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Irrigation Development and Equity Impacts in India

S. Selvarajan
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Policy Paper 14

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Irrigation Development and Equity Impacts in India

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Acronyms and Abbreviations

AICRIP	All India Co-ordinated Research Project
AKRSP	Aga Khan Rural Support Program
ALLFLOW	All Flow Irrigated Area
ALLFT	All lift irrigated area
AVARD	Association of Voluntary Organization for Rural Development
BAIF	Bharatiya Agro-Industries Foundation
BCR	Benefit Cost Ratio
BETSTS	Between the states
CADA	Command Area Development Authority
CERI	Irrigated Cereals Area
CGIAR	Consultative Group on International Agricultural Research
CIA	Canal Irrigated Area
CPR	Common Property Resources
CRIDA	Central Research Institute for Dryland Agriculture
CSWCRTI	Central Soil and Water Conservation Research and Training Institute
DANIDA	
DDP	Desert Development Program
DPAP	Drought Prone Area Programme
EEC	European Economic Community
EAP	Externally Aided Projects
FG	Food grain
FGI	Irrigated foodgrains area
FHH	Farm Households
FLOW	Flow irrigated Area
FOODI	Irrigated food crop area
FPR	Food Prone Areas
FYP	Five Year Plan
GCA	Gross cropped Area
GCAI	Gross cropped area irrigated
GPF	
GWD	Ground Water Development
HRD	Human Resource Development
ICAR	Indian Council of Agricultural Research
ITK	Indigenous Technical Knowledge
IWDP	Integrated watershed Development Programme
MDCIDFPD	Magnitude of deviation of current canal irrigation distribution from proportional distribution
MDCIDFRD	Magnitude of deviation of current canal irrigation distribution from Rawlsian distribution
MOA	Ministry of Agriculture
MRAE	Ministry of Rural Areas and Employment
MYRADA	
NA	Not available

NAS	Net area sown
NBSS&LUP	National Bureau of Soil Survey and Land Use Planning
NCIA	Non-canal irrigated area
NFOODI	Irrigated non-food crop area
NGOs	Non-Governmental Organizations
NIA	Net Irrigated Area
NIACAN	Net irrigated area by canals
NIATNK	Net irrigated area by Tanks
NIATOT	Total Net irrigated area
NIATW	Net irrigated area by Tubewells
NIAWELLS	Net irrigated area by Wells
NSS	National Sample Survey
NWDPRA	National Watershed Development Programs
ORP	Operational Research Project
OSIA	Other sources irrigated Area
POP	Post operative Phase
PPP	Pre Project Phase
PRA	Participatory Rural Appraisal
PRIYA	Society for Participatory Research in Asia
PWMTA	Participatory Watershed Management Training
PWSM	Participatory watershed Management
RCEI	Irrigated rice Area
RRA	Rapid Rural Appraisal
RVP	River Valley Project
SCNI	Irrigated Sugarcane area
SPEECH	
SSUT	Small States and Union Territories
SWC	Soil and Water Conservation
SWD	Surface Water Development
TA	Total Area
TBS	Tarun Bharat Sangh
THH	Total Households
TIA	Total Irrigated Area
TMI-FLIA	Theil's measure of inequality in flow and lift irrigated areas
TMIR-FLIA	Theil's measure of inequality under Rawlsian approach to canal irrigation water distribution
TWIA	Tube Well Irrigated Area
UAS	University of Agricultural Sciences
WALMI	Water and Land Management Institutes
WDPSCA	Watershed Development Projects for Control of Shifting Cultivation Area
WHTI	Wheat irrigated area
WIA	Well irrigated Area
WITHSTS	Within the states
WSD	Watershed Development
WUA	Water Users Associations

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Foreword

Water resource, as an input to agriculture, has become vital for economic growth and sustainable development. Its catalytic role in enhancing the productivity growth to meet the food and income needs of the Indian economy is well established. With looming crisis in water sector, water policies and water plans will have to be vision oriented for ensuring equity and efficiency in multiple uses and sources of water.

Equitable distribution of irrigation benefits while promoting efficiency in its use will be a win-win situation matching with the poverty alleviation and income growth goals of India's agricultural development. Stiff competition is developing between different uses and users of water, which is likely to sharpen as India's annual per capita water availability goes below the water scarce threshold level of 1700 cubic meter within next two decades. For instance, in India, inter-state conflicts over sharing the common river basin are not uncommon in the past. But now, intra-basin conflicts within the state percolating down to village level conflicts are seen frequently as a manifestation of equity issues with multiple users ascertaining their rights over the sharing of this scarce resource.

Equity impacts of water, in its major use, namely, irrigated agriculture has been the central theme of this policy paper. The authors have attempted to quantify the equity impacts of irrigation development in India during 1970 through 1990, using the Agricultural Census database covering major states and small states and union territories. Better understanding of spatial and temporal equity implications of the irrigation development policies pursued in the past shall be useful in evolving future strategies.

We hope that this analytical study, assessing equity dimensions of irrigation development, shall further strengthen the informed decision making process while deliberating future direction for policies and planning in the India's water sector.

March, 2001 — Dr. Mruthyunjaya
New Delhi — Director

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This study has been undertaken to provide a comprehensive assessment of equity status of irrigation development impacts in India covering various time periods and states during the past few decades. The idea for this came from the review of seminal works done by Prof. R.K. Sampath earlier in this area of research. We have updated and consolidated with wider temporal and spatial coverage while addressing the equity issues besides integrating the watershed approach for promoting equitable distribution of irrigation benefits in the future. The continued cooperation, help and instantaneous support received from Prof. R.K. Sampath in understanding the methodologies enunciated in his several write-ups and publications in the past is gratefully acknowledged.

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This study when presented to the faculty received several comments during the discussions, which helped in its refinement. Notably, critical interventions by Dr. Ramesh Chand and Dr. P.K. Joshi during the seminar helped in unraveling the inferences on some of the results particularly for northwestern states. We are highly thankful to them. Help and support received from Heads, Library Services of Krishi Bhavan, Directorate of Economic and Statistics, Central Water Commission, Indian Agricultural Research Institute and Indian Agricultural Statistics Research Institute are thankfully acknowledged.

The usual disclaimer namely for any errors and omissions the authors remain responsible applies here also.

March. 2001 Authors

1

INTRODUCTION

India's agricultural growth *per se* during the 50-year period of independence remains impressive at 2.7 per cent per annum. Around two-third of this production growth was aided by gains in crop productivity. With the unrelenting population growth at 2.1 per cent per annum, per capita availability of food grains during this period has grown at around 0.5 per cent per annum (GOI, 1997). The need based strategies followed during this period mainly focused on intensive input based productivity led agricultural growth for feeding the growing population and making the country self sufficient in food production. As a result India's agricultural sector has made rapid strides in making India not only self sufficient in meeting food needs but also marginally surplus in food (Paroda, 1996). Total annual food grain production has already exceeded 200 MT at the beginning of the new millennium. The first major concern of providing food security during the post independence era is, thus, achieved by matching the supply with demand.

1.1 Emerging scenario in Indian agriculture

Future scenario emerging in Indian agriculture is different from what is hitherto experienced. Firstly, with continuous growth in population, agricultural growth has to still balance between the need to provide food and nutrition security to the country, the need to accelerate income growth to alleviate poverty and the need to quicken the pace of economic growth. For instance, latest estimations on foodgrains demand in India to 2020 reveal that with an anticipated rise in the growth rate of per capita income in India from the current trend of 3.5 to 5.5 per cent, total cereals demand will increase by around 140 per cent over 1990 (Bhalla and Hazell, 1998). Secondly, in tune with economic liberalization, impending agricultural policy resolution and GATT agreements, agricultural technology management has to become highly efficient in order to exploit the expanding production and marketing opportunities. Thirdly, with shrinking resource base for supporting future production growth (Appendix.1), the challenges are unprecedented as compared to the pre-green revolution era. For instance, in the past four decades ending with 1990's, the resource base consisting of land and water for an average farm holding to support eight persons has considerably declined. Reduced farm land for producing food, continuous decline in land area for meeting fuel and fodder needs, slowing of net irrigation expansion due to maintenance, investment, physical and environment related constraints, falling growth in total factor productivity and falling public investments in agricultural research in real terms make the future resource, production and technology management scenario quantitatively different from what was experienced during the later half of this century. Finally, improving the use efficiency of existing resources like land, water, fertilizer, infrastructure etc. will be crucial to relax the supply side constraints on future agricultural growth (Rao and Gulati, 1994). The role of Irrigation water will remain crucial in the whole process of agricultural growth planning primarily in view of its complementarity with other yield enhancing and/or cost saving inputs.

1.2 The setting and objectives

Demands on irrigation systems, both surface and ground water based, are accelerating with population growth and development, and with competition with domestic and industrial uses. Per capita water availability has continuously fallen from 6000 Cubic metre in 1947 to 2300 Cubic metre in 1997 which is projected to further fall to 1600 Cubic metre per annum in 2017. The total annual renewable fresh water available in India is assessed at 2085 BCM (Billion cubic metre). Annual requirement of fresh water is projected to increase from 552 BCM in 1990 to 870 BCM in 2000 and 1330 BCM in 2025. The share of irrigation water in absolute terms is expected to increase by two-third in 2025 over that of 1990 level but will decline as a percent of total water needs from 83 to 58 percent during this period due to the increasing competition from other uses. In addition to temporal variability in water needs and supply, spatial variability also adds another dimension towards the status and sustainable use of water. For instance, Brahmaputra basin accounting for only six per cent of the country's area holds 29 per cent of the country's water resources. In some parts of the western and southern regions, water availability is as low as one-fourth of the national average. In Punjab and Haryana states, more than 50 per cent of the blocks are categorised as over exploited and dark areas in ground water use. Permanent depletion of ground water acquifer as in the case of Mehsana district in Gujarat and Coimbatore district in Tamil nadu and increase in the number of stressed ground water blocks from 253 in 1985 to 422 in 1993 signals the disturbing trends emerging in India's water sector. As competition for limited water supply increases, responding effectively to these demands is a continuous process requiring careful and critical understanding of existing status, impacts and emerging prospects in irrigation water management.

Paradoxically, water scarcity and inefficiency in its use co-exits in India's water resource management system. Irrigation retains its crucial role in productivity-led future agricultural production, in alleviating poverty and reducing inequality in income distribution in rural areas. In the past, agricultural development in general and irrigation development in particular has evolved around productivity and food security related concerns. Research scholars have adequately documented productivity impacts of irrigation in India. Equity impacts in irrigation management is commonly adopted and now recognized by irrigation professionals across different disciplines as one of the most important *objectives* in India. Empirical analyses of equity impacts by and large concentrated at micro level within the irrigation system and that too capturing the farm location related inequity aspects within the watercourses (Bromley *et al*., 1980 and Palanisami, 1989). Empirical analyses of macro level equity impacts of irrigation development and use are scanty. Available evidences on the equity impact of irrigation distribution are restricted in its temporal coverage (Sampath, 1990). While irrigation development in the past was not specifically designed to target desired multiple impacts, equity implications as influenced during the course of irrigation development initiatives in the past four decades can no longer be ignored while formulating future water resource development strategies. A shift in water resource development and management paradigm is contingent upon the existing status and diverse impacts and experiences gained so far in this sector. This paper sets to address the following issues in the context of India's irrigation water management.

Objectives

1. To comprehensively review the existing status of irrigation water development in India,

2. To highlight the equity impacts of irrigation water development in India and

3. To suggest future irrigation water development strategies

1.3 Outline of the report

Following the introductory part, in the second chapter, existing status of India’s irrigation development is outlined. Trends and shifts in the sources of irrigation at national and state level are discussed. Irrigation distribution in India at farm level covering sources and crop shares is also attempted in this chapter. In third chapter, equity impacts of irrigation development at all India and state levels are quantified and presented covering different irrigation attributes. Different irrigation distribution policies are considered while assessing the equity impacts at farm households (FHHs) level. In fourth chapter, irrigation water development strategies are presented. Integrated approach involves the efficient and equitable utilization of surface water, ground water and rainwater. Covering surface water, ground water and watershed approach, the past experiences are outlined for evolving future strategies. Conclusions of the study are outlined in the fifth and last chapter of the report.

2
EXISTING STATUS OF IRRIGATION DEVELOPMENT

2.1 India's irrigation development: trends and shifts

Recognising the importance of irrigation as a crucial input in India's agricultural development, harnessing of water resources for irrigation has been given an important place in our successive five-year Plans (FYP). The ultimate irrigation potential of the country from major and medium projects is assessed at 58.5 million hectare (Mha). The irrigation potential from minor projects is estimated at 55 Mha, which is undergoing reassessment in view of the possible improvements in water management practices. As against this, the irrigation potential created during the pre-plan period was 22.6 Mha. Further, an estimated 62 Mha of additional irrigation potential has been created during 1951-96 (Table.1). Consequently, up to 1996, 74.5 per cent of the total irrigation potential has been harnessed for expanding irrigation facilities. Major and medium irrigation programmes accounted for 38 per cent of the additional irrigation potential created while the remaining 62 per cent of the added irrigation potential came through minor irrigation programmes. Initially, starting from I FYP, major and medium irrigation programmes contributed around two-third of the additional irrigation potential created (Fig.1). Minor irrigation programmes contributed the remaining one-third. This emphasis was gradually changing and completely reversed from IV FYP onwards extending upto VIII FYP. As a result of this, both surface and ground water resources were harnessed at varying levels across space and time with resultant variations in their multiple impacts, which are highlighted later.

Irrigation development in India accounted for a financial outlay of Rs. 690 billion during I FYP to VIII FYP. The outlay on irrigation includes major, medium and minor irrigation projects and CADA but excludes the flood control programmes. The CADA was initiated in 1974/75 as a Centrally sponsored programme to ensure efficient utilisation of created irrigation potential for optimising agricultural production from irrigated lands. The outlay on minor irrigation projects includes both state and institutional sources but exclude private sources. Within minor irrigation projects, institutional sources accounted for nearly half of the outlay during VIII FYP as compared to negligible level during I FYP. This shift in the funding source (Fig.2) from state to institutional source for supporting minor irrigation programmes started almost from II FYP onwards and stabilised at around 50 per cent from IV FYP onwards with only marginal variations. Such a shift in the funding source for minor irrigation development also provided the fillip for increased share of minor irrigation in the additional irrigation potential created from IV FYP onwards.

Table.1 Progress of irrigation development in India, 1950-96

Period	Government outlay in Rs crore				Total at constant prices	Cumulative potential created in Mha			Irrigation outlay as % of total plan outlay
	Major/Medium	Minor	CADA	Total	80/81=100	Major/Medium	Minor	Total	
Pre-plan	NA	NA	Nil	NA	NA	9.70	12.90	22.60	23
I FYP	376	66	Nil	442	2531	12.20	14.06	26.26	23
II FYP	380	162	Nil	542	2780	14.33	14.75	29.08	12
III FYP	576	442	Nil	1018	4180	16.57	17.00	33.57	12
AP	430	556	Nil	986	2860	18.10	19.00	37.10	15
IV FYP	1242	1167	Nil	2409	5578	20.70	23.50	44.20	15
V FYP	2516	1426	148	4090	5929	24.72	27.30	52.02	14
AP	2079	977	215	3271	4174	26.61	30.00	56.61	14
VI FYP	7369	3417	743	11529	10015	27.70	35.25	62.95	11
VII FYP	11107	6193	1448	18748	11821	29.92	43.12	73.04	9
AP	5459	3006	619	9084	4266	30.74	46.54	77.28	8
VIII FYP	22415	11096	2510	36021	13176	35.83	55.9	91.73	8
1992/93	3047	1806	323	5176	2071	31.13	47.90	79.03	7
1993/94	3501	1924	375	5800	2142	31.60	49.09	80.69	7
1994/95	3598	2082	401	6081	2026	32.27	50.22	82.49	6
1995/96	5046	1520	499	7065	2584	33.04	51.31	84.35	6

As percentage of total plan expenditure, outlay on irrigation constituted 23 per cent in I FYP, which came down by almost half in subsequent two plan periods before marginally improving during annual plans and IV and V FYPs. Starting from VI FYP, the share of irrigation outlay has been coming down continuously and has reached six per cent during 1995/96.

2.2 Sources of irrigation development in India: trends and shifts

Changing emphasis on irrigation development per se as well as the sources of irrigation expansion has reflected in differing magnitudes of exploitation of surface and ground water resources over time (Table 2).

Table. 2 Sources of irrigation in India, 1950-93 (Mha)

Year	Canal			Tank	Well			Others	NIA
	Govt.	Pvt.	Total		TW	Oth	Total		
1950/51	7.2	1.1	8.3	3.6	neg	6	6	3	20.9
1955/56	8	1.4	9.4	4.4	neg	6.8	6.8	2.2	22.8
1960/61	9.2	1.2	10.4	4.6	0.2	7.2	7.4	2.4	24.8
1965/66	9.8	1.1	10.9	4.4	neg	8.6	8.6	2.5	26.4
1970/71	12	0.9	12.9	4.1	4.5	7.4	11.9	2.3	31.2
1975/76	12.9	0.9	13.8	4	6.8	7.6	14.4	2.4	34.6
1980/81	14.5	0.8	15.3	3.2	9.5	8.2	17.7	2.6	38.8
1985/86	15.7	0.5	16.2	3.1	11.5	8.6	20.1	2.7	42.1
1990/91	16.5	0.5	17	3.3	14.3	10.1	24.4	3.1	47.8
1991/92	16.8	0.5	17.3	3.3	15.2	10.9	26.1	3.2	49.9
1992/93	16.6	0.5	17.1	3.3	15.8	10.7	26.5	3.3	50.2
1993/94	16.6	0.5	17.1	3.1	16.4	11.4	27.8	3.4	51.4
1994/95	16.8	0.5	17.3	3.3	17.2	11.7	28.9	3.5	53.0
1995/96	16.6	0.5	17.1	3.1	17.9	11.8	29.7	3.5	53.4
1996/97	16.8	0.5	17.3	3.3	18.4	12.4	30.8	3.6	55.0

Source: Economic survey, Government of India (Various years) and Centre for Monitoring Indian Economy, Agriculture, November 2000.

