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Water for Food and Rural Development
Developing Countries

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Abstract: *The use of water for food production accounts for about 75 percent of the total withdrawal in developing countries and is crucial for sustenance. It is also important for addressing poverty and rural development. With developing countries endeavoring to enter the mainstream of development, a formidable challenge in water resources development, resource use efficiency and environmental conservation is faced by these countries, in which management of water for food will continue to remain prominent. A review of the current state of the sector in the developing countries is presented with a brief case study in India for realism. It is clear that although considerable development in the area has occurred, there are serious policy, engineering, environmental and management deficiencies. Approaches for modernisation of the sector are suggested in terms of quantum change in concepts, policies, planning approaches, institutions. and attitudes. Approaches for implementation are proposed.*

Keywords: *Irrigation, developing countries, water for food, environmental systems management, sustainable development.*

Introduction

The developing countries face the very serious challenges of natural resource constraints and environmental degradation as they try to enter the mainstream of industrial development. As has been pointed out, the average per capita GNP of the developing and the industrialised countries is about $1,000 and $21,000, respectively. With the doubling of the population, the developing countries will constitute about 85 percent of the world's population, abd will have to increase their use of resources by a factor of almost 36 (21x2x0.85). Therefore, to avoid increasing damage to the environment, they would need to boost resource-use efficiency by the same factor (Daly, 1993). Their position may not be that bad due to sectoral changes in the economy, but the fact remains that a very formidable natural resource/environmental challenge is faced by the developing countries, the situation being even worse for the countries that are even lower down on the scale, which includes the two largest ones India and China, accounting for about 40 percent of the world population.

Management of water for agriculture is of particular importance in developing countries for several reasons. About 75 percent of the population lives in villages and is dependent for subsistence and employment on agriculture. Accelerated agricultural growth is crucial for reducing the incidence of poverty, lowering of unemployment and contributing to socio-economic development. Food self-sufficiency is imperative globally in each country and (if resource availability permits the possibility), as the poor countries often do not have trading capability. Efficient irrigation, implying adequate, reliable and timely supplies of water is, thus, crucial for food sufficiency, modern agriculture, and rural development. Therefore, the issue of water for food is extremely important for developing countries. Further, it must be enlarged to include issues of rural development, as in the past irrigation has generally been developed to stabilise sustenance agriculture in developing countries without much concern for socio-economic development.

A long-term perspective of development has to be worked out as implementation takes time. Further, sustainability also demands a long-term perspective. Our focus of study, therefore, is to develop a vision and policy, and approaches for their implementation. In this context, a brief historical overview and the current state are presented as a background. It is briefly analysed, with a brief presentation of an Indian scenario as an example, which represents one of the largest developments in this area. Much has been written on the subject. It will be seen that our vision, policy and plan is slightly different.

Historical Perspective

Civilizations developed in regions endowed with fertile land and adequate water where agriculture was established over a period of time. The leading areas were India, China, the Fertile Crescent, and Egypt. There were both rainfed agriculture and irrigated agriculture. Quasi-stable population size and socio-economic development were established, corresponding to socio-technological development particularly in the area of water management and agriculture. Irrigation, however, was supplemental to rain and it could neither provide assurance against the vagaries of nature, or ensure high yields. Famines and droughts were common.

A new dimension was introduced in irrigation when the colonial powers took control of the old civilizations, particularly with the establishment of British rule in India (Framji et al., 1981; Stone, 1984; Chaturvedi, 1985). The conditions were particularly favourable to the introduction of canal irrigation on a large scale, which had several benefits. It was remunerative, contributed to to mitigation of famines thereby promoting law and order, and established the role of the reigning power (Chaturvedi, 1985). Starting with the large colonial countries like British India, a culture of colonial canal irrigation was introduced in the developing countries, which were mostly under colonial rule. The scale, quality of irrigation, technology and management differed from region to region depending upon environmental and socio-economic conditions, but in general, a poor quality irrigation, neither adequate, timely or reliable, was provided, to stabilize the sustenance agriculture of these countries. China also has a long history of irrigation and large parts of agricultural areas were irrigated in some form, although estimates are uncertain (Vermier, 1977). The irrigation in China was also of the same type for the same reasons. By the time of independence of these countries in about 1950, about 96 million ha of cultivated area was irrigated, mostly in the developing countries, but also in the United States.

Water resources development was also being undertaken in the western world in this period. Large-scale development was undertaken in the US from the late 19th and early 20th centuries for navigation, flood control and other purposes. Advances in the science, and particularly, the art of engineering were made and several impressive multipurpose dams were constructed. Socio-economic conditions were also different and advances in the agriculture sector were also taking place, which demanded reliable, adequate and timely water supplies and not poor quality of irrigation as introduced by the colonial powers in the developing countries. Thus, two types of water resources development had been introduced; one in the First World and another in the Third World.

The third phase of water resources development in the developing countries started after these countries achieved their Independence. Inspired by the achievements in the US, large-scale development was undertaken. By 1995, an area of 225.5 million hectares had been brought under irrigation predominantly in developing countries, with India, China, the United States and Pakistan each with an area of 50.1, 49.8, 21.4, and 17.2 million hectares, respectively, accounting for about 54 percent of the irrigated area. Additional statistical data are shown in Table 1 and Table 2.

However, this was not modernization but an extension of the Third World irrigation as low yields and increasing environmental degradation demonstrate. Paradoxically, advances in the hydrosciences and systems planning have taken place only recently and these have been internalized even in the First World only to a limited extent (Hall and Dracup, 1970; L'vovich and White, 1990).

Water resources development for food continues to occupy an important position but the euphoria of the past has mellowed down because of several factors (Postel, 1992). Future development will be increasingly difficult technologically and increasingly more costly. Environmental concerns require more refined treatment and often those issues are addressed with a fundamentalistic fervour leading to wasteful delays. The challenge of sustainable development is also being realized gradually, resulting in more costly, though, scientific, development.

Table 1. Irrigation Areas by Continent (10^6 ha)

Continent	*1900*	*1940*	*1950*	*1960*	*1970*	*1985*	*2000*
Europe	3.5	8	10	21	30	30	45
Asia	30	50	65	135	170	220	300
Africa	2.5	4	5	7	9	12	18
North America	4	9	13	17	25	32	35
South America	0.5	1.5	3	5	7	10	15
Australia and Oceania	0	3.0	0.5	1	1.4	2.2	3

Source: Framji et al., 1981.

