results of using harvested rainwater are the following:

| Location | % Yield Increase | Crop |
|---|---|---|
| Ambala | 100-200 | Not specified |
| Dehradun | 80-88 | Wheat & paddy |
| Chandigarh | > 200 | Wheat |
| | 100 | Mustard |
| Kota | 80 | Wheat |

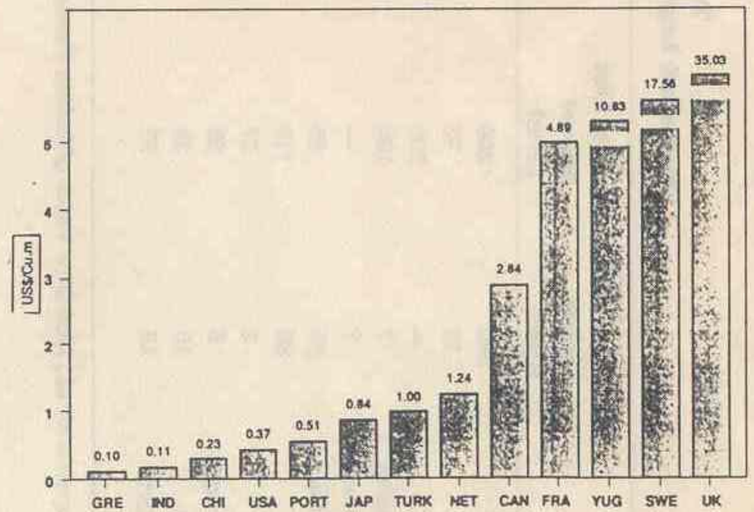


*Enhancing irrigation efficiencies:* Water-use efficiencies in Indian farms range from 2000 to 3000 tonnes of water per tonne of foodgrains produced. An indication of the economic productivity of water use in Indian agriculture, relative to other nations, is given in figure 5. A field study estimates that 60 percent of the farmers irrigating rice fields apply excessive water.[36] The pattern in wheat fields is also similar.

*Extending water use:* Water saved by better irrigation efficiencies can be used to irrigate larger land areas, or for ecological protective functions. There is a need to achieve a better balance between intensive and extensive irrigation patterns. The latter will service a larger farming population.

Water use can also be extended by growing low water-consuming crops over larger areas. In the case of foodgrains, this would mean cultivating more coarse cereals in place of wheat and rice. Such a shift is also desirable from a nutritional point of view.[37] Table 5 shows a comparison between an average and an improved Indian diet. Using the figures for foodgrains consumption in the improved

FIGURE 5. AGRL GDP/UNIT IRRG WITHDRAWAL




SOURCE : For Agrl. GDP (1) *World Development Report 1984*, The World Bank, Washington, Table 3, pp 222 (2) *World Development Report 1988*, The World Bank Washington, Table 3, pp 226.
For Agrl. Water Withdrawal (3) *World Resources, 1988-89*, World Resources Institute, New York, Table 21.1, pp 318-319.
For India (4) R. B. 3 SHAH : Water Resources Development Scenario for India, In Commemorative Volume, CBIP, New Delhi, 1987

Table 5

**Average & Improved Indian Diets**

| Foods | Average Diet Amount (Gms) | Improved Diet Amount (Gms) | Nutrient | Average Diet Amount | Improved Diet Amount |
|---|---|---|---|---|---|
| Cereals | 540 | 200 | Protein | 57 gms | 66 gms |
| Pulses | 12 | 70 | Fat | 24 gms | 50 gms |
| Millets | — | 200 | Carbohydrate | 490 gms | 430 gms |
| Leafy vegetables | 7 | 100 | Calories | 2,400 | 2,430 |
| Roots and tubers | 7 | — | Calcium | 360 mg | 0.8 gm |
| Other vegetables | 85 | 85 | Iron | 24 mg | 40 mg |
| Milk | 80 | 170 | Phosphorus | — | 1.4 gms |
| Fruits | 5 | 57 | Vitamin A value | 340 μg | 960 μg |
| Meat, fish & eggs | 5 | 28 | Thiamine | 0.7 mg | — |
| Oils and fats | 15 | 28 | Riboflavin | 0.6 mg | — |
| Sugar & jaggery | 13 | 57 | Vitamin B | — | 1.8 mg |
| | | | Vitamin C | — | 200 mg |

*Source:* C Gopalan et. al., *Nutritive Value of Indian Foods*, National of Nutrition, ICMR, Hyderabad, 1987.



diet, the needs for the stationary population are:

| | |
|---|---|
| Rice | 75 MT |
| Wheat | 50 MT |
| Coarse Cereals | 124 MT |
| Pulses | 43 MT |
| Total | 292 MT |