Net irrigated area from canal sources has more than doubled to reach 17.1 Mha during 1992/93 from 8.3 Mha in 1950/51. Canal irrigated area is exclusively dominated by government canals. The share of private canals in canal-irrigated area has continuously declined from 13.3 per cent in 1950/51 to only 2.9 per cent in 1992/93. Tank irrigated area has increased during 1950's and thereafter, continuously declined before stabilising at around 3.1 to 3.3 Mha during 1980's. Area irrigated by wells showed only a modest increase during 1950's through mid-1960s before registering impressive expansion during 1966-93 during which the area has more than tripled. There was also a perceptible shift in the sources of area irrigated by wells. During 1951-66, contribution of tube wells remained almost negligible. Starting from 1966 onwards, area irrigated by tubewells increased substantially to reach 15.8 Mha in 1993, contributing 59.6 per cent of the area irrigated by the wells. As on 1993, the total net irrigated area of 50.2 Mha is accounted for by canals (34.1 per cent), by wells (52.9 per cent), by tanks (6.5 per cent) and by others (6.5 per cent). In 1951, the respective share of canals, wells and tanks remained at 39.7, 28.7 and 17.2 per cent of the net irrigated area. The intensive installation of tubewells since 1970s has resulted in wells emerging as the dominating source of irrigation in Indian agriculture. Other sources of irrigation fluctuated around 2.2 to 3.3 Mha accounting for 6 to 14 per cent of the net irrigated area over time.

The growth in source-wise irrigated area exhibited different trends over different time periods in accordance with the shifts in irrigation development policies pursued from time to time. The preceding discussions indicated a perceptible shift in the irrigation development strategies based on which two periods; namely 1951-66 (Period I) and 1971-93 (Period 2) can be broadly grouped for growth analysis (Fig. 3).

The annual compound growth rate for canal-irrigated area came down from 1.8 in Period I to 1.3 in Period 2. Within the Period 2, the growth rate for canal-irrigated area has fallen from 1.7 per cent in 1970s to 0.9 percent in 1980s extending upto early 1990s. While the pace of expansion of canal-irrigated area is almost maintained in 1970s, it has considerably slowed down during 1981-93. The area commanded by tanks has grown at an annual rate of 1.3 per cent during Period 1. But, during the Period 2, the growth rate for tank-irrigated area has become negative at 1.1 per cent. Almost the entire fall in growth rate for tank irrigated area has happened during 1970s with no change in 1980s and beyond. Area irrigated by wells grew at 2.4 per cent during Period 1, which was accelerated to 3.7 per cent during Period 2. Within Period 2, the growth rate of area irrigated by wells was the highest at 4.1 per cent during 1970s, which came down to 3.4 per cent during the later period ending early 1990s.

2.3 Sources of irrigation development in states: trends and shifts

The growth in source-wise net irrigated area also exhibited different temporal and spatial trends as a consequence of shifts in irrigation development policies pursued in the past (Table. 3). As on 1972, excluding the states of minor importance in terms of individual sources of irrigation, the expansion in source-wise irrigated area was analyzed.

Table. 3 State-wise sources of irrigation, 1972-93

	Canals			Tanks			Wells			Others			Total		
	1972@	1982#	1993#	1972	1982	1993	1972	1982	1993	1972	1982	1993	1972	1982	1993
Andhra Pradesh	1521	15.5	-1.7	813	28.6	-30.2	568	38.5	79.5	96	9.0	54.3	2998	23.2	9.1
Bihar	874	33.9	-20.2	144	-30.5	28.0	582	71.2	70.8	785	-6.4	-21.0	2385	25.8	11.4
Gujarat	230	82.8	32.3	40	-0.5	-35.0	1980	-14.7	21.7	20	-75.4	-40.0	2271	-5.1	22.5
Haryana	965	22.6	14.9	1	-54.5	100.0	594	77.7	17.3	5	112.8	190.0	1565	43.7	16.9
Himachal Pradesh	1	185.7	350.0	1	25.0	0.0	1	185.7	50.0	89	-2.8	-3.5	91	1.8	6.5
Jammu Kashmir	265	9.5	-0.7	1	328.6	-33.3	2	42.9	-33.3	8	48.1	58.3	276	11.7	1.0
Karnataka	459	26.3	55.7	362	-11.4	-19.9	247	62.6	80.3	106	58.3	85.0	1174	25.2	49.3
Kerala	217	-51.2	0.9	74	-23.0	-15.8	6	-100.0	0.0	142	-45.8	48.1	439	-45.3	39.6
Madhya Pradesh	766	41.6	55.5	154	-12.6	31.1	620	61.4	132.2	102	98.0	192.1	1642	47.5	97.2
Maharashtra	307	34.4	36.4	213	32.5	36.5	771	48.0	18.1	77	66.2	36.7	1367	43.6	25.8
Orissa	602	33.1	17.1	175	18.2	44.0	29	621.3	302.9	46	-100.0	0.0	851	42.7	70.4
Punjab	1369	-3.4	3.2	0	0.0	0.0	1504	37.8	15.7	32	-62.0	716.7	2905	17.3	13.3
Rajasthan	811	16.6	51.0	179	-52.4	143.5	1151	58.7	53.5	32	39.3	-28.9	2173	33.6	54.0
Tamil Nadu	931	-3.2	-5.5	924	-20.0	-14.9	820	27.4	14.9	35	-29.0	-32.0	2710	0.0	-0.4
Uttar Pradesh	2419	32.4	1.1	360	-48.3	-54.8	3905	50.6	29.9	306	-11.3	33.2	6989	36.5	18.7
West Bengal	960	-34.6	14.2	303	23.3	-29.5	17	2511.8	60.4	209	14.1	-8.4	1489	13.1	13.5
All India	13090	19.8	9.0	3761	-12.4	-1.6	12219	52.3	42.6	2477	-1.3	32.4	31547	26.9	25.2

@ Figures for 1972 are net irrigated area in thousand hectares for 1971/72.
# Figures for 1982 and 1993 represent percentage change over 1972 and 1982 respectively.

2.3.1 Canal irrigated area

Among the major states, in case of canal-irrigated area, during 1972-82, the percentage increase was the highest in case of Gujarat (82.8 per cent) followed by Madhya Pradesh (41.6 per cent), Maharashtra (34.4 per cent), Bihar (33.9 per cent) and Orissa (33.1 per cent). Remaining states registered less than one-third increase in canal irrigated area over the 1972 level. Kerala and West Bengal registered decline in canal irrigated area during this period. Marginal decline in canal-irrigated area was also observed in case of Punjab and Tamil Nadu. During 1982-93, canal irrigated area registered impressive expansion in states like Karnataka, Madhya Pradesh, Rajasthan, Maharashtra and Gujarat. All these states registered more than one-third increase in canal-irrigated area in 1993 over the 1982 level. Orissa, West Bengal and Haryana states have recorded 14 to 17 per cent increase in canal-irrigated area during 1982-93 period. Bihar, Tamil Nadu, A.P and Jammu & Kashmir registered decline in canal irrigated area during this period.

Considering both the time periods together, it was observed that states like Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Orissa and Rajasthan have consistently increased the area under canal irrigation during 1972-93. In case of Tamil Nadu, the decline in canal irrigated area is consistent although only marginally (3.2 and 5.5 per cent during 1972-82 and 1982-93 respectively). For other states both expansion and contraction in canal-irrigated area was observed during this time period 1972-93.

2.3.2 Tank irrigated area

Among the major states, maximum expansion in tank irrigated area was observed during 1972-82 in case of Maharashtra (32.5 per cent), followed by Andhra Pradesh (28.6 per cent), West Bengal (23.3 per cent) and Orissa (18.2 per cent). Among the states with declining tank-irrigated area during the same period, Haryana and Rajasthan were leading with 52.4 to 54.5 per cent fall, followed by Uttar Pradesh (48.3 per cent), Bihar (30.5 per cent), Kerala (23 per cent) and Tamil Nadu (20 per cent). During 1982-93, Rajasthan registered maximum expansion in tank-irrigated area with 143.5 per cent followed by Haryana (100 per cent), Orissa (44 per cent), Maharashtra (36.5 per cent), Madhya Pradesh (31.1 per cent) and Bihar (28 per cent). Maximum decline in tank irrigated area during 1982-93 was observed in case of Uttar Pradesh (54.8 per cent), followed by Gujarat (35 per cent), Andhra Pradesh (30.2 per cent) and West Bengal (29 .5 per cent).

Across two time periods covering 1972-93, only Maharashtra and Orissa have consistently expanded the area under tank irrigation. On the other hand, Uttar Pradesh, Tamil Nadu, Karnataka and Kerala have registered continuous decline in tank-irrigated area during the same periods. For other states both expansion and contraction in tank-irrigated area was observed during 1972-93.

2.3.3 Well irrigated area

Well-irrigated area includes the area irrigated by both wells and tubewells. During 1972-82, except Kerala and Gujarat, all other states registered increase in the area irrigated by wells by over 25 per cent. Expansion in well-irrigated area was the highest in West Bengal and Orissa. This was followed by states like Haryana, Bihar, Karnataka, Madhya Pradesh, Rajasthan and Uttar Pradesh accounting for more than 50 per cent expansion in well-irrigated area during this period. Well-irrigated area declined only in case of Kerala and Gujarat during 1972-82. During 1982-93, Orissa and Madhya Pradesh recorded maximum expansion in well-irrigated area. Bihar, Himachal Pradesh, Karnataka, Rajasthan and West Bengal sustained the growth in well-irrigated area during 1982-93 also by registering above 50 per cent growth during this period. While Andhra Pradesh accelerated the well irrigation growth during this period, Tamil Nadu, Haryana, Maharashtra, Punjab and Uttar Pradesh slowed down as compared to the earlier period of 1972-82. Considering both the periods together, impressive and consistent growth of more than 50 per cent in each period is observed in case of several states like; Bihar, Himachal Pradesh, Karnataka, Madhya Pradesh, Orissa, Rajasthan and West Bengal. Barring Jammu and Kashmir with decline in well-irrigated area and Kerala with no change in well-irrigated area, all other states have expanded the area under well irrigation during the later period of 1982-93. Consequently, at all India level also, well-irrigated area has gone up continuously by 52.3 and 42.6 per cent respectively in 1972-82 and 1982-93.

2.3.4 Total irrigated area

Total irrigated area across the sources has gone up consistently by over 25 per cent during each of the period namely 1972-82 and 1982-93. Only Tamil Nadu has stagnated in providing additional irrigation facilities. Both consistency and improvement in irrigation expansion was observed in case of Karnataka, Madhya Pradesh, Orissa, Rajasthan, and West Bengal. In case of Gujarat and Kerala, total irrigated area declined during 1972-82 but expanded subsequently in 1982-93. In all the remaining states, total irrigated area continued to expand in both the periods but with a declined rate of growth in the later period.

2.4 Shifts in irrigation sources

Varying magnitudes of growth in source-wise irrigated area over time has also resulted in perceptible shifts in the importance of different sources of irrigation over space and time. The state-wise shifts in the sources of net irrigated area during the period 1972-93 are given in Table. 4.

Table. 4 State-wise shifts in sources of irrigated area, 1972-93

	Canals			Tanks			Wells			Others		
	1972	1982	1993	1972	1982	1993	1972	1982	1993	1972	1982	1993
Andhra Pradesh	50.7	47.6	42.9	27.1	28.3	18.1	18.9	21.3	35.0	3.2	2.8	4.0
Bihar	36.7	39.0	27.9	6.0	3.3	3.8	24.4	33.2	50.9	32.9	24.5	17.4
Gujarat	10.1	19.5	21.1	1.8	1.9	1.0	87.2	78.4	77.8	0.9	0.2	0.1
Haryana	61.7	52.6	51.7	0.1	0.0	0.0	38.0	47.0	47.1	0.3	0.4	1.1
Himachal Pradesh	0.8	2.2	9.1	0.9	1.1	1.0	1.5	4.3	6.1	96.8	92.5	83.8
Jammu Kashmir	96.0	94.2	92.6	0.3	1.0	0.6	0.8	1.0	0.6	2.9	3.9	6.1
Karnataka	39.1	39.5	41.2	30.8	21.8	11.7	21.1	27.3	33.0	9.0	11.4	14.1
Kerala	49.5	44.2	31.9	16.9	23.8	14.3	1.3	0.0	19.7	32.4	32.1	34.0
Madhya Pradesh	46.6	44.8	35.3	9.4	5.6	3.7	37.7	41.3	48.6	6.2	8.3	12.4
Maharashtra	22.4	21.0	22.8	15.6	14.4	15.6	56.4	58.1	54.6	5.6	6.5	7.1
Orissa	70.7	65.9	45.3	20.6	17.0	14.4	3.4	17.0	40.3	5.4	0.0	0.0
Punjab	47.1	38.8	35.4	0.0	0.0	0.0	51.8	60.8	62.1	1.1	0.4	2.5
Rajasthan	37.3	32.6	31.9	8.2	2.9	4.6	53.0	62.9	62.7	1.5	1.6	0.7
Tamil Nadu	34.3	33.2	31.5	34.1	27.3	23.3	30.3	38.6	44.5	1.3	0.9	0.6
Uttar Pradesh	34.6	33.6	28.6	5.1	1.9	0.7	55.9	61.6	67.5	4.4	2.8	3.2
West Bengal	64.5	37.3	37.5	20.3	22.1	13.8	1.1	26.4	37.3	14.1	14.2	11.5
All India	41.5	39.2	34.1	11.9	8.2	6.5	38.7	46.5	53.0	7.9	6.1	6.5

Figures refer to state-wise percentage of net irrigated area under each source in respective years.

At all India level, canals dominated the source of irrigation with 41.5 per cent in 1972, closely followed by wells with 38.7 per cent. However in 1982, wells became the dominating source of irrigation with a share of 46.5 per cent, which further increased to 53 per cent in 1993. Consequently, the share of canals in the irrigated area has come down to 34.1 per cent in 1993. Tanks as a source of irrigation also came down from 11.9 to 6.5 percent during the period 1972-93.

Among the states, despite continuous decline in the share of canal irrigated area in the total net irrigated area during this period, canals continued its domination as the major source of irrigation in case of Andhra Pradesh, Haryana, Jammu and Kashmir, Karnataka, Orissa and West Bengal. The share of canal irrigation in the net irrigated area has consistently declined in every state during this period, 1972-93 excepting Gujarat, Himachal Pradesh, Karnataka and Maharashtra.

In case of tanks as a source of irrigation, only Maharashtra has retained its share at around 15 per cent during this period. Every other state has recorded decline in the share of tanks in the net irrigated area during 1972-93. Drastic decline in the tanks' share in irrigated area is observed in Karnataka, Andhra Pradesh and West Bengal.

Orissa and West Bengal registered maximum increase in the share of wells as a source of irrigation during 1972-93. The share in irrigated area by wells has more than doubled in Andhra Pradesh and Bihar. Except in Gujarat and Maharashtra where the wells' share in irrigated area has marginally declined, in most of the other states, this share has continuously increased during this period.

2.5 Farm level irrigation distribution in India: trends and shifts

2.5.1 Distribution of total farm households and area

Distribution of total households and area across different farm sizes for the country as a whole covering five points of time during the period 1970/71 to 1990/91 is given in Table. 5.

Total farm households (FHHs) in India increased from 70.5 million (1970/71) to 106.6 million (1990/91), registering an annual growth rate of over 2.5 per cent. Total farm household area in India however increased only marginally from 162.1 million ha in 1970/71 to 165.5 million ha in 1990/91, recording an annual growth rate of little over 0.1 per cent during this period. Average farm holding size has consequently come down by about one-third from 2.3 ha in 1970-71 to 1.55 ha in 1990/91.

Table 5. Distribution of FHHs and area across farm sizes, 1971-91

Year	Farm size (ha)					
	0-1	1-2	2-4	4-10	>10	All
Total house holds ('000 No.)						
1970/71	35682	13432	10681	7932	2766	70493
1976/77	43636	14438	11373	7946	2361	79754
1980/81	49763	16072	12455	8068	2166	88524
1985/86	53899	17922	13252	7917	1918	94908
1990/91	63389	20092	13923	7580	1654	106638
Total area ('000 ha)						
1970/71	14545	19282	29999	48234	50064	162124
1976/77	17223	20484	31569	47972	40307	157555
1980/81	19730	23169	34645	48543	37705	163792
1985/86	22009	25708	36666	47144	33002	164529
1990/91	24894	28827	38375	44752	28659	165507
Change in 1990/91 over 1970/71 (%)						
Total households	77.6	49.6	30.4	-4.4	-40.2	51.3
Total area	71.2	49.5	27.9	-7.2	-42.8	2.1
Farm holding size	-3.7	-0.1	-1.9	-2.9	-4.3	-32.5

Among different farm sizes, maximum growth in farm households is observed in less than 1 ha size. Number of farm households in this size group has increased by 77.6 per cent during 1970/71 to 1990/91. This was closely followed by 1-2 ha size group whose size has increased by 49.6 per cent. Least expansion was recorded by 2-4 ha size group farms with 30.4 per cent growth during the same period. In case of farm sizes exceeding 4 ha, number of farm households has declined marginally by 4.4 per cent in case of 4-10 ha category and substantially by 40.2 per cent in case of above 10 ha farm size group. Rate of expansion in number of households has consistently exhibited inverse relationship with the farm size across all the time periods considered here. In fact over 3/4th of the increase in the farm households in 1990/91 over 1970/71 has occurred within the 0-1 ha size group. If 1-2 ha size group is also included, then over 95 per cent of the increase in the number of farm households is registered with less than 2 ha size group. Right to land ownership is a necessary condition to acquire right to irrigation water facilities. Therefore, observed shift in the growth of farm households over time, mostly in the range of less than 2 ha size will have different implications on distribution of water and hence income depending on the irrigation water development policies adopted in the past.