Table 2. Net Irrigated Area, Top 20 Countries and World, 1989

Country	*Net Irrigated Area (thousand hectares)*	*Share of Cropland That is Irrigated (%)*	*Irrigated Food Production/Total Food Production (%)*
China	45,349	47	70
India	43,039	25	55
Soviet Union	21,064	9	-
United States	20,162	11	-
Pakistan	16,220	78	80
Indonesia	7,550	36	50
Iran	5,750	39	-
Mexico	5,150	21	-
Thailand	4,230	19	-
Romania	3,450	33	-
Spain	3,360	17	-
Italy	3,100	26	-
Japan	2,868	62	-
Bangladesh	2,738	29	-
Brazil	2,700	3	-
Afghanistan	2,660	33	-
Egypt	2,585	100	-
Iraq	2,550	47	-
Turkey	2,220	8	-
Sudan	1,890	15	-
Other	36,664	7	-
World	235,299	16	-

Source: Postel, 1992. The figures for food production are from Rangley (1987). (-) = data not available.

Comparative Global Scene

The socio-economic, political and environmental conditions vary considerably in the developing countries. To arrive at a meaningful consideration, besides considering the current state and futures issues in each country, it is helpful to group the countries on some reasonable basis. Since the problem of water shortage will be an important consideration, it may be in order to adopt the grouping on this basis. Several criteria have been proposed (Falkenmark et al, 1989; Raskin et al., 1997), but as discussed by Seckler et al.(1998), good criteria would be (i) the percent increase in water "withdrawals" over the 1990 to 2025 period, and (ii) water withdrawals in 2025 as a percentage of the "Annual Water Resources" (AWR) of the country, which has also been followed here. Because of their enormous populations and water use, combined with extreme variations within these countries, India and China were considered separately. The 116 remaining countries were classified into five groups according to these criteria as shown in Figure 1. The grouping, generally, also reflects climatic-hydrologic and socio-economic homogeneity.

The countries in each group are as follows:

- Group 1: Libya, Saudi Arabia, UAE, Kuwait, Oman, Jordan, Yemen, Israel, Afghanistan, Egypt, Tunisia, Iraq, Singapore, Iran, Syria, Pakistan, and South Africa.
- Group 2: Congo, Zaire, Gabon, Niger, Cameroon, Côte d'Ivoire, Botswana, Lesotho, Burundi, Guinea-Bissau, Uganda, Nigeria, Ghana, Benin, Angola, Haiti, Mozambique, Liberia, Somalia, Sudan, Paraguay, Ethiopia, Chad, and Burkino Faso.
- Group 3: Nicaragua, Central African Republic, Tanzania, Guinea, Nepal, Peru, Kenya, Guatemala, Senegal, Mali, Bolivia, Turkey, Zimbabwe, Namibia, Colombia, Zambia, Brazil, Venezuela, Algeria, Australia, Cambodia, Gambia, Madagascar, Indonesia, Malaysia, Belize, Albania, Morocco, Honduras, New Zealand, Myanmar, Mauritania, El Salvador, Lebanon, and Chile.
- Group 4: Canada, USA, Philippines, Jamaica, Switzerland, Sweden, Vietnam, Ecuador, Norway, Poland, Mexico, France, Argentina, Greece, Austria, Bangladesh, Belgium, Costa Rica, and Dominican Republic.
- Group 5: South Korea, Denmark, UK, North Korea, Panama, Sri Lanka, Romania, Netherlands, Thailand, Spain, Cuba, Germany, Bulgaria, Finland, Surinam, Portugal, Uruguay, Hungary, Japan, Guyana, and Italy.

Some salient characteristics of development and future outlook for each group are given in Table 3. A more detailed perspective of some large countries, principally developing ones, but also some advanced ones for contrast is given in Table 4.

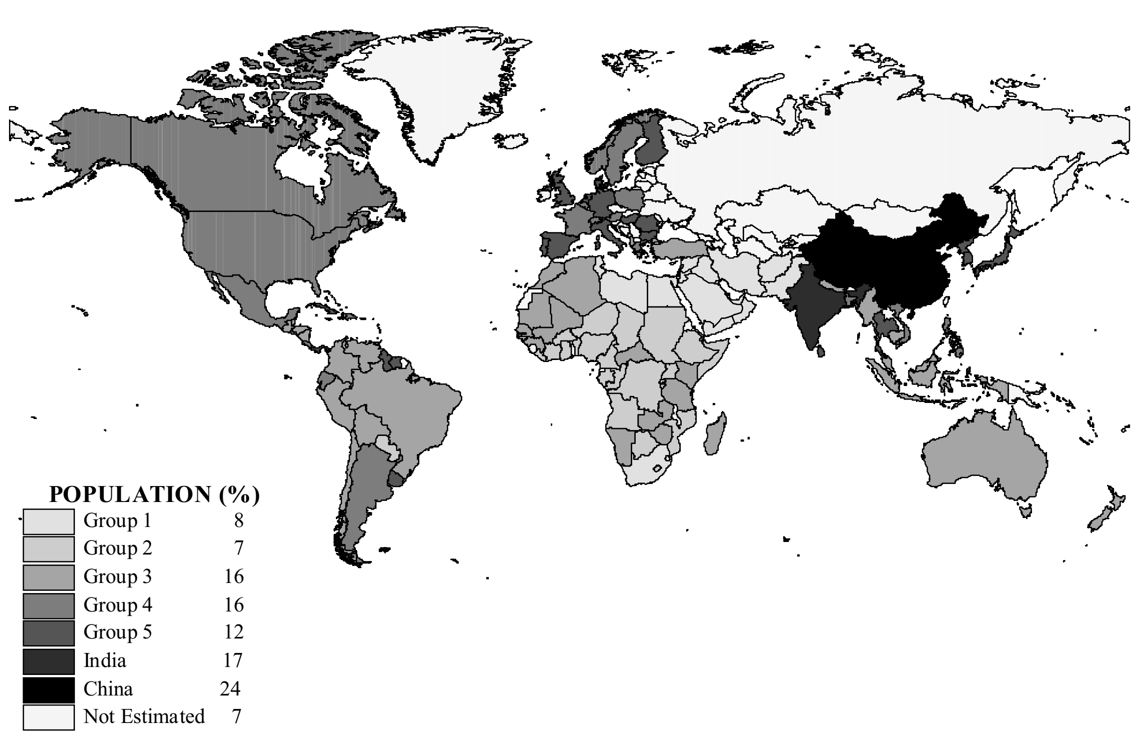

Figure 1. IWMI indicator of relative water scarcity. Percentages for India, China, and the five groups are based on the total population of the countries studied. Percentage of "not estimated" category is based on the world population.