Given the above structure of foodgrain production, we have calculated the production potentials using different farm yields and water-use efficiencies, as done earlier. We have also limited the total irrigation water available for foodgrain production to 50.4 Mha-m. The figures range from :

— 228 MT for low farm yields and low water-use efficiencies

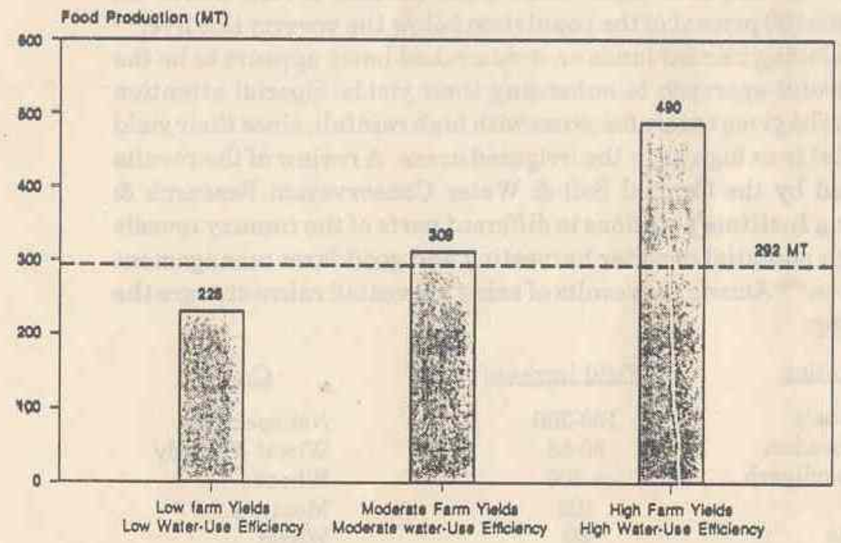
— 309 MT for moderate farm yields and moderate water-use efficiencies.

— 490 MT for high farm yields and high water -use efficiencies.

The results are plotted in Figure 6. The results show that:

(1) The nutritional needs can be met at moderate farm yields and water efficiencies

**FIGURE 6. IMPACT OF CHANGING CROPPING PATTERN ON FOOD PRODUCTION POTENTIALS**




NOTES : Food Production Potentials are at net Water Available

Table 6

**Outlay and Development of Irrigation Potential**

| | Outlay/Expenditure (Rs. in crores) | | Irrig. Potential Cumulative (Million hectares) | | |
|---|---|---|---|---|---|
| | Major and medium irrig. | Minor irrig. | Major and Medium irrig. | Minor irrig. | Total |
| Pre-Plan benefits | * | | 9.7 | 12.9 | 22.6 |
| First Plan | 380 | 66 | 12.20 | 14.06 | 26.26 |
| Second Plan | 380 | 142 | 14.30 | 14.9 | 29.09 |
| Third Plan | 581 | 328 | 16.06 | 17.01 | 33.61 |
| Annual Plan (66-69) | 434 | 326 | 18.10 | 19.00 | 37.10 |
| Fourth Plan (69-74) | 1237[b] | 513 | 20.70 | 23.50 | 44.20 |
| Fifth Plan (74-78) | 2442[a] | 631 | 24.82 | 27.30 | 52.12 |
| Annual Plan (78-79) | 977 | 237 | 25.86 | 28.60 | 54.46 |
| Annual Plan (79-80) | 1079 | 260 | 26.60 | 30.00 | 56.60 |
| Sixth Plan (80-85) | 7516 | 1802 | 30.50 | 37.40 | 67.90 |
| Seventh Plan (85-90) | 11556 | 2805 | 34.8 | 46.0 | 30.8 |

* Includes Rs. 80 crores incurred during the pre-plan period.
(b) Excludes Plan outlay of Rs. 50.54 crores on unapproved Cauvery basin projects.
(a) Excludes non-Plan outlay of Rs 52.24 crores on unapproval Cauvery Basin projects.
*Source:*(1) Seventh Five Year Plan 1985-90, Vol. II, Planning Commission, GOI, New Delhi, 1985.



(2) With high farm yields and efficiencies we can provide more food and better nutrition.
(3) The land and water required are within the net area and volume available respectively.
(4) If irrigation losses can be cut, extra water can be saved for productive or ecological protection purposes, e.g., flushing polluted rivers, flooding wetlands and conserving groundwater, particularly in drought-prone areas.

It is now obvious that changing cropping patterns is the most effective way of extending water use, meeting the nation's future food needs and nutritional requirements.