2.5.2 Distribution of Irrigated farm households

Distribution of irrigated farm households across different farm sizes for the country as a whole covering five points of time during the period 1970/71 to 1990/91 is given in Table. 6.

Table 6. Distribution of irrigated FHHs across farm sizes, 1971-91

Year	Farm size (ha)					
	0-1	1-2	2-4	4-10	>10	All
	Wholly irrigated farms ('000 No.)					
1970/71	8770	1919	1117	538	91	12435
1976/77	11471	2494	1419	613	97	16094
1980/81	14254	3154	1897	897	145	20347
1985/86	17344	4152	2480	1140	176	25292
1990/91	19707	4672	2727	1194	177	28477
	Partially irrigated farms ('000 No.)					
1970/71	5807	3719	3472	2900	1052	16950
1976/77	6837	3714	3455	2772	830	17608
1980/81	8882	3947	3499	2585	698	19611
1985/86	7104	3532	3114	2254	585	16589
1990/91	10245	4475	3550	2342	518	21130
	Change in 1990/91 over 1970/71					
Wholly irrigated farms	124.7	143.5	144.1	121.9	94.5	129.0
Partially irrigated farms	76.4	20.3	2.2	-19.2	-50.8	24.7
Irrigated farms	105.5	62.2	36.8	2.9	-39.2	68.8

Currently, as on 1990/91, 49.6 million FHH are having wholly or partially irrigated holdings. Irrigated FHH in India has increased by more than two-third during the period 1970/71 to 1990/91. Maximum increase of over 100 per cent is recorded in marginal FHH category and the magnitude of growth in irrigated FHH is inversely related to the farm size. Only in case of more than 10 ha farm size, there is a decline in the number of irrigated FHH by 39.2 per cent during this period. Similar trend is also observed while considering wholly and partially irrigated FHH separately.

The magnitude of growth is more in case of wholly irrigated farms than in partially irrigated farms, which is also desirable from improving the efficiency of use of resources in a wholly irrigated farm environment. However, from equity point of view it remains to be seen whether such an irrigation development path pursued in the past has resulted in more equitable distribution of the irrigation facilities across different farm sizes.

To understand this issue further, percent distribution of irrigated FHH across different farm sizes is provided in Table.7.

Table 7. Percent of irrigated FHHs across farm sizes, 1971-91

Year	Farm size (ha)					
	0-1	1-2	2-4	4-10	>10	All ('000 No.)
	Wholly irrigated farms as a percent of total					
1970/71	70.5	15.4	9.0	4.3	0.7	12435
1976/77	71.3	15.5	8.8	3.8	0.6	16094
1980/81	70.1	15.5	9.3	4.4	0.7	20347
1985/86	68.6	16.4	9.8	4.5	0.7	25292
1990/91	69.2	16.4	9.6	4.2	0.6	28477
	Partially irrigated farms as a percent of total					
1970/71	34.3	21.9	20.5	17.1	6.2	16950
1976/77	38.8	21.1	19.6	15.7	4.7	17608
1980/81	45.3	20.1	17.8	13.2	3.6	19611
1985/86	42.8	21.3	18.8	13.6	3.5	16589
1990/91	48.5	21.2	16.8	11.1	2.5	21130
	Irrigated farms as a percent of total					
1970/71	49.6	19.2	15.6	11.7	3.9	29385
1976/77	54.3	18.4	14.5	10.0	2.8	33702
1980/81	57.9	17.8	13.5	8.7	2.1	39958
1985/86	58.4	18.3	13.4	8.1	1.8	41881
1990/91	60.4	18.4	12.7	7.1	1.4	49607

For India as a whole, nearly 4/5th of the irrigated FHHs own less than 2 ha of farm holding size in 1990/91. This is higher by 10-percentage point as compared to the distribution of small and marginal holdings in the total irrigated FHHs in 1970/71. Which means in totality, small and marginal holdings account for higher share in the irrigated FHHs now as compared to two decades back. Across the time periods also, there is some consistency in this trend that means the irrigation development policies pursued in the earlier decades did promote distribution of irrigation facilities in favour of small and marginal farms. In all other categories of farm size there is a consistent decline in the percent share of irrigated FHHs.

Among wholly irrigated farms, the percent share of marginal and small FHHs remained more or less constant during this period fluctuating between 69 and 71 per cent and between 15 and 16 per cent respectively. But in case of partially irrigated farms, the share of marginal farms substantially increased from 34.3 per cent in 1970/71 to 48.5 percent in 1990/91. Wholly and partially irrigated farms as a percent of irrigated FHHs is given in Table.8.

Table 8. Percent distribution of wholly and partially irrigated FHHs, 1971-91

Year	Farm size (ha)					
	0-1	1-2	2-4	4-10	>10	All
	Wholly irrigated farms as a percent of total					
1970/71	60.2	34.0	24.3	15.6	8.0	42.3
1976/77	62.7	40.2	29.1	18.1	10.5	47.8
1980/81	61.6	44.4	35.2	25.8	17.2	50.9
1985/86	70.9	54.0	44.3	33.6	23.1	60.4
1990/91	65.8	51.1	43.4	33.8	25.5	57.4
	Partially irrigated farms as percent of total					
1970/71	39.8	66.0	75.7	84.4	92.0	57.7
1976/77	37.3	59.8	70.9	81.9	89.5	52.2
1980/81	38.4	55.6	64.8	74.2	82.8	49.1
1985/86	29.1	46.0	55.7	66.4	76.9	39.6
1990/91	34.2	48.9	56.6	66.2	74.5	42.6

Currently, 57.4 per cent of the irrigated farms are wholly irrigated with the rest getting only partial irrigation facilities. This share is 35.7 per cent higher than that of the share realised in 1970/71 level. In the marginal farm holding size, nearly two-third of the irrigated marginal FHH is wholly irrigated with the rest being partially irrigated. This percentage share of wholly irrigated farms in the irrigated marginal FHH category in 1990/91 is 9.3 per cent higher than that of 1970/71. Also in case of irrigated small FHHs, the percentage share of wholly irrigated farms has gone up from 34 percent in 1970/71 to 51.1 percent in 1990/91. Substantial increase in the share of wholly irrigated farms in the irrigated small and marginal FHH categories shows that the irrigation development policies pursued in the past has generated differing impacts across different farm sizes. The inferences are; one, FHH in India has grown annually @ 2.5 per cent; two, irrigated FHH has grown annually @ 3.4 per cent; three, consequently, per cent of irrigated farms in the total FHH has increased from 41.7 per cent in 1970/71 to 46.5 per cent in 1990/91 (Table.9).

Table 9. Irrigated FHHs as a percent of total FHHs across farm size, 1971-91

Year	Per cent of total FHHs with irrigation facilities					
	0-1 ha	1-2 ha	2-4 ha	4-10 ha	>10 ha	All
1970/71	40.9	42.0	43.0	43.3	41.3	41.7
1976/77	42.0	43.0	42.9	42.6	39.3	42.3
1980/81	46.5	44.2	43.3	43.2	38.9	45.1
1985/86	45.4	42.9	42.2	42.9	39.7	44.1
1990/91	47.3	45.5	45.1	46.6	42.0	46.5

Here also, maximum percentage increase in the irrigation coverage during 1971-91 has occurred in the marginal FHHs followed by small FHHs at the aggregate all India level. Further, across farm holding sizes, not much variation is observed in the share of irrigated FHHs in the total FHHs in each size. Irrigated marginal FHH category had the highest share of 47.3 per cent and FHHs with more than 10 ha holding size had the lowest share of 42 per cent. The changes in the absolute and percentage share of irrigated FHHs across farm size at the national level observed during this period indicate a movement towards better equitable distribution of irrigation facilities compared to 1970/71. But, a lot depends on the spatial and source-wise analysis of the equity impacts of irrigation development during the past four decades.

2.5.3 Distribution of irrigated area

Distribution of net and gross irrigated area by farm sizes for the study period is given in Table. 10.

Table 10. Distribution of irrigated area by farm size, 1970/71 to 1990/91

Year	Farm size (ha)					
	0-1	1-2	2-4	4-10	>10	All
	Net irrigated area ('000 ha)					
1970/71	4393	4741	6604	8332	5037	29107
1976/77	5606	5425	7133	7980	3693	29837
1980/81	6872	6618	8713	9873	4727	36803
1985/86	8062	7656	9694	10360	4700	40472
1990/91	9457	9085	10971	11286	4905	45704
	Gross irrigated area ('000 ha)					
1970/71	5390	5833	8147	10231	6116	35717
1976/77	6693	6419	8622	9447	4268	35449
1980/81	8467	8193	11201	13158	6325	47344
1985/86	10659	9970	12821	13551	6227	53228
1990/91	13215	12075	14505	14866	6998	61659
	Per cent change in 1990/91 over 1970/71					
Net irrigated area	115.3	91.6	66.1	35.5	-2.6	57.0
Gross irrigated area	145.2	107.0	78.0	45.3	14.4	72.6
Irrigation intensity	13.9	8.0	7.2	7.3	17.5	9.9

Net irrigated area has gone up from 29.1 Mha in 1970/71 to 45.7 Mha in 1990/91, registering an annual growth rate of 2.85 per cent. Gross irrigated area increased from 35.7 Mha to 61.7 Mha during the same period, registering an annual growth rate of 3.63 per cent. Since gross irrigated area expanded faster than the net irrigated area during 1971/91, the intensity of irrigated area has gone up by one-tenth during this period.

Expansion in net irrigated area is maximum in marginal FHHs. Annual growth rate during 1971-91 is 5.77 per cent followed by the small farm category which registered 4.58 per cent. Across farm size, expansion in net irrigated area was inversely related to the farm size. Similar trend was also observed in case of gross irrigated area. But in all farm sizes, growth in gross irrigated area is higher than that of net irrigated area. Even here, farm holdings with less than 2 ha size performed better than holdings of higher sizes. For instance, growth in gross irrigated area is 25.9 per cent higher than the growth in net irrigated area. Consequently, intensity of irrigated area has also registered maximum growth in marginal FHHs (13.9 per cent) followed by small FHHs (8 per cent). Only in case of farm holdings with more than 10 ha, net irrigated area declined marginally by 2.6 per cent.

2.5.4 Distribution of surface irrigation facilities

Distribution of surface irrigation facilities that include canal and tank irrigated area across different farm sizes is given in Table. 11.

Table 11. Distribution of surface irrigation facilities by farm size, 1971-91

Year	Farm size (ha)					
	0-1	1-2	2-4	4-10	>10	All
	Canal irrigated area ('000 ha)					
1970/71	1769	1991	2714	3477	2221	12172
1976/77	2234	2268	2909	3197	1515	12123
1980/81	2696	2656	3360	3778	1883	14373
1985/86	3095	2865	3514	3775	1858	15107
1990/91	3348	3061	3645	3851	1762	15667
	Tank irrigated area ('000 ha)					
1970/71	737	668	800	828	477	3510
1976/77	742	627	730	732	361	3192
1980/81	941	742	753	636	260	3332
1985/86	805	636	638	509	196	2784
1990/91	940	682	654	503	178	2957
	Per cent change in 1990/91 over 1970/71					
Canal irrigated area	89.3	53.7	34.3	10.8	-20.7	28.7
Tank irrigated area	27.5	2.1	-18.3	-39.3	-62.7	-15.8

Canal irrigated area increased by 3.5 Mha during the last four decades. On the other hand, tank irrigated area declined by 5.5 Mha. It is a paradox that while irrigation infrastructure is being expanded through increase in canal irrigation network at a substantial investment, existing irrigation infrastructure in the form of tank irrigation is allowed to shrink. Tank irrigated area has fluctuated during this period especially in the marginal and small FHHs. However, tank irrigation has expanded at an annual rate of 1.38 per cent in the marginal farm category and just by 0.1 per cent in the case of small farm category. In all other farms, with a holding size of more than 2 ha, tank irrigated area has declined and annual rate of decline varied from 0.9 per cent to 3.1 per cent. Despite the limited expansion of tank irrigated area, its role in promoting equity cannot be ignored since share of small and marginal farm holdings in the total farm holdings in the tank command area is very high as of now. Hence, deteriorating tank infrastructure will adversely affect the performance of the tanks and thereby affecting the overall equity of irrigation development. This is more so, since tank irrigation is still an important source of irrigation in several southern states.

For instance, the deteriorating status of tank irrigation infrastructure in Andhra Pradesh is highlighted in Fig.4. Andhra Pradesh has witnessed sharp deterioration in the minor irrigation (MI) infrastructure following the collapse of traditional institutions like *kudimaramath* that took care of maintenance of thousands of tanks for several centuries. As of to-day, all minor irrigation sources together (consisting of 12351 in number) irrigate

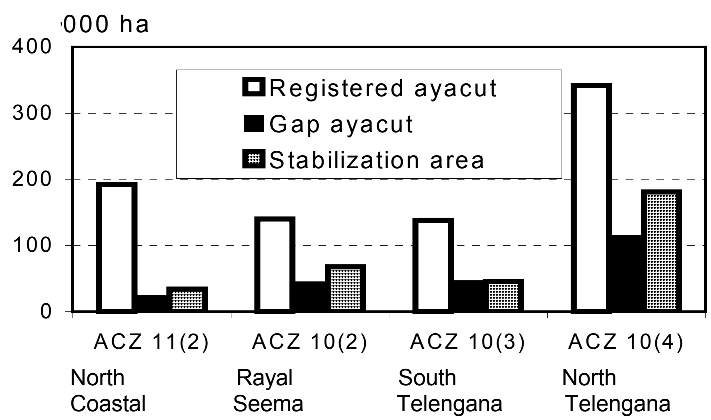

Fig. 4 Deteriorating minor irrigation tank infrastructure in A.P state, 1990s

only, 44.2 per cent of the registered ayacut as against 82 per cent for all the tanks in early 1950s (Table. 12).

Tanks as a source of irrigation in 1960s through 1990s depressed overall annual growth in net irrigated area by about 1/4th in the state of Andhra Pradesh. Neglect of minor irrigation sector's maintenance with major emphasis on major and medium projects has led to continuous deterioration in the performance of minor irrigation (MI) tanks. Total number of minor irrigation sources in A.P is 12351 with a total ayacut of

12.52 lakh ha spread across 23 districts of the state which are grouped under six sub zones under two agro-climatic zones. The tank command area falling under two agroclimatic zones (ACZ 10 and 11) and four sub zones was classified into fully irrigated area, partially irrigated area (stabilization area) and gap ayacut (Fig. 4).

Table. 12 Declining performance of minor irrigation system in AP, 1956-98

Period	Average MI sources (Number)	Average Net irrigated area (Lakh ha)	Average Ayacut area (Lakh ha)	Average Net irrigated area per MI source (ha)	Average Ayacut per MI source (ha)
For Minor Irrigation and Panchayat Raj sources including very large tanks					
1956	58527	10.8	n.a	18.4	n.a
1967-69	65571	10.7	n.a	16.4	n.a
1970-79	69387	10.0	n.a	14.4	n.a
1980-89	75257	8.8	n.a	11.7	n.a
1990-98	75593	7.9	n.a	10.5	n.a
	(82825)		18.6		22.4
For only Minor Irrigation sources					
1990-98	9147	4.0	n.a	44.2	n.a
	(12351)		12.5		101.4

Note: Figures in parentheses indicate total number of tanks existing under respective categories. MI sources indicate the number of tanks actually in use for irrigation in respective periods. (Source: Season and Crop Report of Andhra Pradesh and Statistical Abstract of Andhra Pradesh, Department of Economics and Statistics, Government of Andhra Pradesh (various years) and Chief Engineer (MI), Minor Irrigation Department, Government of Andhra Pradesh.

The total gap ayacut area in all the 4 sub zones is estimated to be 2.26 lakh ha. This is nearly 5 percent of current net irrigated area from all the sources for the state as a whole. Another 3.30 lakh ha of area currently irrigated by MI Tanks is the area that is partially irrigated during 1990s. This works out to 8 percent of the current net irrigated area from all the sources for the state as a whole. MI tanks located in North coastal sub zone are able to continuously irrigate around 70 percent of the registered ayacut during 1990s. More than 4/5th of the gap ayacut and area for stabilization are located in Rayalseema and Telangana regions of AP

Out of 12351 MI sources, 30% is located in eight drought prone districts viz.; Prakasam, Chittoor, Cuddapah, Anantapur, Kurnool, Nalgonda, Mahaboobnagar, Rangareddy and 26 % of the Ayacut area under MI sources is located in these districts. As per Central Ground Water Board (Southern region), Ministry of Water resources assessment, more than 4/5th of the mandals identified under grey and dark categories are located in the Rayalseema and Telengana regions. Furthermore, tanks irrigate

29% of net irrigated area, presently cultivated by marginal farm holdings. 54% of the net area irrigated by all tanks in the state is distributed between marginal and small farm holdings. In terms of number of farm holdings, 80% of the farms receiving tank irrigation are small and marginal farms (less than 2 ha in size) in Andhra Pradesh state. Marginal farms (less than 1 ha in size) alone constitute 60% of all the farms getting irrigated by tanks. Farms that are less than 0.5 ha in size constitute 40% of all the farms receiving irrigation water from tanks in the state. This implies that deteriorating performance of the tanks in the state will have unfavourable distribution impacts between regions as well as between various farm size groups within the region. The infrastructure status of MI tanks in the state of A.P as exists today demand appropriate intervention to restore its potential functioning in meeting the multiple needs of the village society. In the neighbouring state of Tamil Nadu also, the area irrigated by tanks has come down from 9.36 lakh ha in 1960/61 to 6.74 lakh ha in 1994/95. As percentage of net irrigated area, the tanks' share has declined from 38% in 1960/61 to 23% in 1994/95 (DoA, Tamil Nadu, 1997).

2.5.5 Distribution of ground water irrigated area

Distribution of well and tubewell irrigated area across the farm sizes in India during 1971/91 is given in Table.13.