Table 3. Some Salient Statistics of Water for Food by Groups of Countries

Country	ID	*1990 Data* Population 1990 (millions)	Population Growth 1990-2025 %	Annual Water Resou. (AWR) km³	Total With-drawals (DWR) km³	Per Capita Withdrawals Dom. m³	Per Capita Withdrawals Ind. m³	Per Capita Withdrawals Irrig. m³	*1990 Irrigation* Net Irrig. area (NIA) (10³ha)	Total Irrig. With-drawals km³	Annual Irrig. Inten-sity %	With-drawals Gross irr. area m/ha/yr	Net Gross irr. area m/ha/yr	Effec. Effic. %
		1	2	3	4	5	6	7	8	9	10	11	12	13
World		5,285	160%	47,196	3,410				245,067					
118 Countries		4,892	160%	41,463	2,905	54	114	426	220,376	2,086	146%	0.65	0.28	43%
% of Total		93%		88%	85%	9%	19%	72%	90%					
Group	1	377	222%	857	407	55	39	985	37,507	371	138%	0.72	0.39	54%
% of Total		8%		2%	14%	5%	4%	91%	17%	18%				
Group	2	348	257%	4,134	28	10	4	67	3,101	23	148%	0.51	0.30	58%
% of Total		7%		10%	1%	13%	5%	82%	1%	1%				
Group	3	777	176%	17,358	220	59	33	192	23,301	149	156%	0.41	0.18	43%
% of Total		16%		42%	8%	21%	12%	68%	11%	7%				
Group	4	796	146%	11,261	800	126	397	482	38,735	383	144%	0.69	0.31	45%
% of Total		16%		27%	28%	13%	39%	48%	18%	18%				
Group	5	589	108%	2,968	399	80	239	359	24,623	211	130%	0.66	0.20	31%
% of Total		12%		7%	14%	12%	35%	53%	11%	10%				
China		1,155	132%	2,800	533	28	32	401	47,965	463	184%	0.53	0.21	39%
% of Total		24%		7%	18%	6%	7%	87%	22%	22%				
India		851	164%	2,085	518	18	24	569	45,144	484	145%	0.74	0.29	40%
% of Total		17%		5%	18%	3%	4%	93%	20%	23%				

Source: Seckler et al., 1998.

Group 1 consist of countries that are water scarce by both criteria. These countries are mainly in West Asia and North Africa. They account for eight percent of the global population and are mostly developing countries except for some oil rich and newly industrialised countries. For these countries, water scarcity will be a major constraint on food production. They have a very high percentage of withdrawal for food production on account of the climatic considerations. The problem of water resources management in these countries has been discussed in detail by Rogers and Lydon (1993).

The countries in the four remaining groups have sufficient water to satisfy their needs until 2025. Group 2 countries, which contain seven percent of the world's population, are mainly in sub-Saharan Africa. They must develop more than twice the amount of water they currently use to meet reasonable future requirements. They include some of the least developed countries, socio-politically and techno-economically. As water withdrawal figures reveal they have undertaken very little development of water resources. Irrigated cropland and yields are low.

Group 3 countries, which contain 16 percent of the population, are scattered throughout the developing world. They need to increase their withdrawals by between 24 and 100 percent with an average of 48 percent to meet the future requirements. From environmental, socio-economic, and resource use efficiency criteria, three geographic groups of countries emerge, the conditions being least developed in the African region.

Group 4 countries are mostly in the developed world dominated by the US and Canada. They represent 16 percent of the population and need to increase their withdrawals by less than 25 percent.

Group 5 countries with about 12 percent of the population are mostly advanced countries, particularly countries in Europe and rapidly industrialized countries of the far east, excluding Japan. Their yields are the highest. It is interesting to note that although climatic conditions do not particularly demand irrigation, considerable emphasis has been placed on it of late to ensure high yields and reliability (Framji et al., 1981).

China and India have undertaken water resources development on a very large scale, but even larger scale developments and improvements are required to meet the future demands. Together, they represent about 41 percent of the global population or about 50 percent of the developing countries population. The figures conceal the wide regional disparities and each country has to be studied in detail to appreciate the seriousness of the water for food and rural development challenge. Although land, water, population, and general resource scarcity are com-

Table 4. Water for Food and Rural Development: Some Salient Statistics

S. No.	*Country*	*Socio-Economic Characteristics* *Population tion (1995) (millions) (WR,T8.1)*	*Rate of Increase 1990-95 (percent) (WR,T8.1)*	*GNP/ Capita (1993) (US$) (WR,T7.1)*	*Rate of Growth 1983-93 (percent) (WR,T7.1)*	*Calories available as % of need (1988-90) (WR,T8.3)*	*Population density per 1,000 hectares (1995) (WR,T9.1)*	*Sectoral Economic Breakup (1993) (percent) (WR,T7.1)* *Agri-culture*	*Indus-try*	*Ser-vices*
1	2	3	4	5	6	7	8	9	10	11
	Group 1									
1	Saudia Arabia	17,880	2.2	7,953	2.5	120	83	6	50	43
2	Yemen	14,501	5.0				275	21	24	55
3	Israel	5,629	3.8	13,920	4.7	125	2,730			
4	Syria	14,661	3.4	1,219	0.8	126	798	30	23	48
5	Egypt	62,931	2.2	660	4.0	132	632	18	22	60
6	Iraq	20,449	2.5	2,363	14.9	128	468			
7	Iran	67,283	2.7	2,159	1.6	125	411	21	36	43
8	Afghanistan	20,141	5.8			72	309			
	Group 2									
1	Zaire	43,901	3.2	264	2.1	96	194			
2	Uganda	21,297	3.4	180	3.9	93	1,067	53	12	35
3	Nigeria	111,721	3.0	300	5.1	93	1,227	34	43	24
4	Ghana	17,453	3.0	430	4.7	93	767	48	16	36
5	Mozambique	16,004	2.4	90	3.1	77	204	33	12	55
6	Sudan	28,098	2.7	493		87	118	34	17	50
7	Ethiopia	55,053	3.0	100		73	500	60	10	29
8	South Africa	41,465	2.2	2,980	1.2	128	340	5	39	56
	Group 3									
	Africa									
1	Tanzania	29,685	3.0	90	4.0		336	56	14	30
2	Kenya	28,261	3.6	270	3.7	89	497	29	18	54
3	Algeria	27,939	2.3	1,780	0.8	123	117	13	43	43
4	Moroco	27,028	2.1	1,040	3.3	125	606	14	32	53
	Latin America									
5	Chile	14,262	1.6	3,170	7.5	102	190			
6	Peru	23,780	1.9	1,490	-0.6	87	186	11	43	46
7	Colombia	35,101	1.7	1,400	3.9	106	338	16	35	50
8	Brazil	161,790	1.7	2,930	2.6	114	191	11	37	52
	South Asia									
9	Indonesia	197,588	1.6	740	5.9	121	1,091	19	39	42
10	Malaysia	20,140	2.4	3,140	6.7	120	613			
11	Myanmar	46,527	2.1		-0.1	114	708	63	9	28
	Group 4									
	North America									
1	Canada	29,436	1.2	19,970	2.4	122	32	3	32	65
2	U.S.A.	263,250	1.0	24,740	2.5	138	275			
3	Mexico	93,674	2.1	3,610	2.4		491	8	28	63
	Europe									
4	France	57,981	0.4	22,490	2.2	143	1,054	3	29	69
	South Asia									
5	Vietnam	74,545	2.2	170		103	2,290	29	28	42
	Group 5									
	Europe									
1	U.K.	58,258	0.3	18,060	2.2	130	2,411	2	33	65
2	Romania	22,835	-0.3	1,140	-4.8	116	991	21	40	40
3	Italy	57,187	0.1	19,840	2.3	139	1,945	3	32	65
4	Germany	81,591	0.6	23,560			2,336	1	38	61
5	Netherlands	15,503	0.7	20,950	2.6	114	4,570	4		
6	Spain	39,621	0.2	13,590	3.4	141	793	5	35	61
	South Asia									
7	Thailand	58,791	1.1	2,110	8.9	103	1,151	10	39	51
	Far East									
8	N. Korea	23,917	1.9			121	1,986			
9	S. Korea	44,995	1.0	7,660	9.0	120	4,557	7	43	50
10	Japan	125,095	0.3	31,490	4.1	125	3,322	2	41	57
	Group 6									
1	India	935,744	1.9	300	5.0	101	3,147	31	27	41
2	Bangladesh	120,433	2.2	220	4.0	88	9,252	30	18	52
3	Pakistan	140,497	2.8	430	4.8	99	1,823	25	25	50
	Group 7									
1	China	1,221,462	1.1			112	1,310	19	48	33