## Need for a new policy framework

Since independence the main thrust in developing India's water resources has been on the creation of large storage capacities, i.e., big dams. A secondary focus has been on the exploitation of groundwater resources. In contrast, land and water management practices to maximise soil productivity and water-use efficiencies have been largely ignored.[38]

It is estimated that nearly 15 percent of all the planned development expenditure has been on major and medium (M&M) surface water projects.[39] Between 1951 and 1985, a total of over Rs.15026 crore were spent on M&M projects, as against Rs.4305 crore on minor irrigation.[40] The investment disparity has been maintained during the Seventh Plan period, 1985-90, and in all probability will continue through the Eighth Plan period (see Table 7). In contrast, very little has been spent on soil and water conservation or Command Area Development (CAD) programmes. Thus, between 1951 and 1985, only Rs.2723 crore were spent on forestry and soil and water conservation.[41] As against over Rs.26000 crore allocated in the draft Eighth Plan to M&M schemes, only Rs.2500 crore have been allocated for CAD programmes.[42]

Many M&M schemes are multipurpose projects designed to provide irrigation water, generate power and control floods. On all three counts, the actual benefits have fallen far short of the intended benefits. These have been reviewed extensively elsewhere. The main criticisms focus on their costs, poor productivities, degradation of the environment, sustainability and equity.

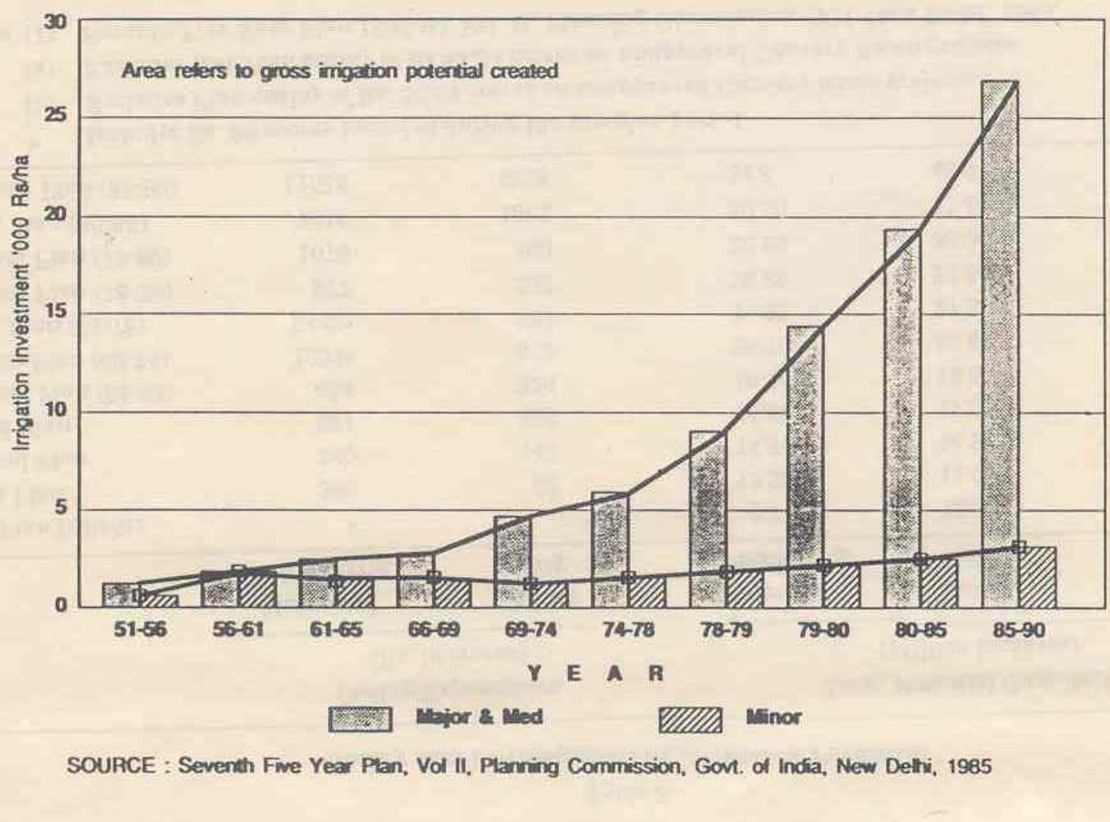
Table 7

**Conventional Development versus Alternate Development**

| Characteristic | Conventional Development Strategy | Alternate Development Strategy |
|---|---|---|
| Engine of Development | Industrialization | Meeting the Basic Needs of the Common People and Conflict Resolution |
| Central Thesis | Maximizing the monetary wealth of the nation | Development on a sustainable basis with social justice. |
| Assumptions | Wealth of the nation will trickle down to the poorest | — |
| Decision-Making | Centralized, non-participatory | Decentralised, participatory |
| Resource Distribution | Transfer of resources from poor to the rich, rural to urban areas. | Resource sharing through employment and distribution of means of production |
| Knowledge Systems | Downgrades traditional knowledge in favour of 'modernism' | Builds on traditional knowledge |
| Relationship with nature | Antithetical, emphasizes mono-cultures | Harmonious, recognizes strength in diversity |