Table 13. Distribution of ground water irrigation by farm size

Year	Farm size (ha)					
	0-1	1-2	2-4	4-10	>10	All
	Well irrigated area ('000 ha)					
1970/71	842	975	1459	2036	1357	6669
1976/77	806	904	1390	1973	1097	6170
1980/81	858	1036	1647	2254	1210	7005
1985/86	885	1136	1629	2035	1058	6743
1990/91	1013	1611	2311	2844	1305	9084
	Tube well irrigated area ('000 ha)					
1970/71	677	742	1159	1535	729	4842
1976/77	1270	1142	1519	1553	496	5980
1980/81	1793	1698	2341	2661	1154	9647
1985/86	2579	2457	3266	3526	1373	13201
1990/91	3309	3013	3555	3442	1364	14683
	Per cent change in 1990/91 over 1970/71					
Well irrigated area	20.3	65.2	58.4	39.7	-3.8	36.2
Tubewell irrigated area	388.8	306.1	206.7	124.2	87.1	203.2

Well-irrigated area has gone up from 6.7 Mha to 9.1 Mha during this period registering an annual growth rate of 1.81 per cent. Tubewell irrigated area recorded an increase of around 10 Mha with an annual average growth rate of over 10 per cent. Relative to tubewell irrigated area expansion, well irrigated area remained more or less stagnant during this period. Among all farm holdings, least annual growth of around one per cent was observed in the marginal farm holdings obviously because of unviable farm size to make capital investment in wells. Large holdings of more than 10 ha registered marginal decline in the area irrigated by wells during the same period.

Over time, informal institutional sharing of wells by more number of marginal farm holdings also came under social stress resulting in limited growth in well-irrigated area under this category. Declining ground water table also contributed to the failure of wells totally or partially restricting the per well command area in states like Karnataka. Initial failure and falling life of irrigation wells has become a common feature in hard rock regions. For example, in eastern dry zone of Karnataka, the (negative binomial) probability of well failure is estimated to be 40 per cent (Nagaraj *et al.,*1994). Maximum growth in well-irrigated area has been recorded in the farm holding sizes ranging from 1 to 4 ha in which annual average growth rate varied from 2.92 to 3.26 per cent during 1971/91.

In case of tubewell-irrigated area, expansion is phenomenal in the marginal FHHs followed by small FHHs. The magnitude of expansion in tube well-irrigated area is inversely related to the farm holding size. With a skewed distribution of farms in favour of marginal and small holdings, faster expansion in tubewell irrigation in the marginal and small holding categories tend to promote overall equity in the distribution irrigation facilities.

Annual average growth in tubewell-irrigated area is maximum at 19.4 per cent in marginal FHH followed by 15.3 per cent in small FHH. In both categories, recorded growth is much higher than the over all growth of 10.16 per cent observed across farm sizes during the period 1971/91. In other words, growth in farm holdings less than 2 ha was the driving force behind the over all expansion in the tubewell irrigated area during the past four decades. Innovative pumping technology matched by electricity expansion and coverage in the farm sector made ground water pumping scale neutral providing assured irrigation coverage and thereby, complementing the adoption of seed cum fertilizer led modern technology.

2.5.6 Percent distribution of irrigated area

The percentage distribution of farm households, total area, irrigated area and source-wise irrigated area during 1970/71 to 1990/91 by different farm sizes is given in Table.14. The share of marginal FHH in the total

FHH has increased from 51 per cent to 59 per cent during the past four decades. Both marginal and small FHHs alone account for 78 per cent of the total FHHs in the country as of 1990/91 cultivating nearly one-third of the total area. This has implications for the equitable distribution of irrigation impacts from the past irrigation water development strategies.

Table 14. Irrigation distribution by farm size over time (%)

Farm size(Ha)	Year	THH	Total area	CIA	TIA	WIA	TWIA	NIA	GIA
0-1	1970/71	51	9	15	21	13	14	15	15
	1976/77	55	11	18	23	13	21	19	19
	1980/81	56	12	19	28	12	19	19	18
	1985/86	57	13	20	29	13	20	20	20
	1990/91	59	15	21	32	11	23	21	21
1-2	1970/71	19	12	16	19	15	15	16	16
	1976/77	18	13	19	20	15	19	18	18
	1980/81	18	14	18	22	15	18	18	17
	1985/86	19	16	19	23	17	19	19	19
	1990/91	19	17	20	23	18	21	20	20
2-4	1970/71	15	19	22	23	22	24	23	23
	1976/77	14	20	24	23	23	25	24	24
	1980/81	14	21	23	23	24	24	24	24
	1985/86	14	22	23	23	24	25	24	24
	1990/91	13	23	23	22	25	24	24	24
4-10	1970/71	11	30	29	24	31	32	29	29
	1976/77	10	30	26	23	32	26	27	27
	1980/81	9	30	26	19	32	28	27	28
	1985/86	8	29	25	18	30	27	26	25
	1990/91	7	27	25	17	31	23	25	24
>10	1970/71	4	31	18	14	20	15	17	17
	1976/77	3	26	12	11	18	8	12	12
	1980/81	2	23	13	8	17	12	13	13
	1985/86	2	20	12	7	16	10	12	12
	1990/91	2	17	11	6	14	9	11	11
All	1970/71	100	100	100	100	100	100	100	100
	1976/77	100	100	100	100	100	100	100	100
	1980/81	100	100	100	100	100	100	100	100
	1985/86	100	100	100	100	100	100	100	100
	1990/91	100	100	100	100	100	100	100	100

Collectively, small and marginal farmers are now operating 32 per cent of the total area as against 21 per cent of the total area operated by them four decades back. But the share of small and marginal FHH in the total FHH has gone up from 70 percent in 1971 to 78 percent in 1991. Since providing irrigation water is expected to have a catalytic impact on farm income and hence alleviation of rural poverty, spreading irrigation coverage in proportion to the share of FHHs in different size groups is useful to promote the equity impacts of irrigation development in India.

In terms of the distribution of net and gross irrigated area among the farm sizes, it is seen that the share of farm holdings with less than 2 ha has improved from 31per cent in 1970/71 to 41 percent in 1990/91. In 1970/71, the share of small and marginal holdings together in the canal irrigation source is 31 per cent. By 1990/91, this share of canal irrigation source in holdings with less than 2 ha went up to 41 per cent. Similarly, small and marginal holdings accounted for 40 per cent of tank irrigated area in 1970/71, which went up to 55 per cent in 1990/91. While tank irrigated area itself is declining due to the neglect of this important traditional infrastructure, its increased importance for the small and marginal holdings underlines its continued importance in improving the equitable distribution of irrigation benefits in favour of farm households with less than 2 ha.

Distribution of well-irrigated area highlights its dominance in the holdings with 1 to 10 ha size and stagnancy in its expansion or even decline in its percentage share in case of other farm sizes. In 1970/71, the share of FHH with less than 2 ha size accounted for 29 per cent of total tubewell irrigated area. But in 1990/91, this share of small and marginal FHH in total tubewell irrigated area has increased to 44 per cent underlying the scale neutrality of this technology, the adoption of which was necessitated by the spread of modern varieties during the green revolution period.

Analysis of percentage distribution of FHHs and area across different farm sizes revealed the following: One, FHHs are predominantly distributed in the smallest holding size category of less than 1 ha and this trend will continue. Two, such a distribution will tend to sharpen more the equity related issues particularly in irrigation water, which are invariably, linked with the ownership rights of the land. Three, distribution of canal, tank and tubewell irrigated area has changed following the irrigation development strategies pursued in the past four decades. Four, the observed change in the source-wise distribution of irrigation benefits indicate a shift towards small and marginal FHHs whose share in canal, tank and tubewell irrigated area at aggregate national level has improved during the period 1971-91. However, only empirical analysis of the equity impacts of irrigation development by sources and regions over different time periods will help in the assessment of current status and needed future strategies.

2.5.7 Distribution of cereals crop area

The distribution of area under rice, wheat and cereal group as a whole is presented in Table. 15.

Table 15. Distribution of cropped area by farm size, 1976/77 to 1990/91

Year	Farm size (ha)					
	0-1	1-2	2-4	4-10	>10	All
	Rice area ('000 ha)					
1976/77	7872	7850	9283	8485	3575	37065
1980/81	9107	8702	10128	9317	3657	40911
1985/86	10172	9310	10405	8706	3634	42227
1990/91	11508	9891	10739	8391	3073	43602
	Wheat area ('000 ha)					
1976/77	2884	2655	3724	4730	2895	16888
1980/81	3393	3256	4821	6178	3655	21303
1985/86	4254	4118	5615	6275	3418	23680
1990/91	4972	4599	5659	6261	3162	24653
	Cereals area ('000 ha)					
1976/77	14354	15351	21372	26757	16792	94626
1980/81	16429	17509	24428	29712	17855	105933
1985/86	18660	19495	25639	27897	15432	107123
1990/91	21004	21210	26090	20638	12856	101798
	Percent change in 1990/91 over 1976/77					
Rice area	46.2	26.0	15.7	-1.1	-14.0	17.6
Wheat area	72.4	73.2	52.0	32.4	9.2	46.0
Cereals area	46.3	38.2	22.1	-22.9	-23.4	7.6

Total area under rice increased by about 1.26 per cent per annum while, wheat area expanded by 3.29 percent per annum during the period 1976-91. Area under cereal crops as a whole increased by around half a percent per annum. Rice and wheat area expansion provides differing patterns. Maximum rice area expansion occurred in the marginal farm households with an annual growth of 3.3 per cent followed by small farm household category with an annual growth of 1.9 per cent. Farm households with a holding size of 2-4 ha recorded little over 1 per cent expansion in rice area while more than 4 ha holding size categories registered decline in both absolute and percentage rice area during 1970/71 to 1990/91.

Wheat area expanded in all farm-holding sizes. In small and marginal FHHs, the rate of expansion in wheat area is highest and almost same. Wheat area expanded in farms with holding size of 2-4 ha and 4-10 ha at 32.4 to 52 per cent during this period. Cereals as a group registered expansion in area in case of farms with holding size up to 4 ha but declined by over 1.6 per cent annually in farms with holding size more than 4 ha during the period 1977-91. The distribution of irrigated area under rice, wheat and cereals by farm size is given in Table. 16.

Table 16. Distribution of irrigated area by crop and farm size, 1971- 91

Year	Farm size (ha)					
	0-1	1-2	2-4	4-10	>10	All
	Rice irrigated area ('000 ha)					
1970/71	2486	2489	3128	3170	1609	12882
1976/77	2954	2766	3329	2992	1169	13210
1980/81	3773	3457	3944	3681	1371	16226
1985/86	4359	3726	4169	3652	1496	17402
1990/91	5436	4446	4729	3856	1433	19900
	Wheat irrigated area ('000 ha)					
1970/71	1428	1572	2334	3100	1812	10246
1976/77	2130	1892	2518	2820	1240	10600
1980/81	2621	2403	3459	4324	2142	14949
1985/86	3327	3142	4221	4520	2168	17378
1990/91	4190	3748	4496	4847	2276	19557
	Cereals irrigated area ('000 ha)					
1970/71	4391	4591	6247	7357	4070	26656
1976/77	5594	5179	6659	6755	2857	27044
1980/81	6922	6436	8310	9114	4089	34871
1985/86	8339	7522	9332	9205	4123	38521
1990/91	10345	8981	10253	9718	4094	43391
	Percent change in 1990/91 over 1970/71					
Rice irrigated area	118.7	78.6	51.2	21.6	-10.9	54.5
Wheat irrigated area	193.4	138.4	92.6	56.4	25.6	90.9
Cereals irrigated area	135.6	95.6	64.1	32.1	0.6	62.8

Total rice irrigated area registered an average annual growth rate of 2.73 per cent during 1971/91. Expansion in wheat-irrigated area during the same period was at an annual average rate of 4.55 per cent. Irrigated area under cereals as a group itself has expanded at an impressive rate of 3.14 per cent per annum during the past four decades ending 1990/91. Among different farm sizes, the rate of expansion in the irrigated area under rice, wheat and cereals showed inverse relationship with the farm size. Marginal farm holdings recorded 5.94 per cent growth in the irrigated rice area per annum followed by small farm holdings with an annual average growth rate of 3.93 per cent. The irrigated area under rice registered a decline of about half a percent, only in case of holdings with more than 10 ha.

Wheat irrigated area almost trebled during the period 1971/91 registering an average annual growth rate of 9.7 per cent in case of marginal farm holdings. In holding sizes of 1-4 ha, irrigated area under wheat either doubled or more than doubled during this period. Unlike in case of rice, wheat area expanded in case of all the remaining farm sizes also.

The crop-wise irrigated area distribution under cereals by farm size revealed the following: One, with increased irrigation coverage for marginal and small farm holdings, the share of irrigated area allocation for wheat followed by rice has increased substantially during the past four decades ending 1991. Two, more equitable distribution of irrigation benefits is expected to bring in more irrigated area under cereal crops particularly wheat and rice. Three, promoting equity in irrigation development over space and farm size will diversify the present narrow production base of cereal crops like rice and wheat.

2.5.8 Distribution of food and non-food crop area

The distribution of area under food grains, food crops and non-food crops is presented in Table. 17.

Table 17. Distribution of cropped area by food and non-food crop groups

Year	Farm size (ha)					
	0-1	1-2	2-4	4-10	>10	All
Food grains' area ('000 ha)						
1976/77	15938	17675	24982	33119	22382	114096
1980/81	18594	20044	28513	36087	22770	126008
1985/86	21165	22444	30237	34394	19793	128033
1990/91	23614	24439	30727	32084	16697	127561
Food crops' area ('000 ha)						
1976/77	17509	18829	26913	35354	23538	122143
1980/81	20266	21501	30499	38187	23768	134221
1985/86	23414	24218	32374	36369	20723	137098
1990/91	26412	26778	33312	34422	17690	138614
Non-food crops' area ('000 ha)						
1976/77	1915	2767	5087	9546	8407	27722
1980/81	2594	3727	6679	11111	8723	32834
1985/86	3551	4800	7478	11072	7634	34535
1990/91	4303	6253	9316	12559	8253	40684
Percent change in 1990/91 over 1970/71						
Food grains area	48.2	38.3	23.0	-3.1	-25.4	11.8
Food crops area	50.8	42.2	23.8	-2.6	-24.8	13.5
Non-food crops area	124.7	126.0	83.1	31.6	-1.8	46.8

Area under foodgrains increased at an annual rate of 0.84 per cent. Area under food crops registered an annual average growth of 0.96 per cent during 1977-91. Non-food crops showed an impressive growth of 3.34 per cent per year during this period. Since rice and wheat area dominated the area under food grains, the growth rates observed in case of foodgrains in almost all farm sizes exhibited more or less similar trends as observed in case of rice and wheat area. Similarly, food grains being the dominating group within the food crops area, the trends in growth rate registered across different farm sizes remained almost similar to that of food grains. Noticeable decline in area under food grains as well as food crops was observed only in case of more than 10 ha category. Farms with 4-10 ha holding size registered marginal decline in the area under food grain and food crops during this period. In case of non-food crops, area expansion was maximum in marginal as well as small farm holdings with an annual average growth rate of around 9 per cent. This growth rate is much higher than that of other farm sizes excepting those with more than 10 ha, which recorded marginal decline in the area under non-food crops. The distribution of irrigated area under food grain, food and non-food crops by farm size is given in Table. 18.

Table 18. Distribution of irrigated area by food and non-food crops

Year	Farm size (ha)					
	0-1	1-2	2-4	4-10	>10	All
Foodgrains ('000ha) 1970/71	4615	4843	6225	7889	4482	28054
1976/77	5797	5387	6993	7225	3117	28519
1980/81	7165	6699	8748	9802	4443	36857
1985/86	8678	7931	9902	9940	4487	40938
1990/91	10640	9359	10789	10436	4491	45715
Food crops ('000ha) 1970/71	5020	5299	7319	8824	5074	31536
1976/77	6381	6020	7928	8328	3586	32243
1980/81	7936	7501	9909	11061	4968	41375
1985/86	9725	8918	11174	11148	4910	45875
1990/91	12106	10750	12425	11939	4967	52187
Non-food crops ('000ha) 1970/71	370	535	828	1405	1093	4231
1976/77	312	399	694	1119	682	3206
1980/81	531	692	1292	2097	1417	6029
1985/86	935	1052	1647	2403	1316	7353
1990/91	1178	1422	2203	3022	1646	9471
	Percent change in 1990/91 over 1970/71					
Food grains' irrigated area	130.6	93.2	73.3	32.3	0.2	63.0
Food crops' irrigated area	141.2	102.9	69.8	35.3	-2.1	65.5
Non-food crops' irrigated area	218.4	165.8	166.1	115.1	50.6	123.8

The area under food grain and food crops expanded, individually, by almost same magnitude of around 3.2 per cent per annum during 1971/91. However, the rate of expansion in non-food crops is almost double than that of food grain and food crops during the same period.

Irrigated area under food grains as well as food crops more than doubled in the marginal FHHs, registering an annual average growth rate of around 6.5 to 7 per cent. The irrigated area expansion in other farm sizes up to 10 ha is less than that of marginal farms but still impressive. The irrigated area expansion under food grain and food crops in case of farms with holding size more than 10 ha is either negligible or marginally negative. In case of non-food crops, the irrigated area expansion is impressive at an annual average rate of 8.3 to 10.92 per cent in farms with holding size up to 4 ha.

Analysis of area under food and non-food crops across farm holdings and different time periods revealed the following: One, rate of expansion in area under food grain and food crops is inversely related to the farm size. Two, this expansion is limited to farms with holdings less than 4 ha. Three, despite the small share of non-food crops in the total area, the area under non-food crops has expanded in all size groups impressively except in more than 10 ha farms. Four, almost similar trends but larger in magnitude are observed in the expansion of irrigated area under food grain, food and non-food crops across all farm sizes. Finally, distribution of irrigation benefits exhibited differing impacts on the distribution of crop and crop group wise irrigated area under cereals, food grain, and food and non-food crops.

2.5.9 Per cent distribution of crop area

The distribution of crop area by farm size expressed as a percent of total crop wise area under each farm size is given in Table 19. In 1976/77, 27 per cent of the gross cropped area was operated by farm holdings with less than 2 ha size. This share went up to 35 per cent in 1990/91. In case of rice, 42 per cent of the total rice area in 1976/77 is cultivated by farm holdings with less than 2 ha which increased further to 49 per cent in 1990/91.