Sources: WR = World Resources Institute (1996); IWMI = International Water Management Institute (Seckler, 1998).

Table 4. Water for Food and Rural Development: Some Salient Statistics (con't)

S.No	*Country*	*Environmental*										
										Sectoral use/capita (m^3) (IWMI)		
		Geographical area (Mha)	*Cropland (Mha) (1993) (WR, T10.2)*	*Cropland (% of geographical area)*	*Annual Water Resources (km^3) (AWR) (IWMI0)*	*Withdrawal of AWR % (DWR) (WR, T13.1)*	*Water Withdrawal/capita m^3 (WR, T13.1)*	*Cropland per capita (ha)*	*Water/Cropland (m)*	*Domestic*	*Industrial*	*Irrigation*
1	2	12	13	14	15	16	17	18	19	20	21	22
	Group 1											
1	Saudia Arabia	214.97	3.74	1.74	2.4	164	497	0.209	0.06	94	10	936
2	Yemen	52.45	1.48	2.82	4.1	136	335	0.102	0.28	18	3	231
3	Israel	2.08	0.44	20.91	2.2	86	408	0.077	0.51	65	20	322
4	Syria	18.52	5.78	31.18	26.3	9	435	0.394	0.46	41	20	956
5	Egypt	100.14	2.80	2.80	68.5	97	956	0.044	2.45	53	79	781
6	Iraq	43.49	5.45	12.53	75.4	43	4,575	0.267	1.38	71	118	2,178
7	Iran	164.80	18.15	11.01	137.5	39	1,362	0.270	0.76	65	22	1,004
8	Afghanistan	64.75	8.05	12.44	65.0	52	1,830	0.400	0.81	102	34	1,566
	Group 2											
1	Zaire	234.54	7.90	3.37	1,019.0	0	10	0.180	12.90	5	1	2
2	Uganda	23.60	6.77	28.69	66.0	0	20	0.318	0.97	6	2	12
3	Nigeria	92.38	32.39	35.06	280.0	1	41	0.290	0.86	11	6	20
4	Ghana	23.85	4.32	18.11	53.2	1	35	0.248	1.23	12	5	18
5	Mozambique	78.30	3.18	4.06	208.0	0	41	0.199	6.54	6	3	30
6	Sudan	250.58	12.98	5.18	154.0	12	633	0.462	1.19	28	7	597
7	Ethiopia	122.19	13.93	11.40	88.0	2	51	0.253	0.63	6	2	44
8	South Africa	122.10	13.18	10.79	50.0	27	359	0.318	0.38	96	61	404
	Group 3											
	Africa											
1	Tanzania	94.51	3.50	3.70	89.0	1	40	0.118	2.54	3	1	36
2	Kenya	58.26	4.52	7.76	30.2	7	87	0.160	0.67	17	3	66
3	Algeria	238.17	7.85	3.30	14.3	30	180	0.281	0.18	45	27	108
4	Morocco	44.65	9.92	22.22	30.0	36	427	0.367	0.30	21	13	402
	Latin America											
5	Chile	74.18	4.26	5.74	468.0	4	1,626	0.298	10.99	358	309	959
6	Peru	128.52	3.43	2.67	40.0	15	300	0.144	1.17	57	27	216
7	Colombia	113.89	5.46	4.79	1,070.0	0	174	0.156	19.60	71	28	75
8	Brazil	851.20	48.96	5.75	6,950.0	1	246	0.303	14.20	54	47	145
	South Asia											
9	Indonesia	190.43	30.99	16.27	2,530.0	1	96	0.157	8.16	12	11	73
10	Malaysia	32.97	4.88	14.80	456.0	2	768	0.242	9.34	177	230	361
11	Myanmar	67.65	10.09	14.91	1,082.0	0	101	0.217	10.73	7	3	91
	Group 4											
	North America											
1	Canada	997.62	45.50	4.56	2901.0	2	1,602	1.544	6.38	288	1,121	192
2	U.S.A.	936.34	187.78	20.05	2,478.0	19	1,870	0.713	1.32	243	842	785
3	Mexico	197.25	24.73	12.54	357.4	22	899	0.264	1.45	54	72	773
	Europe											
4	France	54.70	19.44	35.54	198.0	19	665	0.335	1.02	106	459	100
	South Asia											
5	Vietman	32.96	6.70	20.33	376.0	8	414	0.090	5.61	54	37	323
	Group 5											
	Europe											
1	U.K.	24.10	6.13	25.42	71.0	17	205	0.105	1.16	4	158	43
2	Romania	23.75	9.94	41.86	208.0	13	1,134	0.435	2.09	91	374	669
3	Italy	30.12	11.86	39.38	167.0	34	986	0.207	1.41	138	266	582
4	Germany	35.25	12.12	34.37	171.0	27	579	0.148	1.41	64	405	110
5	Netherlands	3.72	0.93	25.11	90.0	9	518	0.060	9.64	26	316	176
6	Spain	50.48	19.66	38.94	94.3	28	781	0.496	0.48	94	203	484
	South Asia											
7	Thailand	51.40	20.80	40.47	179.0	18	602	0.354	0.86	24	36	542
	Far East											
8	N. Korea	12.05	2.00	16.60	67.0	21	687	0.084	3.35	76	110	502
9	S. Korea	9.89	2.06	20.78	66.1	42	632	0.046	3.22	120	221	291
10	Japan	37.77	4.46	11.82	547.0	17	735	0.036	12.26	125	243	368
	Group 6											
1	India	328.76	169.65	51.60	2,085.0	18	612	0.181	1.23	18	24	569
2	Bangladesh	14.20	9.69	68.27	2,357.0	1	220	0.080	24.31	7	2	211
3	Pakistan	80.39	21.25	26.43	418.3	33	2,053	0.151	1.97	26	26	1,226
	Group 7											
1	China	956.50	95.98	10.03	2,800.0	16	461	0.079	2.92	28	32	401