FIGURE 7. PLAN INVESTMENTS IN IRRIGATION




SOURCE : Seventh Five Year Plan, Vol II, Planning Commission, Govt. of India, New Delhi, 1985

Despite these shortcomings, there is little indication that water resources development planners are moving away from their focus on major and medium projects. This is evident from the break-up of the outlay in the Eighth Plan, mentioned earlier, and from the growing pressure for inter-basin water transfers in the future.

The logic of the current water management strategy is derived from the present economic development model. This model proposes that the goal of economic development should be to maximise the wealth of a nation and that this can be done by maximising the ratio of the monetary value of the national output to that of the inputs. (It also assumes that somehow this wealth will trickle down to the last person, hence the common name "trickle-down" model.) Unfortunately, this strategy cannot feed India's future population.

The current approach to water resources management is biased in favour of centralised management. Again, the logic flows from a highly centralised model of development planning and governance. But water is a dispersed natural resource and is meant to be so used. (It is not hard to see that our cultural diversities are a reflection of natural diversities - many of them spring from the variations in water availability.) By maximising the harnessing of rainwater, it is possible to support a comfortable lifestyle even in semi-arid and arid regions.

The alternative approach of promoting the cultivation of low water-consuming crops, suggested above, is in conflict with the present economic development model. Coarse cereals fetch low prices. In economic terms, they are "inferior goods". Raising their market value becomes difficult because of possible consumer resistance. (Hence there is a need for public education to highlight the value of a nutritious diet.)

By extending irrigation facilities to more farmers, while reducing its intensity, and by emphasising rainfed agriculture, the alternative cropping pattern promotes the concepts of sustainability and equity. It has been argued that sustainability, equity and participatory democracy do not fit in easily with this economic model.[44] Hence an alternative economic development framework is needed. The principles of an alternative economic development model are outlined — and contrasted with the present model — in Table 7.

Once an appropriate development framework has been defined, the new water resources management approach will require the following thrusts:



(1) Scientific research on (a) production processes to conserve water use in the non-irrigation sectors; (b) enhancing productivities through soil and water management on rainfed agricultural lands, and (c) watershed development in different agro-ecological regions.

(2) A decentralised approach to natural resources management.

(3) Public education to promote consumer preference for a nutritious diet.

We stand today at the edge of a new century. This is an opportune time to review the past and forge a new, more just future.

## Conclusion

In our paper, we have focused our effort on determining the carrying capacity of India's water resources. Our analysis shows that the current approach to water resources management will greatly enhance conflicts over water use and will not be able to fulfill the food demand of India's climax population in the next century. Its sustainability is also doubtful.

There is, therefore, an urgent need to adopt a radically new approach to water resources management, based on a conservationist ethos. This will require minimising non-irrigation demands and shifting emphasis towards low water-consuming crops and rainfed agriculture. We have shown that, by doing so, it is possible to provide for the food and nutrition demands of the climax population.

The value of our analysis is not so much in the exactness of the numerical results, as in the issues it highlights. Thus, once the basic requirement of 292 MT of foodgrains for the improved diet is adequately met, the remaining water can be used for producing more fine cereals or vegetables rather than simply striving to attain a numerical target of, say, 490 MT — the high productivity figure. The shift in the cropping pattern is accompanied by a significant reliance on rainfed agricultural lands. Recognising that water is a dispersed resource in nature, water resources management must emphasise optimisation of the use of rainwater where it falls, i.e., moving away from the present focus on big irrigation projects.

India is one of the wettest nations in the world. If we cannot manage within this bounty, then who can?

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## APPENDIX

**Abbreviations Used**

| | | |
|---|---|---|
| CHI | — | China |
| SWI | — | Switzerland |
| UK | — | United Kingdom |
| YUG | — | Yugoslavia |
| SWE | — | Sweden |
| FR/FRA | — | France |
| TUR/TURK | — | Turkey |
| IND | — | India |
| GER | — | Germany |
| GRE | — | Greece |
| JAP | — | Japan |
| ITA | — | Italy |
| NET | — | Netherlands |
| SPA | — | Spain |
| POR/PORT | — | Portugal |
| USA | — | United States of America |
| CAN | — | Canada |
| ARG | — | Argentina |