Similarly, share of wheat area in small and marginal holdings increased from 33 to 39 per cent in this period. Cereals as a group in these holdings of less than 2 ha also increased their share from 31 to 42 per cent during 1977-91.

Share of food as well as non-food crops also increased by 31 to 53 per cent in 1990/91 over that of 1976/77. It is thus observed that, with increase in gross cropped area, increased share of area under rice, wheat, food and non-food crops are recorded in small and marginal farm households.

Table 19. Crop area distribution by farm size (%)

Farm size (Ha)	Year	Total area (GCA)	Rice	Wheat	Cereal	FG	Food	Non-Food
0-1	1976/77	13	21	17	15	14	14	7
	1980/81	14	22	16	16	15	15	8
	1985/86	16	24	18	17	17	17	10
	1990/91	17	26	20	21	19	19	11
1-2	1976/77	14	21	16	16	15	15	10
	1980/81	15	21	15	17	16	16	11
	1985/86	17	22	17	18	18	18	14
	1990/91	18	23	19	21	19	19	15
2-4	1976/77	21	25	22	23	22	22	18
	1980/81	22	25	23	23	23	23	20
	1985/86	23	25	24	24	24	24	22
	1990/91	24	25	23	26	24	24	23
4-10	1976/77	30	23	28	28	29	29	34
	1980/81	30	23	29	28	29	28	34
	1985/86	28	21	26	26	27	27	32
	1990/91	26	19	25	20	25	25	31
>10	1976/77	21	10	17	18	20	19	30
	1980/81	19	9	17	17	18	18	27
	1985/86	17	9	14	14	15	15	22
	1990/91	14	7	13	13	13	13	20
All	1976/77	100	100	100	100	100	100	100
	1980/81	100	100	100	100	100	100	100
	1985/86	100	100	100	100	100	100	100
	1990/91	100	100	100	100	100	100	100

The distribution of irrigated crop area by farm size is given in Table 20. Overall share of total irrigated area (GIA) increased by 35.5 per cent during the period 1971-91 in case of holdings less than 2 ha. This share, in case of bigger holdings with more than 2 ha, declined by 14.5 per cent during the same period. Percentage of irrigated area under rice and wheat respectively operated under less than 2 ha holding size improved by 29 and 38 per cent during the past four decades. Share of wheat and rice irrigated area remained same in the 2-4 ha holding size group but declined by 22.9 to 29.7 per cent respectively during the past covering 1971-91. Irrigated area under cereal crops in farm holdings with less than 2 ha occupied 45 per cent of the irrigated area under cereals in 1990/91, which is 36.4 per cent higher than that of 1970/71.

Table 20 Irrigated crop area distribution by farm size (%)

Farm size (ha)	Year	Total area (GIA)	Rice	Wheat	Cereal	FG	Food	Non-Food
0-1	1970/71	15	19	14	16	16	16	9
	1976/77	19	22	20	21	20	20	10
	1980/81	18	23	18	20	19	19	9
	1985/86	20	25	19	22	21	21	13
	1990/91	22	27	21	24	23	23	12
1-2	1970/71	16	19	15	17	17	17	13
	1976/77	18	21	18	19	19	19	12
	1980/81	17	21	16	18	18	18	11
	1985/86	19	21	18	20	19	19	14
	1990/91	20	22	19	21	20	21	15
2-4	1970/71	23	24	23	23	22	23	20
	1976/77	24	25	24	25	25	25	22
	1980/81	24	24	23	24	24	24	21
	1985/86	24	24	24	24	24	24	22
	1990/91	24	24	23	24	24	24	23
4-10	1970/71	29	25	30	28	28	28	33
	1976/77	27	23	27	25	25	26	35
	1980/81	28	23	29	26	27	27	35
	1985/86	25	21	26	24	24	24	33
	1990/91	24	19	25	22	23	23	32
>10	1970/71	17	12	18	15	16	16	26
	1976/77	12	9	12	11	11	11	21
	1980/81	13	8	14	12	12	12	24
	1985/86	12	9	12	11	11	11	18
	1990/91	11	7	12	9	10	10	17
All	1970/71	100	100	100	100	100	100	100
	1976/77	100	100	100	100	100	100	100
	1980/81	100	100	100	100	100	100	100
	1985/86	100	100	100	100	100	100	100
	1990/91	100	100	100	100	100	100	100

The share in respect of foodgrains and food was 43 and 44 per cent respectively, which is higher by around one-third as compared to their share in 1970/71. The analysis of irrigated crop area distribution across farm sizes in the past four decades reveals the following: One, additional gross irrigated area generated during the past four decades got distributed more in favour of small and marginal FHHs. Two, irrigated area share of rice and wheat in the small and marginal holdings has increased but declined in case of holdings with more than 4 ha. Three, since rice and wheat are the dominant crops in cereals, food grain and food crop groups, similar trend was observed in the share of irrigated area allocation under cereals, food grain and food crop groups.

2.5.10 Per cent distribution of irrigated crop area share

The distribution of irrigated crop area expressed as a percent share of total crop area by farm size is given in Table 21.

Table 21 Irrigated crop as a percent of total crop area by farm size, 1977-91

Year	Farm size (Ha)	Area (GCA)	Rice	Wheat	Cereals	FG	Food	Non-Food
1976/77	0-1	34	38	74	39	36	36	16
	1-2	30	35	71	34	30	32	14
	2-4	27	36	68	31	28	29	14
	4-10	21	35	60	25	22	24	12
	>10	13	33	43	17	14	15	8
	All	24	36	63	29	25	26	12
1980/81	0-1	37	41	77	42	39	39	20
	1-2	32	40	74	37	33	35	19
	2-4	30	39	72	34	31	32	19
	4-10	27	40	70	31	27	29	19
	>10	20	37	59	23	20	21	16
	All	28	40	70	33	29	31	18
1985/86	0-1	40	43	78	45	41	42	26
	1-2	34	40	76	39	35	37	22
	2-4	32	40	75	36	33	35	22
	4-10	29	42	72	33	29	31	22
	>10	22	41	63	27	23	24	17
	All	31	41	73	36	32	33	21
1990/91	0-1	43	47	84	49	45	46	27
	1-2	37	45	81	42	38	40	23
	2-4	34	44	79	39	35	37	24
	4-10	32	46	77	47	33	35	24
	>10	25	47	72	32	27	28	20
	All	34	46	79	43	36	38	23

Irrigated area share in the gross cropped area has increased from 34 per cent to 43 per cent in case of marginal farm holdings and 30 to 37 per cent in case of small farm holdings during this period namely 1976/77 to 1990/91. Percent of gross cropped area irrigated in different farm sizes varied inversely with the farm size and this inverse relationship was maintained in all the decades ending 1990/91. The impact of irrigation development on the percentage share of gross cropped area irrigated varied with farm size even though the inverse relationship as observed above remained intact during the period covered in this study.

Across farm sizes, percentage share of irrigated area in the gross cropped area has expanded at an annual growth rate of around 3 per cent during 1977-91. Irrigated area under rice grown under irrigation increased its share from 36 percent in 1977 to 46 percent in 1991. Share of irrigated area under wheat improved substantially from 63 per cent to 79 per cent during this period. The percentage share of cereals, FG, food and non-food crops cultivated under irrigated situation got more than doubled during the same period.

Among different farm sizes, increasing trend in the share of irrigated area in each of the major crop and crop group considered here is observed in all the FHH categories. Notably, share of wheat irrigated area increased substantially in the farms with holding size above 10 ha. Share of irrigated area under non-food crops also nearly doubled for all the farm sizes with impressive increase in the share observed in all the FHH categories.

Distribution of crop area expressed as a percent of gross cropped area for each farm size is given in Table 22. Share of rice area in the total GCA remained almost same during the period 1977-91 but wheat area share improved from 11 to 14 per cent during this period. Area share of cereals, foodgrains and food crops declined but non-food crop area share in the gross cropped area increased by 27.8 per cent during the same period.

Between farm sizes, rice area share in 1990/91 accounted for 37 per cent of gross cropped area in marginal farms, which recorded marginal fluctuations during 1977-91. Share of wheat area in gross cropped area increased by one-third to reach 16 per cent in 1990/91 from 12 per cent in 1970/71. Both wheat and rice occupied little over half of the gross cropped area in the marginal FHH category. Percentage share of rice and wheat in the gross cropped area of respective farm size groups exhibited inverse relationship with farm size. Largest farms with more than 10 ha holding size allocated 24 per cent of gross cropped area for rice and wheat.

Share of non-food crop in the gross cropped area improved marginally in the holding sizes of less than 2 ha and substantially in holding sizes with more than 2 ha. Share of cereals, foodgrains and food declined with differing magnitudes in different farm sizes during the period 1977-91.

Table 22 Crop area distribution by farm size (%)

Farm size (ha)	Year	Total area (GCA)	Rice	Wheat	Cereal	FG	Food	Non-Food
0-1	1976/77	100	36	12	71	82	87	13
	1980/81	100	40	15	72	81	89	11
	1985/86	100	38	16	69	78	87	13
	1990/91	100	37	16	68	77	86	14
1-2	1976/77	100	29	12	67	78	84	16
	1980/81	100	34	13	69	79	85	15
	1985/86	100	38	16	69	78	87	13
	1990/91	100	30	14	64	74	81	19
2-4	1976/77	100	29	12	67	78	84	16
	1980/81	100	27	13	66	77	82	18
	1985/86	100	32	14	67	77	83	17
	1990/91	100	25	13	61	72	78	22
4-10	1976/77	100	19	11	60	74	79	21
	1980/81	100	19	13	60	73	77	23
	1985/86	100	18	13	59	72	77	23
	1990/91	100	18	13	44	68	73	27
>10	1976/77	100	11	9	53	70	74	26
	1980/81	100	11	11	55	70	73	27
	1985/86	100	13	12	54	70	73	27
	1990/91	100	12	12	50	64	68	32
All	1976/77	100	25	11	63	76	82	18
	1980/81	100	24	13	63	75	80	20
	1985/86	100	25	14	62	75	80	20
	1990/91	100	24	14	57	71	77	23

As of now, more than 4/5th of the gross cropped area is allocated for food crops in the marginal FHHs. In the largest FHHs, little over two-third of the gross cropped area is allocated for food crops. This is again inversely related with the farm size. Share of cereals in gross cropped area is now little over two-third and food grain crop share in gross cropped area is little over three-fourth in the marginal holdings. With increase in farm size, these shares have come down to half of gross cropped area getting allocated for cereals and little less than two-third of gross cropped area getting allocated for food grain crops in the farms with more than 10 ha holding size. The percentage allocation of gross cropped area for food and non-food crops individually for major crops and crop groups revealed marginal decline in the share of rice, cereals, food grains and food and marginal increase in wheat and non-food crops.

Distribution of irrigated crop area expressed as a per cent of gross irrigated area in each farm size category is given in Table 23.

Table 23 Irrigated crop area distribution by farm size over time (%)

Farm size (Ha)	Year	Area (GIA)	Rice	Wheat	Cereal	FG	Food	Non-Food
0-1	1970/71	100	46	26	81	86	93	7
	1976/77	100	44	32	84	87	95	5
	1980/81	100	45	31	82	85	94	6
	1985/86	100	41	31	78	81	91	9
	1990/91	100	41	32	78	80	91	9
1-2	1970/71	100	43	27	79	83	91	9
	1976/77	100	43	29	81	84	94	6
	1980/81	100	42	29	79	82	92	8
	1985/86	100	37	32	75	80	89	11
	1990/91	100	37	31	74	77	88	12
2-4	1970/71	100	38	29	77	76	90	10
	1976/77	100	39	29	77	81	92	8
	1980/81	100	41	31	78	81	91	9
	1985/86	100	33	33	73	77	87	13
	1990/91	100	32	31	70	74	85	15
4-10	1970/71	100	31	30	72	77	86	14
	1976/77	100	32	30	72	76	88	12
	1980/81	100	28	33	69	74	84	16
	1985/86	100	27	33	68	73	82	18
	1990/91	100	26	32	65	70	80	20
>10	1970/71	100	26	29	66	73	82	18
	1976/77	100	27	29	67	73	84	16
	1980/81	100	21	34	64	70	78	22
	1985/86	100	24	35	66	72	79	21
	1990/91	100	22	34	62	68	75	25
All	1970/71	100	36	29	75	78	88	12
	1976/77	100	37	30	76	80	91	9
	1980/81	100	34	32	74	78	87	13
	1985/86	100	33	33	72	77	86	14
	1990/91	100	32	32	70	74	85	15

Share of irrigated rice in gross irrigated area has declined in every farm size over time. For all farm sizes, this share has gone down from 36 per cent in 1970/71 to 32 percent in 1990/91. The magnitude of this decline in irrigated rice area share is directly related to the farm size increasing from little over 10 to 15 per cent during the period 1971-91. On the contrary, share of wheat in gross irrigated area has increased in every farm size with differing magnitudes during this period.

Across all farm sizes, around two-third of the gross irrigated area is getting allocated for rice and wheat which remained more or less stable during this period. This share showed inverse relationship with the farm size. Marginal decline in the share of gross irrigated area getting allocated for cereals, foodgrains and food crops is also observed in all the farm size categories during the study period. Marginal increase in the share of non-food crops in the gross irrigated area is registered in the small and marginal FHHs but with increase in farm size beyond 2 ha, this share has gone up substantially by 39 to 50 per cent during the past four decades ending 1991.

3

EQUITY IMPACTS OF IRRIGATION DEVELOPMENT

Irrigation development policies pursued in the past five decades have targeted to bring more and more area under irrigation facilities through harnessing surface water and developing ground water. The distribution of land in association with the availability and accessibility to irrigation facilities will determine the equity impacts over space and time. While resultant equity impacts is neither designed explicitly nor targeted specifically while evolving irrigation development policies in the past, it would be useful to understand these impacts to plan for corrective future management strategies if and so needed.

3.1 Approach for equity impact analysis

Availability of land and accessibility to irrigation water play crucial role in the determination of the level and distribution of agricultural production and therefore income in many developing countries and India is no exception to this. Equitable distribution of land and water is therefore an essential pre-requisite for ensuring equitable distribution of income while alleviating poverty through irrigation-led agricultural development strategies. Conversely, quantitative assessment of inequality in irrigation water distribution is considered extremely important for strengthening irrigation policy decision making to achieve desired development objectives. With increasing dimensions of development goals in every sector, a balanced irrigation development can no longer rest only on regional equity but will have to factor in farm level equity implication as well.

With the economic literature on income distribution providing the background, equity in irrigation distribution can be considered in terms of positive or objective and normative or subjective approaches. Given the nature of the problem of equity, Sampath (1988) argued that any useful measure of equity must integrate both objective and normative measures. Deriving from the income distribution analysis, seven axioms namely irrigation scale independence, equal additions, principle of population, weak principle of transfers, strong principle of transfers, symmetry and normalized values are used for evaluating the robustness of different positive measures of equity. Seven equity measures are considered such as range, relative mean deviation, variance, coefficient of variation, standard deviation of algorithms, Gini coefficient and Theil's information measure. Among these, Theil's entropy measure is observed to be more versatile than the remaining measures analyzed. Theil's information measure fulfills many of the important axioms besides being amenable for decomposition analysis. While detailed studies have been conducted in understanding the problems of efficiency in the use of irrigation, distributional aspects of irrigation development have started receiving attention only since 1980s (Bromley *et al*., 1980, Lenton, 1984, Palanisami, 1980, Malhotra *et al*., 1984, Aberrantly, 1986) but the focus of such studies getting limited to the inequity problems in irrigation distribution in terms of farm location on the water course and farm size in particular project contexts (Bromley *et al*. 1980). Up to 1980s, no analysis of inequity in irrigation distribution even at a macro level was ever attempted in India.

Farm-size wise distribution of irrigation and irrigation assets has started receiving attention only in 1990s. Sampath (1990) using National Sample Survey (NSS) analyzed the level of inequity in irrigation distribution across farm size-groups in India with the agricultural year 1976/77 as the reference year. Using the same set of data, Sampath (1992) analyzed and described the relationship between the size of operational holding on the one hand and various irrigation-related variables. The study representing pre-1975 period concluded that, both over all irrigation development in India as well as predominantly government controlled development and distribution of flow-sources of irrigation, especially of canal irrigation does not seem to have promoted equity in the distribution of irrigation across farm size groups. With the same set of data, Sampath (1992) evaluated the nature of irrigation distribution in India using Rawlsian criterion of equity in distribution and estimated the performance of different states according to the Rawlsian notion of fairness in distribution. Considerable inequality across farm size groups in the distribution of irrigated areas in general and canal irrigated areas in particular with wide interstate differences in the levels of inequality is observed in the pre-1975 period. Switching over to a Rawlsian based distribution of canal irrigation tend to reduce the levels of inequality in overall irrigation development in all states.

Sampath (1992) also analyzed the levels of inequality in irrigation distribution over time utilizing agricultural census aggregate data. The distribution analysis was done for different sources of irrigation and for different farm sizes over a period of time covering 1970/71, 1976/77 and 1980/81 for India as a whole. The results showed mixed trends with the inequality in the distribution of irrigated area (both net and gross) declining in the period 1970/71 to 1976/77 and increasing in the period 1976/77 to1980/81 indicating the lack of consistency in the irrigation development policies pursued during pre-1980 period.

Since then, however, substantial investments have been made especially in medium and minor irrigation besides other private sources of ground water development. A shift in the paradigm of irrigation development from regionally balanced development in 1950s through 1970s towards balanced development within the region since 1980s assumes significance in view of its possible implications on equity related issues.

Only a detailed empirical analysis of the equity impacts of such irrigation development strategies over space and time can capture the improvement or otherwise of equity impacts which is extremely important for improved irrigation policy decision-making.