Table 4. Water for Food and Rural Development: Some Salient Statistics (con't)

S.No.	Country	Resource Use							
		Net Irrigated area (NIA) (Mha) (IWMI)	Irrigated area as % of crop-land (WR, T10.2)	Annual irriga-tion intensity (%) (IWMI)	Average production of cereals/ capita (kg)	Yield of cereals (kg/ha) (WR, T10.1)	Irrig. With-drawals on NIA (m) (IWMI)	Annual net gross irr. area (m) (IWMI)	Irriga-tion effecti-ness (%) (IWMI)
1	2	23	24	25	26	27	28	29	30
	Group 1								
1	Saudia Arabia	0.900	12	150	265	4,266	1.67	0.52	47
2	Yemen	0.348	24	96	56	1,100	0.75	0.55	70
3	Israel	0.206	42	121	39	2,199	0.73	0.30	50
4	Syria	0.693	15	166	350	1,417	1.70	0.48	47
5	Egypt	2.648	100	189	234	5,921	1.66	0.52	60
6	Iraq	3.525	47	129	129	883	1.12	0.46	53
7	Iran	7.000	51	105	246	1,750	0.85	0.53	65
8	Afghanistan	3.000	37	84	126	1,147	0.79	0.66	70
	Group 2								
1	Zaire	0.009	0	200	39	872	0.88	0.11	26
2	Uganda	0.009	0	200	89	1,549	2.37	0.13	11
3	Nigeria	0.230	3	148	120	1,237	0.84	0.23	40
4	Ghana	0.006	0	200	83	1,199	4.56	0.39	17
5	Mozambique	0.105	4	114	38	430	0.41	0.20	56
6	Sudan	1.946	15	104	158	561	0.75	0.48	67
7	Ethiopia	0.162	1	189	83	1,346	1.28	0.27	40
8	South Africa	1.290	10	160	253	1,893	1.16	0.33	45
	Group 3								
	Africa								
1	Tanzania	0.144	4	138	123	1,155	0.63	0.20	44
2	Kenya	0.054	1	200	98	1,548	2.91	0.39	27
3	Algeria	0.384	7	130	90	841	0.70	0.26	49
4	Morocco	1.258	13	131	193	975	0.78	0.29	49
	Latin America								
5	Chile	1.265	30	137	191	4,299	1.00	0.36	50
6	Peru	1.450	37	80	83	2,679	0.32	0.28	70
7	Colombia	0.680	10	130	104	2,518	0.36	0.13	49
8	Brazil	2.700	6	171	274	2,256	0.80	0.18	39
	South Asia								
9	Indonesia	4.410	15	137	276	3,864	0.30	0.08	34
10	Malaysia	0.335	7	200	104	3,026	1.93	0.08	8
11	Myanmar	1.005	10	118	374	2,808	0.38	0.12	39
	Group 4								
	North America								
1	Canada	0.718	2	100	1,674	2,566	0.74	0.19	26
2	U.S.A.	20.900	11	163	1,227	5,092	0.94	0.31	54
3	Mexico	5.600	24	167	290	2,708	1.17	0.29	42
	Europe								
4	France	1.300	8	100	977	6,517	0.44	0.25	58
	South Asia								
5	Vietnam	1.840	28	183	314	3,343	1.17	0.21	32
	Group 5								
	Europe								
1	U.K.	0.164	2	100	35	6,609	1.51	0.13	9
2	Romania	3.109	31	98	661	2,449	0.50	0.36	70
3	Italy	2.711	23	188	341	4,739	1.22	0.28	43
4	Germany	0.482	4	100	436	5,588	1.81	0.19	11
5	Netherlands	0.555	60	100	90	7,515	0.47	0.18	38
6	Spain	3.402	17	117	398	2,317	0.56	0.27	57
	South Asia								
7	Thailand	4.238	21	143	399	2,278	0.71	0.16	31
	Far East								
8	N. Korea	1.420	73	100	192	3,195	0.77	0.12	15
9	S. Korea	1.345	65	100	167	5,815	0.93	0.15	16
10	Japan	2.846	63	200	109	5,588	1.60	0.03	4
	Group 6								
1	India	45.144	28	145	221	2,062	1.07	0.29	40
2	Bangladesh	2.936	32	161	237	2,656	0.78	0.15	30
3	Pakistan	16.940	80	116	162	1,894	0.88	0.37	49
	Group 7								
1	China	47.965	52	184	328	4,482	0.97	0.21	39

parable in China and India, development and resource use efficiency is higher in China (Gustafson, 1986).

Review of Water Development

Development of water for food has significant socio-economic and environmental impacts besides its contribution to agricultural production. The development activities also have differing engineering and managerial characteristics in different countries. The current scene is, therefore, reviewed in these terms.

Socio-economic Impacts

Development of water for food production is imperative for meeting increasing food demands. Past developments have been able to make substantial contributions to food production. Although irrigated land is only 16 percent of the cultivated land, it contributes 36 percent of the total food production. In several developing countries, such as India, China, Pakistan, and Indonesia, which account for a large proportion of the population in developing countries, the proportion is even higher. Thus water for food will continue to be an important component of the total demand, currently accounting for 65 percent of global water use.

As detailed studies of the irrigation sector in India have shown, irrigation has fundamentally influenced agricultural productivity, incomes, employment, and regional development (World Bank, 1991). However, the impact has varied considerably depending on the type of irrigation, the agroclimate, and above all, on the technical quality and management of irrigation.

Irrigation increases cropping intensity and contributes to expansion of cropped areas. It increases yields, stabilizes output, provides diversification of crops, and increases farm incomes and employment. Through its influence on agricultural incomes, irrigation development has a multiplier effect on non-farm incomes. It contributes to poverty alleviation and regional development.