3.2 Methodology for equity impact analysis

Among various measures of inequality evaluated and discussed in the context of irrigation development in India, only Theil's information theoretic measure fulfills all the relevant equity axioms in addition to being easily amenable for decomposition analysis (Theil, 1967). A detailed discussion on the reasons for the choice of Theil's measure of inequality among all others is elucidated in Sampath, 1990.

Theil's entropy measure has attractive cardinal properties when one considers the decomposition of overall inequality in the country as a whole in terms of its constituent parts and hence more frequently used in the literature. Some of its applications in the analysis of inequality in irrigation distribution can be found in India, Pakistan, Sri Lanka and Bangladesh. For quantifying the extent of inequity in irrigation distribution across agricultural farm households, Theil’s entropy measure has been used in this study.

Using Theil's entropy measure, inter-farm size inequality in irrigation distribution in India was analyzed at all-India level as well as at the state level. Furthermore, the inequality at the all India level was also decomposed into its constituent parts namely 'between states' inequality and 'within states' inequality. Such an analysis will help in quantifying the sources of inequality for better irrigation policy decisions. This analysis was further extended as follows. More irrigation attributes were covered to understand the inequality status in irrigation distribution with respect to different sources of irrigation. More time periods covering 1970s through 1990s were taken up to provide reasonable insight into the distribution impacts of past irrigation development strategies for better irrigation policy decision making in the future. For comparison, several irrigation distribution policies like proportional distribution of water and Rawlsian based distribution were considered in the analysis. Methodological approach followed for equity impact analysis is given in the Appendix 2.

3.3 Data base

Cross-sectional database for this study was drawn from All India Report on Agricultural Census for the years 1970/71, 1976/77, 1980/81, 1985/86 and 1990/91 published by the agricultural census division of the Ministry of Agriculture, Government of India. This census is done once in five years and latest available report is for 1990/91. The coverage of this census is not uniform across periods. For instance, Agricultural census, 1970/71 provides data by farm size and state-wise for 12 farm size classifications. Agricultural census, 1976/77 provides data by farm size and state-wise for 13 farm size classifications. Agricultural census, 1980/81 and 1985/86 provides data by farm size but not for state-wise for 13 farm size classifications. Finally, the latest available Agricultural census, 1990/91 provides data by farm size and state-wise for five farm size classifications.

In this paper, for percentage analysis of irrigation distribution impact, all the census data for the period 1970/71 to 1990/91 are used. For applying the Theil's entropy measure and Theil's forecast error measure to estimate the levels of unfairness in distribution using Rawlsian notion of fairness in distribution, selected census period data as permitted by uniformity in their coverage are used. For providing common base for inter-temporal comparison of inequity impacts of irrigation distribution, farm sizes are also standardized into five size groups. They are 0 to 1 ha, 1 to 2 ha, 2 to 4 ha, 4 to 10 ha and more than 10 ha for the purpose of quantifying the inequity in irrigation distribution.

For quantifying the between states and within states contribution to irrigation inequity and estimating the state level inequity in irrigation distribution, the analysis was restricted to only two census periods namely agricultural census, 1970/71 and agricultural census, 1990/91. No state-wise coverage was provided for the agricultural census reports available during 1980/81 and 1985/86. The data collection methodology for the agricultural census was complete enumeration by retabulation of data already available in the land records. In a few states where land records are not maintained, the data was collected through sample surveys.

For this study, 16 states are covered that include Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Maharashtra, Orissa, West Bengal, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Kerala, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh. Small states like Arunachal Pradesh, Assam, Goa, Manipur, Mizoram, Meghalaya, Nagaland, Sikkim and Tripura and all Union Territories are combined into small states and union territories (SSUT) for the purpose of this analysis making the total number of constituents to 17 including SSUT.

3.4 Inequity impacts: current & Rawlsian distribution, all India

The temporal distribution of levels of inequality under current and Rawlsian distribution are given in Table 24.

Table 24 Levels of inequality under current and Rawlsian distribution of irrigation, all India

Year	Size-Classes	TMI-FLIA	TMIR-FLIA	MDCIDFRD	MDCIDFPD
Existing farm size classifications					
1970-71	12	0.426068	0.112675	0.87490	0.23225
1976-77	13	0.396312	0.140112	0.82234	0.31877
1980-81	13	0.497081	0.132794	0.77040	0.25286
1985-86	13	0.477649	0.130494	0.75383	0.21647
1990-91	5	0.469871	0.062226	0.78204	0.17115
Adjusted farm size classifications for 1976/77 to 1985/86					
1970-71	12	0.426068	0.112675	0.87490	0.23225
1976-77	12	0.395299	0.139370	0.85586	0.29807
1980-81	12	0.496098	0.132099	0.80669	0.23850
1985-86	12	0.476590	0.144871	0.81863	0.20931
1990-91	5	0.469871	0.062226	0.78204	0.17115
Uniform farm size classifications					
1970-71	5	0.392903	0.034601	0.88839	0.25710
1976-77	5	0.366417	0.054155	0.82788	0.30701
1980-81	5	0.457504	0.039454	0.79880	0.24650
1985-86	5	0.441292	0.037856	0.76760	0.21888
1990-91	5	0.469871	0.062226	0.78204	0.17115

The analysis was done for different numbers of farm size classes as available in the agricultural censuses as well as for aggregated numbers of farm size classes to ensure a common base for temporal comparison. Subsequent analysis and discussion is restricted to five-farm size classification only which is set by the agricultural census database available for 1990/91.

Table 24 provides the inequality indices of (I) current levels of Theil's entropy measure of inequality in the overall distribution of flow and lift irrigated areas (TMI-FLIA) across five farm size household categories; (2) expected levels of Theil's information theoretic measure of inequality that would occur under the Rawlsian approach to canal irrigation water distribution (TMIR-FLIA), (3) the magnitude of deviation of current canal irrigation distribution from Rawlsian distribution (MDCIDFRD). (4) the magnitude of deviation of current canal irrigation distribution from proportional distribution (MDCIDFPD). Proportional distribution distributes the irrigation water across farms in proportion to the area they operate as is widely followed in India like *warabandi* system in northwest India.

Perusal of Table 24 indicates the following: (1) Inequality levels are sensitive to the number of farm size categories, generally declining with the aggregation of farm sizes into less numbers. Hence, they are not strictly comparable across time periods if farm size classifications vary over time. (2) Theil's measure of inequality index for the overall distribution of flow and lift irrigated areas for India as a whole indicates mixed trends during 1970s and 1980s. While within the decade, the trend is one of declining inequality index, between decades, increasing levels of inequality in the distribution of flow and lift irrigation is observed. Such a mixed trend is attributed to lack of consistency in the irrigation development policy (Sampath, 1992). (3) During 1971-91, Theil's measure of inequality index for the overall distribution of flow and lift irrigated areas for India as a whole has gone up by around one-fifth. (4) Expected Theil's measure of inequality index under the Rawlsian approach to canal irrigation water distribution has come down substantially. Adopting a discriminatory policy of distributing irrigation water in favour of small farms, following the Rawlsian approach, helped in reducing the inequality in irrigation distribution across FHHs. Such an appropriately designed irrigation water distribution policy also has the potential of promoting both efficiency and equity in the realization of benefits from irrigation. (5) Deviation of current canal irrigation distribution from Rawlsian distribution indicates an index value of 0.78204 for 1990/91, which is 12 per cent less than that of 1970/71 levels. High values for this index indicates that according to the Rawlsian approach, there is a high degree of unfairness in the distribution of existing canal irrigated area in the country as a whole. Comparison of both MDCIDFRD and TMIR-FLIA indicates the scope for designing alternate distribution policies in the irrigation sector. (6) Deviation of current canal irrigation distribution from proportional distribution indicates the extent of inefficiency in realizing the stated objectives. This deviation has declined from 0.25710 in 1970/71 to 0.17115 in 1990/91. During this period, actual distribution has come closer to the normative distribution based on proportional distribution policy pursued and such a declining trend also remained consistent during the period 1971-91. However, it remains to be seen as to how the actual distribution vis-a-vis normative proportional distribution behaved across space, namely different states. This depends on how efficiently the proportional distribution of irrigation water is enforced in the irrigated commands of different states, which is discussed in the succeeding sections.

3.5 Inequity impacts: current and Rawlsian distribution, states

The temporal distribution of levels of inequality under current and Rawlsian distribution for selected states are given in Table 25. The analysis was done for 17 states by keeping uniformly the number of farm size classifications at five, across two time periods, namely, 1970/71 and 1990/91.

Table. 25 Temporal distribution of levels of inequality under current and Rawlsian distribution of irrigation by states

States	TMI-FLIA		TMIR-FLIA	
	70/71	90/91	70/71	90/91
Andhra Pradesh	0.29321	0.29660	0.11851	0.06231
Assam	0.32885	0.38236	0.12235	0.13624
Bihar	0.55097	0.36315	0.07098	0.07216
Gujarat	0.12761	0.20788	0.08540	0.08848
Haryana	0.33635	0.50585	0.08064	0.37341
Himachal Pradesh	0.18815	0.30887	0.16160	0.17521
Jammu & Kashmir	0.29906	0.50916	0.08550	0.12483
Karnataka	0.20483	0.56882	0.11041	0.20075
Kerala	0.40971	0.85103	0.11654	0.18311
Madhya Pradesh	0.20531	0.31471	0.13453	0.06183
Maharashtra	0.10994	0.25135	0.05114	0.10145
Orissa	0.23082	0.28401	0.16770	0.18499
Punjab	0.45300	0.40833	0.27314	0.28160
Rajasthan	0.32517	0.35093	0.25107	0.11210
Uttar Pradesh	0.46332	0.48946	0.09673	0.17690
Tamil Nadu	0.29768	0.36923	0.03768	0.12779
West Bengal	0.35745	0.24678	0.11650	0.13677

Table 25 provides the inequality indices of (I) current levels of Theil's entropy measure of inequality in the overall distribution of flow and lift irrigated areas (TMI-FLIA) across five farm size household categories of 17 states for 1970/71 and 1990/91; and (2) expected levels of Theil's information theoretic measure of inequality that would occur under the Rawlsian approach to canal irrigation water distribution (TMIR-FLIA) in different states.

Perusal of this table provides the following inferences: (1) There is wide inter-state variation in the level of inequality in the current distribution of flow and lift irrigated area across five farm size classifications among different states. In 1970/71, highest inequality was recorded in Bihar (0.55097) and least inequality level in the distribution of irrigation was observed in Maharashtra (0.10994). In 1990/91, maximum inequality was observed in Kerala and least in Gujarat. States have undergone variations in different magnitude during these two decades. This depends on the level of surface water development, ground water development and other watershed related conservation programmes for conserving *insitu* rainfall, which will interact with each other to determine the level of inequality in the distribution of irrigated area. Location specific ground and surface water resources available for exploitation becomes critical and if most of the potential is already exploited as in the case of Punjab, then the existing distribution of farm holdings will be the deciding factors for the current level of inequality in irrigated area distribution.

The potential reduction in the inequality of irrigated area distribution following the Rawlsian approach in different states indicates some variation but consistently, the level of inequality comes down by significant magnitude in all the states considered in this analysis. Least inequality in the Rawlsian approach is recorded in Madhya Pradesh and maximum inequality is recorded in Punjab and Haryana. However, as discussed earlier, in states like Punjab and Haryana, where substantial percentage of the potential is already exploited, this index is limited by the existing inequality in the distribution of farm holdings across the FHHs and not in terms of the distribution of irrigated area per se. The existence of scope for minimizing the inequality in the distribution of irrigated area across states is thus quantified and assessed by comparing the existing distribution of flow and lift irrigated area with the Rawlsian approach to the distribution of canal irrigated area.

3.6 Inequity impacts: Rawlsian and proportional distribution, states

The deviation of actual distribution of canal irrigated area from Rawlsian and proportional distribution policy is given in Table. 26.

Table 26 Temporal distributions of levels of inequality under Rawlsian and proportional distribution of Irrigation

States	MDCIDFRD		MDCIDFPD	
	70/71	90/91	70/71	90/91
Andhra Pradesh	0.80872	0.68233	0.41416	0.38801
Assam	0.97893	0.98161	0.24644	0.25585
Bihar	0.94283	0.70991	0.77595	0.35744
Gujarat	1.07079	1.01961	0.30538	0.32463
Haryana	0.90318	1.00770	0.04517	0.08260
Himachal Pradesh	0.82758	0.71645	0.20542	0.23456
Jammu & Kashmir	0.58959	0.75577	0.20077	0.02413
Karnataka	0.99444	0.95894	0.26583	0.16933
Kerala	1.22330	0.69314	0.30488	0.25285
Madhya Pradesh	1.03464	0.96897	0.31990	0.19523
Maharashtra	1.04278	0.92477	0.31543	0.44007
Orissa	0.89283	0.85868	0.30735	0.17112
Punjab	0.56116	1.08534	0.05606	0.13673
Rajasthan	1.25569	1.15538	0.51465	0.33123
Uttar Pradesh	0.91411	0.75168	0.10813	0.02796
Tamil Nadu	0.38982	0.75702	0.03414	0.08994
West Bengal	0.93374	0.77448	0.10266	0.11386

The above table provides, (1) the magnitude of deviation of current canal irrigation distribution from Rawlsian distribution (MDCIDFRD) and (2) the magnitude of deviation of current canal irrigation distribution from proportional distribution (MDCIDFPD) for 17 states by keeping uniformly the number of farm size classifications at five, across two time periods, namely, 1970/71 and 1990/91.

Perusal of Table 26 provides the following inferences: One, The measure of deviation of existing canal irrigated area distribution from the Rawlsian approach indicates very high values for the estimated index. In many states, based on Rawlsian approach, existence of unfairness in the distribution of canal-irrigated area exists. This offers scope to evaluate alternate distribution policies to minimize the inequality in the distribution of canal-irrigated area that is predominantly controlled by the government. Two, As of 1990/91, the magnitude of unfairness in the existing distribution is high in states like Punjab, Gujarat, Rajasthan and Haryana. But again, states like Punjab and Haryana only exhibit the existing inequality in the distribution of land area across holdings rather than the distribution of irrigated area as such since these states have exploited most of their water resource potentials as of now. Three, the deviation of actual distribution of canal irrigated area across farm sizes from the proposed proportional distribution shows wide inter-state variation during both the periods namely 1970/71 and 1990/91. This deviation has come down in many states during the period 1971-91 but still the inequality levels across states in 1990/91 highlights differing realization of the targeted irrigated area distribution under proportional distribution policy.

The physical condition of the irrigation system and enforcement of proportional distribution policies play an important role in these inter-state differences in the observed deviations. Such deviations also contribute to the inefficient performance of the systems as well as negatively impacting the equitable distribution of irrigation water.

3.7 Theil's inequity index for irrigation attributes, all India

The inequality indices for several irrigation related attributes such as; total area (TA), net area sown (NAS), net irrigated area (NIA), canal irrigated area (CIA), tank irrigated area (TIA), well irrigated area (WIA), tubewell irrigated area (TWIA), other sources irrigated area (OSIA), gross irrigated area (GIA), gross unirrigated area (GUIA) and gross cropped area (GCA) are estimated using the Theil's entropy measure. The analysis was done for five farm size classifications covering five different time periods, namely, 1970/71, 1976/77, 1980/81, 1985/86 and 1990/91.

3.7.1 All farm house holds

The estimated inequality index for all farm households and time period is given in Table 27.

Table 27 Theil's inequality index among farm households

Year	1971	1977	1981	1986	1991
TA	0.74498	0.71742	0.69158	0.64227	0.62434
NAS	0.69750	0.66974	0.66023	0.61784	0.59845
NIA	0.41795	0.36960	0.40911	0.39038	0.41959
CIA	0.43705	0.37564	0.40476	0.37893	0.40696
TIA	0.25172	0.26347	0.18747	0.18752	0.11340
WIA	0.52079	0.58749	0.65877	0.62827	0.77841
TWIA	0.45413	0.29982	0.41133	0.39864	0.36621
OSIA	0.28396	0.25296	0.27084	0.23104	0.29917
GIA	0.41703	0.36639	0.43624	0.38881	0.39927
GUIA	0.71204	0.70121	0.68754	0.61841	0.62681
GCA	0.63191	0.60356	0.60538	0.53723	0.53819

The inequality in the distribution of total area has come down from 0.74498 in 1970/71 to 0.62434 in 1990/91, a decline of 16 per cent during this period. Such a trend will help in relaxing the limits to inequality levels imposed by the existing distribution of land area when the level of irrigated area development approaches its potential.

Net sown area also has registered similar trend following the improvement in the distribution of total land area. Net irrigated area and canal irrigated area showed mixed trends declining in 1970s and 1980s independently but with a higher level of inequality in 1980s as compared to 1970s. Even the inequality index for the latest year 1990/91 is higher than the level of 1985/86. Irrigation development will have to internalize the likely distribution impacts of proposed strategies while designing policies in the irrigation sector. Not doing so in the past has resulted in either no impact or negative impact on the equitable distribution of irrigation facilities across farm sizes particularly in the canal irrigation.

Since, canal and tubewell irrigated areas dominated the total irrigated area, the interaction of both will determine the overall distribution impact of gross irrigated area. It is observed that, inequity in the distribution of gross irrigated area has declined continuously up to 1985/86 but marginally increased in 1990/91.

Inequality in tank-irrigated area has continuously declined during the past two decades ending with 1990/91. Generally, the tank-irrigated command is dominated by the small and marginal FHHs. With the steady deterioration of tank irrigation infrastructure, in farms with medium and larger holding size, source of irrigation has shifted from tanks to ground water. This process has further increased the share of small and marginal farm households in the tank irrigated area and thereby minimizing the inequity in the distribution of tank irrigated area over time. But the real concern here is the quality of tank irrigation which affects both the frequency of tank failure as well as level of its performance even in normal years with their shrinking capacity to receive, store and distribute water during the past as outlined in the earlier sections. Tank's failure will affect the small and marginal farm households severely contributing to the inequitable distribution of irrigation benefits in future if they are not rehabilitated and restored to normal functioning with physical and financial sustainability. Promoting equity in the distribution of irrigation benefits has to, therefore, encompass the integrated approach of involving every source of harnessing the rainwater and developing it for irrigation.

Inequality in well-irrigated area has generally increased over time except for a decline in 1985/86. Tube well-irrigated area registered impressive decline in 1970s and marginal decline in 1980s. But, like that of canal irrigation distribution, the level of inequality in tubewell irrigation also exhibited mixed trends between the two decades of 1970s and 1980s.

Between 1971 and 1991, inequality in the distribution of gross unirrigated area and gross cropped area has declined. In 1990/91, distribution of well-irrigated area had the highest inequality (0.77841) followed by gross unirrigated area, total area, net sown area and gross cropped area. It is also observed that inequality index for most of the irrigation attributes except well-irrigated area and that too only in 1990/91 is lesser than that of total area. This indicates that irrigation distribution alongwith net sown area and gross cropped area distributions are relatively more equitable than that warranted by the total area distribution.

3.7.2 Irrigated farm households

The inequality indices for irrigated area related attributes such as; total area (TA), net irrigated area (NIA), canal irrigated area (CIA), tank irrigated area (TIA), well irrigated area (WIA), tubewell irrigated area (TWIA), other sources irrigated area (OSIA), Gross irrigated area (GIA), Flow irrigated area (FLOW), Lift irrigated area (LIFT), irrigated rice area (RCEI), wheat irrigated area (WHTI), irrigated cereals area (CERI), irrigated foodgrains area (FGI), irrigated sugarcane area (SCNI), irrigated food crop area (FOODI) and irrigated non-food crop area (NFOODI) are estimated using the Theil's entropy measure.

The analysis was done for five farms size classifications for five different time periods namely 1970/71, 1976/77, 1980/81, 1985/86 and 1990/91.

Since most of the households do not have irrigation facilities, inequality index was now estimated only for irrigated households and shown in Table. 28.

Table. 28 Theil's inequality among irrigated farm households

Year	1971	1977	1981	1986	1991
TA	0.66271	0.60880	0.61704	0.58098	0.54645
NIA	0.40064	0.36671	0.44107	0.41705	0.43516
CIA	0.41946	0.37261	0.43666	0.40505	0.42197
TIA	0.23831	0.26119	0.21000	0.20722	0.12577
WIA	0.50176	0.58460	0.69875	0.66199	0.79977
TWIA	0.43538	0.29631	0.44330	0.42561	0.38077
OSIA	0.26923	0.25008	0.29741	0.25253	0.31293
GIA	0.39969	0.36345	0.46904	0.41539	0.41425
FLOW	0.37165	0.34662	0.38444	0.36816	0.37915
LIFT	0.39267	0.44942	0.48660	0.48299	0.57752
RCEI	0.26571	0.30147	0.30382	0.28213	0.26952
WHTI	0.44074	0.33663	0.49167	0.44391	0.42437
CERI	0.35060	0.31188	0.40292	0.36827	0.35238
FGI	0.35984	0.32214	0.41760	0.38048	0.36715
SCNI	0.48346	0.51513	0.53871	0.41711	0.37620
FOODI	0.36862	0.33599	0.42424	0.37920	0.36720
NFOODI	0.71007	0.76664	0.92396	0.71228	0.77264

Total area distribution across the farm sizes of irrigated FHHs showed falling inequality during the period 1971/91. Also, the distribution of total area among the irrigated farm households is more equitable than its distribution among the total farm households. At aggregate level, even though rights to water is established through rights to land, distribution of irrigation water has not accentuated the inequality further but only moderated it, as observed during the past two decades ending with 1990/91. Inequality in the distribution of tank irrigated area also declined continuously during these two decades for the same reasons outlined in case of total FHHs in the previous section.

Net irrigated area, canal irrigated area and gross irrigated area moved similar to each other, starting with a declining trend between 1970/71 and 1976/77 but this trend was getting reversed for every five years ending with a higher level of inequality in 1990/91 as compared to 1970/71. Thus overall inequality in the distribution of net irrigated area, canal irrigated area and gross irrigated area has increased with mixed and fluctuating trends within the decade underlining the impact of not having consistent policy in the public irrigation domain to target the equitable distribution of irrigation water.

The inequality index declined initially in 1970s but increased in 1980/81 before again declining in 1980s in case of tubewell irrigated area. Ultimately, the inequality index in respect of tubewell-irrigated area in 1990/91 is less in magnitude than in 1970/71. On the contrary well-irrigated area registered continuous increase in its distributional inequality across the irrigated farm households during 1971-91.

Flow and lift irrigated area distribution across the farm sizes registered increase in inequality in 1990/91 compared to that of 1970/71 but with a fluctuating trend during every five year time period underlining the inconsistency in the over all policy of irrigation development in the past. Inequality in the distribution of irrigated area across the irrigated farm households exhibited mixed trends between the decades as well as within the decade.

Among the individual irrigated crop area distribution considered, rice exhibited least inequality followed by wheat in 1970/71 and sugar cane in 1991. In fact, reduction in the inequality is more emphatic in sugar cane in 1980s indicating adjustment in the cropping pattern in favour of cash crops as a result of the existing distribution impacts of irrigation even without a clear cut and consistent trend. This reinforces the view that a targeted policy for promoting equitable irrigation development will ensure both equity and efficiency in the irrigation water use. Here also, as in the case of all farm house holds, inequality in the distribution of key irrigation attributes like NIA, CIA, TIA, TWIA, GIA, FLOW, and LIFT is considerably less in magnitude as compared to the inequality in the distribution of total area across the irrigated farm households. While inequality in the distribution of most of these irrigation attributes per se has not consistently declined during the past decades, certainly, the distribution impacts has moderated the inequality arising from the distribution of total area across farm holding sizes over time and this has remained consistent too.

3.8 Theil's inequity index for irrigation attributes by states

The inequality in distribution of selected irrigation and area attributes like non-canal irrigated area (NCIA), net area sown (NAS), net irrigated area by canal (NIACAN), net irrigated area by tanks (NIATNK), net irrigated area by wells (NIAWELL), net irrigated area by tubewell (NIATW), total net irrigated area (NIATOT), gross cropped area irrigated (GCAI), gross cropped area (GCA), all flow irrigated area (ALLFLOW), and all lift irrigated area (ALLFT) are considered for different states.

The analysis covered 17 states including SSUT for two time periods namely 1970/71 and 1990/91. The spatial and temporal distribution of inequality in NCIA, NAS and NIATOT are given in Table 29.

Table. 29 State-wise inequity in NCIA, NAS, NIACAN distribution , 1971-91

States	NCIA		NAS		NIACAN	
	1970/71	1990/91	1970/71	1990/91	1970/71	1990/91
AP	0.3503	0.3475	0.6650	0.5198	0.2438	0.1904
BIH	0.4660	0.3018	0.5813	0.3198	0.6101	0.2827
KAR	0.1932	0.4114	0.5238	0.4938	0.2180	0.2842
MP	0.3627	0.4832	0.4682	0.4029	0.1526	0.2022
MAH	0.1568	0.2061	0.3113	0.3150	0.0706	0.0427
ORI	0.2516	0.3611	0.3054	0.4603	0.1614	0.2318
WB	0.2978	0.2203	0.2833	0.2523	0.3234	0.2438
GUJ	0.1777	0.2558	0.2338	0.4124	0.0620	0.1312
HAR	0.3076	0.4964	0.3817	0.5358	0.4510	0.5764
HP	0.4044	0.2377	0.3071	0.2909	0.1737	Neg
JK	0.2348	0.3472	0.3927	0.3588	0.2421	0.3806
KER	0.2648	0.2690	0.3431	0.3323	0.4932	0.4220
PUN	0.4946	0.4171	0.4973	0.4471	0.5486	0.5695
RAJ	0.1846	0.2955	0.7486	0.6286	0.8068	0.5912
TN	0.3030	0.2982	0.4111	0.3809	0.2433	0.3088
UP	0.3748	0.4157	0.4100	0.4106	0.5129	0.3905
SSUT	0.2231	0.5190	0.2916	0.2601	0.3184	0.2361
Mean	0.2969	0.3461	0.4209	0.4013	0.3313	0.3177
Std Dev	0.1007	0.0980	0.1434	0.1041	0.2072	0.1607
C.V (%)	33.9	28.3	34.1	26.0	62.6	50.6
Bet sts	0.1551	0.1264	0.2911	0.3177	0.1302	0.2093
With sts	0.3328	0.3559	0.4580	0.4060	0.3911	0.3153

Following inferences are drawn from the following table: (1) Average inequality in NCIA has increased; and NAS and NIACAN distribution inequality has marginally declined. (2) Variability in the inequality distribution has declined in 1991 as compared to 1971 for all the three attributes namely; NCIA, NAS and NIACAN came down during the period 1971/91. This underlines reduction in the inequality across states associated with the distribution of non-canal irrigated area, net area sown and net irrigated area by canal across farm sizes. Except Maharashtra, Gujarat, Orissa and Haryana, in case of all other states, inequality in the distribution of net area sown across farm sizes has increased in 1991 over 1971. In case of net irrigated area by canal, the inequality in distribution has increased in states like Punjab and Haryana during 1991 compared to 1971 mainly due to the limitation interms of existing inequality in the distribution of land area across farm households. While CV for NIACAN in 1991 has come down to 50.6 per cent it is very high compared to NAS and NCIA. This highlights that while inter-state imbalance in the distribution of inequality in NIACAN has been moderated during the past two decades ending 1991 still considerable scope variability exists among the states. Quantification of source wise contribution to the inequality index will help in identifying the existing potentials for targeting the minimization of inequality in irrigation distribution.

The spatial and temporal distribution of inequality in NIATNK and NIAWELL are given in Table. 30.

Table 30 State-wise inequity in NIATNK and NIAWELL distribution, 1971-91

States	NIATNK		NIAWELL	
	1970/71	1990/91	1970/71	1990/91
AP	0.2783	0.2068	0.6136	0.5425
BIH	0.6988	0.3041	0.3357	0.3325
KAR	0.1095	0.1809	0.3783	0.5847
MP	0.2819	0.2271	0.3792	0.4365
MAH	0.0641	0.0691	0.2372	0.2608
ORI	0.3025	0.3508	0.3081	0.6353
WB	0.2483	0.1945	0.1551	0.4020
GUJ	0.0476	0.2894	0.2057	0.3061
HAR	NA	NA	0.1996	0.5264
HP	0.0510	NA	0.3495	0.3523
JK	0.1878	0.3572	0.1308	NA
KER	0.1284	0.2481	0.2542	0.2411
PUN	NA	NA	0.1836	0.0835
RAJ	0.0616	0.1025	0.5117	0.3405
TN	0.1880	0.1451	0.4633	0.4549
UP	0.2146	0.2335	0.3005	0.6376
SSUT	0.2547	0.3356	0.1273	0.6325
Mean	0.2078	0.2318	0.3020	0.4231
Std Dev	0.1633	0.0898	0.1378	0.1625
CV (%)	78.6	38.7	45.6	38.4
Bet sts	0.4306	0.9000	0.6100	1.0776
With sts	0.2336	0.2099	0.3486	0.4707

Following inferences are drawn from the above table;

One, average inequality index in respect of net irrigated area by tanks and net irrigated area by wells increased in 1991 over 1971 and the increase in inequality is substantial in the case of well irrigated area distribution across the states. However, CV has come down in both the irrigation attributes during the two decades ending 1991. Reduction in the CV for instability index of NIATNK is substantial during this period. But unfortunately this is associated with overall decline in the coverage of tank-irrigated area in the states where tank irrigation remained one of the major sources of irrigation in the past. Sources of instability arising from between the states and within the state are therefore important to understand the future strategies needed for different sources of irrigation development and distribution.

Two, generally for many states, the inequality index for NIA WELL has increased during this period. The development and distribution of well-irrigated area is always conditioned by the availability of ground water potential and hence specific to the ground water aquifer of the region and hence interstate variation is expected to be higher in magnitude. Here also, failure of wells due to well interference and depletion of ground water will have implications in terms of influencing the over all inequality in its distribution. Hence, source wise analysis of inequality index covering both within the state and between the state will be useful for designing future irrigation development strategies.

Three, while rehabilitating and restoring the status of tanks as a source of irrigation and recharging ground water in the dryland and drought prone regions will increase the inter-state variation in the distribution inequality, such an approach will have a major impact in reducing the inequality in its distribution across farm sizes. This is because tank command area is mostly dominated by small and marginal farmhouse holds. Hence, here again, source wise assessment of contribution to the inequality index, arising from within states and between states needs to be done for better planning.

The spatial and temporal distribution of inequality in net irrigated area by tube well (NIATW), total net irrigated area (NIATOT) and irrigated gross cropped area (GCAI) are given in Table 31, based on which following inferences can be drawn: One, mean inequality index for NIATW, NIATOT and GCAI has increased during 1971-91 but the variability in its distribution among the states has come down significantly. Two, inequality index for NIATW has substantially increased in 1991 as compared to that of 1971 in case of states like Karnataka, Madhya Pradesh and Haryana. Of course, the potential reduction in the inequality for NIATW is limited by the existing distribution of land area across farm sizes at least in those of the states like Haryana wherein the potential limit for irrigated area development is nearing its limit. Three, It is further emphasized by high inequality index for the NIATOT in case of states like Punjab and Haryana, which topped the list of states for the year 1990/91.

Table 31 State-wise inequity in NIATW, NIATOT, GCAI among FHHs

States	NIATW		NIATOT		GCAI	
	1970/71	1990/91	1970/71	1990/91	1970/71	1990/91
AP	0.5355	0.5152	0.2966	0.2753	0.2966	0.2527
BIH	0.5618	0.3490	0.5202	0.2949	0.5358	0.3858
KAR	0.1600	0.5478	0.2035	0.3496	0.2160	0.3491
MP	0.2002	0.8628	0.2423	0.3480	0.2440	0.3476
MAH	NA	0.2525	0.1367	0.1612	0.1344	0.1564
ORI	0.2726	0.3352	0.1819	0.2580	0.2101	0.2190
WB	0.4694	0.1996	0.3105	0.2223	0.2733	0.1847
GUJ	0.0562	0.1568	0.1511	0.2293	0.1501	0.2308
HAR	0.3292	0.5003	0.3864	0.5315	0.3807	0.4528
HP	0.8277	0.6408	0.1772	0.2307	0.1456	0.2007
JK	0.1842	0.3572	0.2411	0.3692	0.2588	0.3726
KER	0.4266	0.4853	0.3541	0.3070	0.3912	0.2610
PUN	0.5763	0.4133	0.5199	0.4611	0.4915	0.4642
RAJ	0.3174	0.1840	0.3441	0.3832	0.3415	0.3893
TN	0.4607	0.4101	0.2822	0.3015	0.2650	0.3127
UP	0.4713	0.4152	0.4193	0.4077	0.4297	0.3499
SSUT	0.2261	0.2938	0.3062	0.3794	0.2891	0.3493
Mean	0.3797	0.4070	0.2984	0.3241	0.2973	0.3105
Std Dev	0.1978	0.1789	0.1167	0.0941	0.1176	0.0928
CV	52.1	43.9	39.1	29.0	39.6	29.9
Bet sts	1.1758	0.7349	0.0787	0.1229	0.2112	0.1451
With sts	0.4147	0.3942	0.3458	0.3355	0.3472	0.3789

Least inequality index in total net irrigated area was observed in case of states like Maharashtra followed by West Bengal. Aided by irrigation development and agricultural technology development, variability in irrigated gross cropped area across states has come down in 1991 as compared to two decades back. But for those states, which are nearing their full potential use level of land and water, the inequality in many of the irrigation related attributes across states would have further come down during this period. For instance, again Punjab and Haryana topped the list of states with high inequality index in the distribution of irrigated gross cropped area.

The spatial and temporal distribution of inequality in gross cropped area (GCA), all flow-irrigated area (ALLFLOW) and all lift-irrigated area (ALLLFT) are given in Table 32.

Table 32 State-wise inequity in GCA, ALL FLOW, ALLLFT among FHHs

States	GCA		ALLFLOW		ALLLFT	
	1970/71	1990/91	1970/71	1990/91	1970/71	1990/91
AP	0.6287	0.4578	0.2568	0.1966	0.6050	0.5336
BIH	0.5634	0.4022	0.6186	0.2849	0.4536	0.3449
KAR	0.5067	0.4856	0.1675	0.2561	0.3782	0.5755
MP	0.4335	0.3970	0.1685	0.2037	0.3740	0.4890
MAH	0.2830	0.2962	0.0673	0.0467	0.2372	0.2611
ORI	0.2478	0.3487	0.1803	0.2454	0.2660	0.4934
WB	0.2696	0.1774	0.2979	0.2231	0.3648	0.2170
GUJ	0.2248	0.3981	0.0590	0.1351	0.1892	0.2567
HAR	0.3532	0.4444	0.4510	0.5802	0.3042	0.4999
HP	0.2869	0.2667	0.1734	NA	0.4635	0.4219
JK	0.4047	0.3590	0.2418	0.3717	0.1611	NA
KER	0.3317	0.2657	0.3626	0.3467	0.2650	0.2437
PUN	0.4615	0.4572	0.5486	0.5695	0.4949	0.4127
RAJ	0.5692	0.5369	0.5714	0.5367	0.5046	0.3104
TN	0.3830	0.3888	0.2153	0.2254	0.4630	0.4463
UP	0.4174	0.3680	0.4737	0.3875	0.3996	0.4209
SSUT	0.2717	0.2823	0.3180	0.2354	0.1965	0.5558
Mean	0.3904	0.3725	0.3042	0.3028	0.3600	0.4052
Std. Dev	0.1234	0.0926	0.1739	0.1536	0.1282	0.1186
CV	31.6	24.9	57.2	50.7	35.6	29.3
Bet sts	0.3722	0.2514	0.1109	0.1895	0.4781	0.3187
With sts	0.4348	0.3787	0.3631	0.3032	0.4136	0.3959

From this table, following inferences are drawn: (1) Mean inequality index has come down for GCA and ALLFLOW but increased for ALLLFT during the two decades ending 1991. (2) The variability in the distribution of inequality among the states has come down in respect of all the irrigation attributes considered here namely, GCA, ALLFLOW and ALLFT. (3) Least inequality index for GCA is recorded in case of West Bengal. Maharashtra, Gujarat and Andhra Pradesh registered less inequality in ALLFLOW among all the states considered in this analysis. For ALLLFT, West Bengal led the states with least inequality index followed by Kerala and Gujarat. Haryana, Punjab and Rajasthan are the states with high inequality index for ALLFLOW while Karnataka, SSUT and Andhra Pradesh are the states with high inequality index for ALLLFT during 1990/91.