The quantitative values will differ from country to country, but the Indian figures will give some idea of the order of magnitude of the impacts. It has been estimated that irrigation contributed 60 percent of the increase in gross cropped area. The yields on irrigated lands were more than twice the yields on non-irrigated land, even when the yields of Indian irrigation were less than half the yields achieved in China. On average, farm incomes increased 80 to100 percent as a result of converting to irrigated farming. Incremental labour days per hectare increased on an average 60 to 80 percent. Irrigation had a nonfarm output multiplier of 2.19. Food grain prices fell about 20 percent relative to the price index for all commodities, which had a significant impact on the real incomes of the urban poor and landless rural households for whom food is a large component of consumption. Irrigation had a significant impact on poverty alleviation. For districts where less than 10 percent of the gross area was irrigated, 69 percent of the population had incomes below the poverty line, whereas in districts where irrigation covered more than 50 percent of the cropped area, poverty incidence was only 26 percent. Similarly, irrigation contributed to regional development relative to the quality of the irrigation.

However, a detailed review of the irrigation sector in India has revealed that these benefits have not always been realised. The low productivity of irrigation in most of the developing countries as shown in Table 4, leads to the conclusion that similar conditions prevail generally, a view which is reinforced by the study of water resources development in developing countries carried out by Bower and Hufschmidt (1984).

Productivity is an important measure of economic and resource use efficiency. The figures of productivity relate to the total agricultural sector, but quality of irrigation has a critical role to adoption of other factors of production and modernization of agriculture. The figures of productivity for the developing countries and for the advanced countries are given in Tables 5 and 6. The average yield of developing countries, including India, is less than half that of China. The average yield of the African countries is even less than the average yield of the developing countries. Even the figures for China are considerably lower than those achieved in advanced countries.

Environmental Impacts of Irrigation

Irrigation is provided from surface or groundwater sources. In the former, structures for storage and/or diversion are constructed, and water is carried to fields for irrigation. For groundwater, development is local but will cause change in groundwater levels. Irreversible environmental impacts over a wide geographical area are caused, which have the potential to be significant. While there are direct environmental impacts associated with the construction of dams, the greatest impacts result from the severe temporal and spatial change in the hydrological cycle and its social, environmental, and economic effects. These effects have direct impacts on the soils, vegetation, wildlife and wildlands, fisheries, climate, and especially the human populations in the area.

Irrigation has potential for negative environmental impacts which include: water logging and salinization of soils, increased incidence of water borne and water related diseases, resettlement or changes in lifestyle of local populations, and increases of agricultural pests and diseases resulting from the elimination of dry season-dieback and the creation of a more humid microclimate. The expansion and intensification of agriculture has the potential to cause: increased erosion; pollution of surface and groundwater from agricultural biocides; deterioration of water quality; and increased nutrient levels in the irrigation and drainage water resulting in algal blooms, proliferation of aquatic weeds and eutrification in irrigation

Table 5. Trends in Yields and Growth Rates (1961–92 in 1993 Developing Countries)

		Yields (kg per hectare)				*Annual Growth Rate (percent)*		
		61–63	69–71	79–81	90–92	61–70	70–80	80–92
1	All Cereals	1,171	1,461	1,894	2,466	2.8	2.6	2.1
	China	1,336	2,070	3,017	4,329	6.0	3.7	2.9
	Excluding China	1,116	1,271	1,557	1,952	1.5	2.1	1.9
	India				1,490			
2	Wheat	868	1,153	1,637	2,364	3.7	3.5	3.2
	China	673	1,169	2,046	3,208	7.8	5.4	3.7
	Excluding China	964	1,146	1,460	1,997	2.0	2.5	2.8
	India				2,370			
3	Rice	1,818	2,218	2,653	3,459	2.5	1.7	2.1
	China	2,355	3,281	4,236	5,722	4.9	2.5	2.3
	Excluding China	1,650	1,855	2,145	2,790	1.3	1.5	2.2
	India				1,800			
4	Maize	1,157	1,456	1,958	2,531	3.0	2.9	2.2
	China	1,265	2,005	3,038	4,545	6.2	4.2	3.3
	Excluding China	1,122	1,291	1,572	1,837	1.7	1.6	1.3

Note: Estimates for India are from Plan document. Other estimates are from WRI (1996).

canals and downstream waterways. Increased quantities of agricultural chemicals are usually required in irrigated lands to keep production levels up, which in turn lead to adverse environmental impacts. The potential adverse environmental impacts of using groundwater for irrigation arise from overtapping groundwater supplies. This results in the lowering of the water table, land subsidence, decreased water quality, and salt water intrusion in coastal areas.

The adverse impacts are well enumerated (World Bank, 1991). There has also been very wide publicity. In contrast to negative impacts, there are also very important and pervasive positive environmental impacts, directly and indirectly. Unfortunately, these have not been evaluated and have not been publicized.

Through irrigation, the adverse environmental impact of converting land to agricultural purposes to produce the needed food supplies is reduced on account of higher productivity obtained through irrigation. This is a tremendously important direct positive impact. Thus, it reduces deforestation and degradation of land. This has the important beneficial effect of minimizing air pollution caused by suspended particles generated through deforested and rainfed agricultural land. It also decreases wind generated soil erosion. Indirectly, through eradication of poverty, irrigation minimizes the diverse adverse environmental impacts brought about through poverty, such as deforestation, and water and air pollution. These have significant positive impacts on humans and biotic components of the environment.

An issue that has received considerable publicity is that of displacement of people and disruption of their lifestyle on account of storage projects. Sardar Sarovar is a classical example of this unfortunate notoriety based on misinformation. It is not realized that displacement of people is taking place on a massive scale from the villages because unirrigated land is unable to provide the minimal level of support for the increasing population and particularly with their rising demands for a better life. Thus, migration from nonproductive lands such as hills and arid land has been a historical phenomenon but it has acquired a momentous proportion in developing countries on account of population increase and scarcity of per capita natural resources. Displacement on account of the water resources projects has a dramatic local impact. The goal is to counter and to minimize the diffused uprooting trends through irrigation and evaluation, and the different impact of relocating one concentrated area. Indeed water resources development mitigates this diffused long term impact, and is misjudged because the localized impact is not treated properly on account of the attitudinal and institutional attributes of the bureaucracy of the developing countries.

On the basis of some real life experiences of areas which have received irrigation and others that have not, it can be concluded that on the balance, irrigation has very positive direct and indirect environmental impacts, in developing countries. But the subject requires more thorough and scientific study.

Overview of Water Resources Projects

Water resources projects are traditionally designed to achieve certain specified technological objectives, such as irrigation, flood protection, hydroelectric development and others. Considerable emphasis is placed on the engineering aspects of the subject. Increasingly economic

Table 6. Current Cereal Yields in Selected Countries

SI	*Country*	*Yield*	*Water Use*		*Average Production of cereals (100 metric tonnes)*
			% With-drawal	*Agricul-ture %*	
1	Egypt	5,921	97	85	14,722
2	China	4,482	16	87	401,088
3	India	2,062	18	93	206,608
4	U.S.A.	5,092	19	42	323,029
5	Japan	5,588	17	50	13,603
6	Korea	5,815	42	46	7,523
7	France	6,517	19	15	56,637
8	Germany	5,588	27	20	35,568
9	Italy	4,739	34	59	19,500
10	United Kingdom	6,609	17	3	20,399

Source: WRI (1996)

evaluation is carried out in a sophisticated manner and lately environmental evaluation has also been added.

Large scale development of water resources has taken place in developing countries, but as one review of the activities reveals, the achievements leave much to be desired functionally, economically, and environmentally (Bower and Hufschmidt, 1984). For instance, functionally, water is not provided adequately at appropriate times and with reliability, with the result that the agricultural sector activities cannot be carried out optimally, resulting in poor yields. The irrigation effectiveness, defined as the ratio of water required from evapotranspirative demands to water actually diverted for irrigation, is also poor, resulting in considerable wastage. The adverse environmental impacts are often the result of poor water resources development and management, and are not inherent in irrigation, as some authors occasionally try to demonstrate (Postel, 1999).

Irrigation projects are public sector activities. Review of projects in India, which will be applicable to other developing countries as the administrative culture is often similar, leads to the conclusion that considerable improvement is required in investment focus and financial discipline.

Most of these problems stem from inefficient sector management. The activities are organized by departments established under a colonial-bureaucratic culture with primary focus on engineering activities. The objectives, tasks, and policies are much wider than merely engineering and maintenance of the structural works. It is imperative that water management be considered in the wider context of socio-economic development and also that modernization of the engineering activities and sectoral management perspective be also developed.

India Case Study

Since the activities and impacts are location specific, a focused study will highlight some of the generalized points raised earlier. India represents one of the largest developing countries with extensive water for food development and rural development. A brief overview is carried out from the perspective of policy formulation. Indeed, it will be valuable if a comparative study of India and China is carried out, as China represents another country with a large concentration of poor and extensive water resources development, but with a different socio-economic and political history.

In view of the climatic-hydrologic conditions and agrarian economy, water resources development for irrigation has been undertaken in India since time immemorial. There is evidence of development works and irrigation in early history (Buckley, 1880). But a new chapter was introduced when the British hegemony was established in 1818 (Stone, 1984).

The story starts with the repairing of an old canal system near Delhi as a demonstration of the Imperial role of the East India Company, which was emerging as the ruling power. It was also found to be remunerative and commercially attractive. Similar experience followed with the renovation of old works in southern India. A series of large canals was constructed from 1836 in the western Gangetic basin and later in the Indus basin, which was even more arid.

The technology consisted of diverting the low flows after monsoons by temporary diversion works, which had to be constructed every year as they were washed out during the floods. Technology to construct permanent barrages developed only towards the end of the century. Extensive irrigation, that is, irrigating only a small fraction of the canal command at a time was adopted for several reasons: (1) headwork construction was difficult and expensive; (2) drainage was not provided to keep cost low and, therefore, intensive irrigation would lead to even more water logging; and (3) irrigation over large areas would extend benefits to more people, better mitigating adverse effects of famine and increasing tolerance of a foreign power. About 30 percent of the canal command area was planned to be irrigated, which consisted of three waterings through weekly rotation over the area. As the low season flows continually dwindled until snowmelt in the beginning of summer, the second and third watering were neither adequate nor even available to the entire area. There was no groundwater development as there was no power. Even when it was developed, this was in the public sector (developed by the Government). It was used to irrigate additional areas, rather than to improve the irrigation quality and control water logging through conjunctive surface and groundwater development. There were no storage works which could contribute to assured and reliable water supplies.

Thus, through a constellation of technological, administrative, institutional, financial and policy considerations, poor quality irrigation evolved to stabilize the sustenance agriculture and mitigate floods in the colonial era (Chaturvedi, 1985). It was not adequate, timely, or reliable, with the result that yields were poor and irrigation effectiveness was low. However, an area of 23.5 million hectares was brought under irrigation by 1947. Famines were mitigated but per capita food availability continued to decline and food supply reliability was also strained as population started increasing sharply during the early twentieth century.

Independence was achieved in 1947, the greatest emphasis was laid on development of water for food production. This activity received considerable urgency as severe food shortages occurred, which could be overcome only through wheat aid from the United States of America. Storage works, groundwater development, diversion canals, and watershed development were undertaken at the highest rate consistent with the financial and institutional capabilities. By 1993, an area of 48 million hectares had been brought under irrigation, making India the leader in irrigated area in the world and assuring food self-sufficiency with considerable reliability. It is estimated that by about 2025, all the water resources will be developed through conventional techniques and an area of 113 million hectares will be brought under irrigation. Water for food and rural development accounts for about 83 percent of the total water withdrawals. Water demand will continue to increase with the food sector maintaining its present position (World Bank, 1991).

Water resources development in India has been analyzed by international governmental agencies, and by scientists (GOI, 1992; World Bank,1991; Chaturvedi, 1976, 1985, 1990). Some excerpts from the World Bank study (1991) highlight some of the policy issues: "With the largest irrigation area in the world, Indian irrigation has much to be proud of. . . .Nonetheless, due to rapid expansion of irrigation with its emphasis on new construction, the performance of irrigation and the broader needs of the sector have been neglected. The development impact of irrigation is much less than its potential, and deficiencies in implementation have accumulated over time. The sector is now in crisis. Four issues are of particular concern: productivity, sustainability, investment focus and financial discipline, and sector management."

Plans are being made for interbasin transfer which will provide an additional 200–250 billion cubic meters of surface water, which represent about one third of the currently estimated utilizable water resources. Views, however, differ on the subject of how future development should be undertaken and regarding the feasibility of the proposed massive interbasin transfers. Alternative proposals for scientific development have been made (Chaturvedi, 1999a, 1999b).

Futures Challenges and Modernization

As noted at the outset, only a beginning in water resources development has been made in the developing countries and they have a long way to go to enter the mainstream of development. A quantum change is required in the science, engineering, and management of water resources in which the issue of water for food and rural development will continue to occupy a central place. Some studies focusing on India have shown that if business as usual continues, serious resource scarcity and environmental degradation shall occur as current trends already demonstrate. This situation is typical of many developing countries. Several suggestions for new concepts, policies, technologies, and planning approaches have been made recently. These need consolidation with real life case studies as they are currently being pursued (Chaturvedi, 2000a, 2000b). Some of the issues in this context are briefly discussed below.

Food Security and Development

Concern naturally remains regarding food security in view of increasing population and per capita food requirement on account of continuing economic development. Considerable discussion on the subject has taken place, and instead of engaging ourselves on the subject we will bring out the three main viewpoints (WRI, 1996; Ausubel and Langford, 1997). According to a number of studies by FAO and allied institutions, the dominant view is of cautious optimism. The role of water is considered crucial in this context, as we have emphasised throughout. The second view about future food production is considered pessimistic (Brown and Kane, 1995). Several reasons are given for this view, but detailed analysis does not support it (Chaturvedi, 2000a). A third view, that has not received much attention, involves the human environment in general and food production in particular, in the context of emerging technological trajectories (Ausubel and Langford, 1997; Waggoner, 1997). It is believed that yields can be much higher than the currently are, and correspondingly, environment cannot only be conserved but land can be given to nature (Waggoner, 1997).

An important point to emphasize is that while food security is a necessary condition, it is not a sufficient condition. The basic objective is sustainable development. Much has been written on the subject, but surprisingly, while the subject of intergenerational equity is continuously echoed, the issue of global equity, of which the natural corollary is that of developing countries finding their rightful place in the global community, is almost never mentioned.

Conceptual Issues

Several conceptual shifts are proposed. First, society and environment are integrally related and therefore, modernization of environmental management and societal modernization and development are integrally linked. Second, society is impacting upon environment through economic activities, and the focus should be first on demand side management. There are several components to it, one being that through technological performance, the end use technologies can be made increasingly efficient. This has been strongly emphasized in the energy sector (Reddy et al.,1997). Referring to the land-water sector, the first issue is using the factors of production more efficiently, which will be reflected in yields, and minimization of adverse effects. These are not merely academic issues but applications that have been worked out. Referring to the Indian case study, it has been demonstrated that an entirely different water resources development trajectory than currently proposed emerges if we attempt to increase the yields. To increase yields, specifications of water supply (adequate, timely, and reliable) are extremely important. This does not mean increasing land and water requirements (Chaturvedi, 1999a, 1999b). Third, the supply side has to be modernized. For example, integraded surface and groundwater development, integrated watershed management, and water supplies have to be developed for a quantified systems perspective instead of using the usual bureaucratic stipulations particularly common in developing countries (Chaturvedi, 1987). Fourth, the technologies have to be considered in terms of their lifetime development and use and in the totality of their management. For instance, considerable emphasis has been given on improving irrigation efficiency and the latest technologies have been proposed. While no doubt these are important, one has to carefully work out the trajectory of their development in view of the socio-economic environment of the developing countries. Bower and Hufschmidt (1983), while proposing certain conceptual advances, have observed that to penetrate this environment in order to apply the conceptual framework described above will be difficult and will require analysts who are sensitive to cultural nuances. Unfortunately, this stipulation is generally forgotten. A central issue in the development of water for food, as in all areas, is that people should be at the center of vision. In the developing countries, this means that the focus has to be rural development and not solely food production. This has several implications including the emphasis placed on people's participation, which, however, is only part of the mechanism.

Systems Planning

Considerable advances in water resources systems planning have been made and are continuing (Loucks et al., 1981; Chaturvedi and Rogers, 1985; Chaturvedi, 1987). Suggestions for advances in the context of sustainable development have been made (Loucks, 2000). An important direction of advancement in the context of sustainable development is the integration of the human subsystem and the environmental subsystem, each split up into subsystems and considered integrally in a long term perspective. This introduces three important considerations: (1) consideration at different levels of temporal and spatial integrity; (2) decision making under uncertain conditions; and (3) consideration of different perceptions and management approaches. Some work in this context has been done recently (Rotmans and de Vries, 1997). Considerable applied research focusing on the real life problems of developing countries is required (Hassan, 2000; Chaturvedi, 2000b). These concepts and approaches have been called environmental systems management: expressing a holistic approach, considering economy and environment integrally, considering the environmental vectors integrally in the context of multipurposes and multiobjectives, considering the environmental processes integrally with resource transformation, and undertaking planning with creativity and sensitivity backed by detailed analysis and transparent process in view of the uncertainty and differing management objectives (Chaturvedi 1997, 2000a).

Making it Happen

Another important aspect, often not given adequate emphasis, is that water resources management is not a merely technological activity but a societal activity mediated through perceptions, capabilities, motivations, incentive systems and institutional structures. Institutional modernization is one important issue, particularly in view of the colonial-bureaucratic history of most of the developing countries. In a detailed analysis of water resources management in Asia, the current state has been studied and valuable suggestions for a new approach to managing water resources have been made (Frederiksen et al., 1993; World Bank, 1993). These changes are most important and urgent.

One important issue is that this quantum change or revolution can only be undertaken indigenously. First and foremost in this context is attitudinal revolution. As has been brought out in several studies, an attitude of dependency and inferiority was generated and even fostered under colonial rule (Chaturvedi and Chaturvedi, 1985). It has been said that British not only ruled India, they conquered the Indian mind. This freedom has not been attained as yet. Historical evidence shows, for instance in the latest case of the the development of Japan, above technology and other factors, the dominant issue is that of ideology, as Yamamura (1996) has emphasized. Japanese people and Government decided to become a first rate nation and sought to achieve technological leadership. Similarly, the other developing nations, particularly the two largest ones, China and India, have to resolve to achieve world leadership, particularly in the area of water resources development, which is most important for them. This is not a matter of chauvinism but, starting from introspection it will be realized that they have much to learn from the advanced countries and this can best be achieved by adopting the goal of world leadership in this area as a project (Chaturvedi, 1993). This is imperative from the fact that indigenous development is essential. Support from the international scientific community is extremely valuable, as enjoined in the Agenda 21 (UN, 1992), but it has to be in terms of energizing the developing countries to attain their rightful place in the human community, instead of echoing the concepts of colonial days, as in the current position, where developing agencies and donor countries are seen as "lifting" the developing countries from their current state, but they are visualised as peeping at modernity from the threshold.

Conclusion

Water resources development is extremely important for developing countries where water for food and rural development has a dominant place. Although considerable advances have occurred, the state of the system leaves much to be desired. Very serious future challenges are faced by these countries demanding extensive scientific resource development and the highest use efficiency for sustainable development. This cannot be achieved if business as usual continues as there are serious shortcomings in the current developmental policy and implementation. A quantum change in concepts, planning approaches, technologies, management institutions, and above all, attitudes, is required. The task has to be done indigenously but valuable support can be provided by the advanced countries to bring these countries into the mainstream of human endeavour to take their rightful place in the human community through technological leadership. This matter is of utmost importance and urgency.

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