3.9 Source-wise inequality index

While estimation of inequality index for different irrigation attributes over space and time will help in the better understanding of the past impacts of irrigation development, decomposing such inequalities in terms of different sources will facilitate the future strategies. Inequality in irrigation distribution emanates from two sources; One, inequality in distribution of irrigation development across the states and two, inequality in distribution of irrigation development across farm sizes within the state. Hence, decomposition of the inequality in selected irrigation related attributes are attempted. Both the sources of inequality namely; 'within the states' (WITHSTS) and 'between the states' (BETSTS) inequality are estimated for two periods of time namely, 1970/71 and 1990/91. The decomposed inequality index is given in Table. 33.

Table. 33 Inequality decomposition by sources, 1971-91

Irrigation attributes	1970/71			1990/91		
	BETSTS	WITHSTS	WITHSTS (%)	BETSTS	WITHSTS	WITHSTS (%)
NCIA	0.1551	0.3328	68.2	0.1264	0.3559	73.8
NAS	0.2911	0.4580	61.1	0.3177	0.4060	56.1
NIACAN	0.1302	0.3911	75.0	0.2093	0.3153	60.1
NIATNK	0.4306	0.2336	35.2	0.9000	0.2099	18.9
NIAWELL	0.6100	0.3486	36.4	1.0776	0.4707	30.4
NIATW	1.1758	0.4147	26.1	0.7349	0.3942	34.9
NIATOT	0.0787	0.3458	81.5	0.1229	0.3355	73.2
GCAI	0.2112	0.3472	62.2	0.1451	0.3789	72.3
GCA	0.3722	0.4348	53.9	0.2514	0.3787	60.1
ALLFLOW	0.1109	0.3631	76.6	0.1895	0.3032	61.5
ALLLFT	0.4781	0.4136	46.4	0.3187	0.3959	55.4

Table 33 provides over all estimates of WITHSTS and BETSTS inequality in the development and distribution irrigation during the two decades ending with 1990/91. From this, following inferences could be drawn.

There is considerable inequality in the distribution of NAS in the country, which has marginally come down in 1991 as compared to the level in

1971. Out of this, in 1970/71, 39 per cent of inequality came from BETSTS variability in the distribution of NAS among the states. Remaining 61 per cent of the inequality in the distribution of NAS has come from within the state variability in the distribution of NAS across different farm size holdings. Source-wise contribution to the inequality has changed in 1991 marginally in which, the contribution from WITHSTS inequality has come down to 56 per cent.

Inequality in GCA has come down during 1971-91 period but the source-wise contribution to the inequality for GCA has changed. From a level of 53.9 per cent of contribution to the overall inequality in GCA during 1971, it has gone up to 60.1 per cent in 1991. Inequality in total net irrigated area has gone up during 1971-91 and with it, contribution of within the state variation in the distribution of net irrigated area has come down from 81.5 per cent in 1971 to 73.2 per cent in 1991.

Irrigated gross cropped area retained the inequality index more or less the same during this period but WITHSTS contribution has increased from 62.2 per cent to 72.3 per cent. Another important irrigation attribute namely canal irrigated area also retained its inequality index during 1971-91 but the contribution towards the over all inequality for NIACAN from within the states has come down from 75 in 1971 to 60.1 per cent in 1991. Despite this reduction in the within states contribution to the inequality, the share of WITHSTS is still considerable, indicating the existence of more potential through within the state allocation of NIACAN among different farm sizes to bring down the inequality in the distribution of canal irrigation facilities.

Source wise inequality estimated for NIATNK, NIAWELL and NIATW recorded high levels of overall inequality in their distribution. But the major source for this inequality comes from BETSTS variations in the distribution of tank, well and tubewell irrigation facilities, which varied from 65 to 81 per cent. Obviously, besides the existing imbalance in the distribution of tank and well irrigation development, these sources are specific to location as determined by the agroclimatic and ground water aquifer characteristics.

Non-canal irrigated area also showed high inequality contributed by within the state distribution of this non-canal irrigated area among farm sizes. Incase of ALL FLOW, within the state's contribution to the overall variability has come down from 76.6 to 61.5 percent during 1971-91. The corresponding share for ALLLFT is 46.4 per cent in 1970/71 and 55.4 per cent in 1990/91. The scope for reducing the inequality in flow irrigated area exists more with the within the state source while for all lift irrigated area, the scope for reducing the inequality is relatively less in the WITHSTS source.

4

FUTURE IRRIGATION WATER DEVELOPMENT STRATEGIES

4.1 Equitable irrigation development

Relative equity performance of different sources of irrigation is compared for assessing the future strategies. For this comparison, index of NCIA and NIACAN inequalities over two periods of time is estimated. The states are arranged in the descending order of the index for 1970/71 and 1990/91. An index value of less than unity indicates the superior performance of NCIA in promoting equitable distribution of irrigation benefits across the farm sizes. An index value of more than one indicate the better performance of NIACAN in promoting equitable distribution of irrigation benefits across the selected five FHH categories (Table 34).

Table 34 Index of NCIA and NIACAN inequalities

States	1971	States	1991
Gujarat	2.87	Maharashtra	4.83
Madhya Pradesh	2.38	Madhya Pradesh	2.39
Himachal Pradesh	2.33	Small States & Union Territories	2.20
Maharashtra	2.22	Gujarat	1.95
Orissa	1.56	Andhra Pradesh	1.83
Andhra Pradesh	1.44	Orissa	1.56
Tamil Nadu	1.25	Karnataka	1.45
Jammu & Kashmir	0.97	Bihar	1.07
West Bengal	0.92	Uttar Pradesh	1.06
Punjab	0.90	Tamil Nadu	0.97
Karnataka	0.89	Jammu & Kashmir	0.91
Bihar	0.76	West Bengal	0.90
Uttar Pradesh	0.73	Haryana	0.86
Small States & Union Territories	0.70	Punjab	0.73
Haryana	0.68	Kerala	0.64
Kerala	0.54	Rajasthan	0.50
Rajasthan	0.23	Himachal Pradesh	NA

States like Gujarat, MP, Maharashtra, Orissa and AP exhibited consistent trend in both the time periods. The NCIA/NIACAN index being more than unity in these states, canal irrigated area proved to be superior in promoting equity in the distribution of irrigation benefits. Inequality values for NIACAN remained less than NCIA inequality in both the periods for these states and the magnitude of difference is also high with 1.44 as the lowest and 4.83 as the highest index value among these states. Canal irrigated area provides better option for improving the overall equity in irrigation distribution in these states. Therefore, equitable distribution of canal-irrigated area assumes greater significance in these states. With 2/3rd of the current inequality in canal irrigation distribution coming from within the state source, equitable distribution of irrigation water among the FHH categories within the state assumes greater significance in these states to reduce overall inequality in irrigation distribution.

States like Rajasthan, Kerala, Punjab, Haryana, West Bengal and Jammu and Kashmir consistently registered less than unity value for the index during 1971 and 1991. Relatively, distribution of NCIA has contributed more for improving the equity in irrigation distribution as compared to that of NIACAN in these states. Around 3/4th of the inequality in NCIA distribution has come from within the states source, once again highlighting the necessity of targeting the equitable distribution of irrigation among the different FHH categories within the state. In 1971, in seven out of 17 states, canal irrigated area distribution had a better equity performance than NCIA and this number increased to nine states in 1991. This calls for spatially differentiated strategies by states and irrigation sources to specifically target for equitable distribution of irrigation coverage.

Changes in the inequity levels of 11 irrigation related attributes during the period 1971 and 1991 are given in Table 35. Only in case of AP and Bihar, inequality in the distribution of all irrigation-related attributes has decreased during the two periods of time namely 1971 and 1991. But in case of Orissa, Gujarat and Haryana, inequality in the distribution of all irrigation attributes has increased during this period. States with most of the irrigation attributes recording increase in the levels of inequality during 1971-91 are Karnataka, MP, Maharashtra, Orissa, Jammu & Kashmir and SSUT. States with most of the attributes registering decrease in the levels of inequality during 1971-91 are WB, HP, Kerala, Punjab and Rajasthan. Such a wide variation in the levels of different irrigation attributes observed both over space and time underlines the absence of any definite trend which could be attributed to the past irrigation development policies. Mixed trends can at the best be indicative of not having any policies in the past, primarily focusing on equitable distribution of irrigation. In other words, equitable distribution of irrigation in future will have to be explicitly targeted in the irrigation development strategies.

List of states with inequality levels higher than the mean levels of inequality is given in Table 36.

Table 35. Changes in inequity in 1991

States	Increase in inequity, 1991 over 1971	Decrease in inequity, 1991 over 1971
AP		NCIA, NAS, NIACAN, NIATNK, NIAWELL, NIATW, NIATOT, GCAI, GCA, ALLFLOW, ALLLFT
BIH		NCIA, NAS, NIACAN, NIATNK, NIAWELL, NIATW, NIATOT, GCAI, GCA, ALLFLOW, ALLLFT
KAR	NCIA, NIACAN, NIATNK, NIAWELL, NIATW, NIATOT, GCAI, ALLFLOW, ALLLFT	NAS, GCA,
MP	NCIA, NIACAN, NIAWELL, NIATW, NIATOT, GCAI, ALLFLOW, ALLLFT	NAS, NIATNK, GCA,
MAH	NCIA, NAS, NIATNK, NIAWELL, NIATOT, GCAI, GCA, ALLLFT	NIACAN, ALLFLOW
ORI	NCIA, NAS, NIACAN, NIATNK, NIAWELL, NIATW, NIATOT, GCAI, GCA, ALLFLOW, ALLLFT	
WB	NIAWELL	NCIA, NAS, NIACAN, NIATNK, NIATW, NIATOT, GCAI, GCA, ALLFLOW, ALLLFT
GUJ	NCIA, NAS, NIACAN, NIATNK, NIAWELL, NIATW, NIATOT, GCAI, GCA, ALLFLOW, ALLLFT	
HAR	NCIA, NAS, NIACAN, NIAWELL, NIATW, NIATOT, GCAI, GCA, ALLFLOW, ALLLFT	
HP	NIAWELL, NIATOT, GCAI,	NCIA, NAS, NIATW, GCA, ALLLFT
JK	NCIA, NIACAN, NIATNK, NIATW, NIATOT, GCAI, ALLFLOW	GCA, NAS
KER	NCIA, NIATNK,	NAS, NIACAN, NIAWELL, NIATOT, GCAI, GCA, ALLFLOW, ALLLFT
PUN	ALLFLOW, NIACAN	NIATW, NIATOT, GCAI, GCA, ALLLFT, NCIA, NAS, NIAWELL
RAJ	NCIA, NIATNK, NIATOT, GCAI,	NAS, NIACAN, NIAWELL, NIATW, GCA, ALLFLOW, ALLLFT
TN	NIACAN, NIATOT, GCAI, GCA, ALLFLOW	NCIA, NAS, NIATNK, NIAWELL, NIATW, ALLLFT
UP	NCIA, NAS, NIATNK, NIAWELL, ALLLFT	NIATW, NIATOT, GCAI, GCA, ALLFLOW, NIACAN
SSUT	NCIA, NIATNK, NIAWELL, NIATW, NIATOT, GCAI, GCA, ALLLFT	ALLFLOW, NAS, NIACAN

Table. 36 Changing inequality levels in irrigation distribution

State	SWD%	GWD%	NCIA	NAS	NIACAN	NIATNK	NIAWELL	NIATW	NIATOT	GCAI	GCA	ALLFLOW	ALLLFT
AP	62	24	AP	AP			AP	AP			AP		AP
ASM	32	5											
BIH	51	19				BIH				BIH	BIH		
HAR	70	84	HAR	HAR	HAR		HAR	HAR	HAR	HAR	HAR	HAR	HAR
JK	83	2	JK		JK	JK			JK	JK		JK	
KAR	71	31	KAR	KAR			KAR	KAR	KAR	KAR	KAR		KAR
KER	40	15			KER	KER		KER				KER	
MP	42	16	MP	MP			MP	MP	MP	MP	MP		MP
ORI	48	8	ORI	ORI		ORI	ORI						ORI
PUN	82	94	PUN	PUN	PUN			PUN	PUN	PUN	PUN	PUN	PUN
RAJ	81	51		RAJ	RAJ				RAJ	RAJ	RAJ	RAJ	
TN	90	60					TN	TN		TN	TN		TN
UP	59	38	UP	UP	UP	UP	UP	UP	UP	UP		UP	UP
			SSUT			SSUT	SSUT		SSUT	SSUT			SSUT

SWD refers to current status of surface water development and GWD refers to current status of ground water development

Eleven irrigation-related attributes are considered for this. Punjab, Haryana and Uttar Pradesh are the states to have registered inequality levels higher than the mean levels in respect of most of the irrigation related attributes. Karnataka and Madhya Pradesh are the other states to closely follow similar trends exhibiting high inequality levels in many of the irrigation attributes. In southern states like, Andhra Pradesh, Tamil Nadu and Karnataka, non-canal related irrigation attributes recorded higher inequality levels than the mean values. In case of Kerala, both flow and lift irrigation attributes have shown higher inequality than their mean values.

In most of these states, wherein, higher inequality levels are observed in both flow as well as lift irrigation related attributes, surface water development are nearer to two-third or even higher levels and similarly, ground water development is also much higher than other states. Such a tightening situation sharpens the equity goals in the context of future irrigation development, which has to encompass all the sources of water. Watershed based resource development strategies can no longer be viewed in isolation and will have to be integrated in to the irrigation development planning with equity goals coming to the forefront. In most of these states, watershed approach will have to be the major driving force in the coming years for improving the equity in irrigation distribution through direct augmentation of surface flows and improved ground water recharge. Despite having adequate technology backup in watershed development over years, the pace of progress in saturating the priority areas is far from satisfactory. The current status of diverse experience in watershed development in the country is briefly outlined in the following sections.

4.2 Watershed development: experiences and strategies

Water is a vital input in agriculture. In order to sustain the food security goal realized, rainfed agriculture must contribute to food production growth in future. Currently, rainfed area contributes only 44 per cent to the total foodgrain production. If food production growth in future is to be rainfed-led, then water *inter alia* other inputs holds the key. Keeping in view the financial and other geo-physical constraints, judicious harvesting and utilization of rainwater should be given pre-eminence in every stage of water use planning and development. Only then, overall efficiency as well as equity in the use of irrigation water within the water sector can be ensured.

The watershed concept is not something new in India. Water harvesting practices in the country date back to 300-400 BC. Peoples' participation in impounding and utilizing rainwater was inherent up to the beginning of 20th century. Thereafter, due to a host of reasons, community involvement in water resource management started to decline.

4.2.1 Watershed management approach

Watershed development in India is essentially multi-organizational based both in terms of implementation and participation. Broadly, they are implemented by organizations like central ministries, state departments, external agencies (like World Bank, EEC, DANIDA and individual governments like Germany and Sweden) and the NGO's. Obviously, extent of participation and level of performance varies across the groups. Watershed concept in a technology development and generation mode was initiated during 1970's. The ICAR under All India Coordinated Research Projects on Dry Land Farming took up 23 integrated watershed development models. Thereafter, 15 pilot projects for disseminating water conservation/harvesting technology were launched by the ICAR. In the early eighties, through the combined efforts of ICAR and Department of Agriculture & Cooperation, 42 model watershed development projects were developed. This combined effort was the launching pad for the National Watershed Development Programme for Rainfed Areas (NWDPRA) in the VII FYP. This ambitious plan targeted 99 select watersheds spread across the nation. In the VIII FYP, a number of projects for the integrated development of rainfed areas, based on watershed management approach are initiated. Under the Agricultural Ministry, four projects viz., the National Watershed Development Project for Rainfed Areas (NWDPRA), Soil Conservation in the Catchments of River Valley Projects, Integrated Watershed Management in the Catchments of Flood-Prone Rivers (FPR) and Watershed Development Projects for Control of Shifting Cultivation Area (WDPSCA) in North Eastern India are operational. There are 14 other internationally aided projects in which the Ministry is involved. The Ministry of Rural Areas and Employment is also involved in watershed development through programs such as DPAP, DDP and IWDP.

The magnitude of investment and area treated by the central agencies are provided in the Tables 37 and 38 respectively. From Table 37, it is clear that NWDPRA and RVP are the dominant schemes in the watershed sector. This is followed by FPR and externally aided projects (EAP). Put together, total expenditure incurred by different schemes for watershed development stands at Rs.1368 crores. Area treated by RVP scheme accounts for 30 per cent of total area treated by all schemes. In all, around 80 lakh hectares have been treated. Distribution of problem area by states that requires watershed based treatment, current status of development and balance area to be treated with estimated financial requirements are outlined in Table 39. For the country as a whole, out of 1690 lakh ha of problem area identified, 29.8 per cent has been so far treated. For providing watershed based resource conservation treatment in the remaining 1187.15 lakh ha area, Rs 29736.65 crore is required at current prices. This estimate is based on per hectare cost requirement of

Table 37 Investment in (crore Rs) watershed development under different programs

Programme	Upto VII FYP	A.P, 1990/91	A.P, 1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	VIII FYP total	Grand Total
NWDPRA	-	-	-	-	-	527.53*	-	-	-	-
RVP	307.33	34.04	46.68	46.18	56.77	61.6	65.0	65.0	294.5	682.61
FPR	90.90	16.05	21.93	20.77	21.97	27.38	30.0	35.0	135.12	264.00
WDPSCA	-	-	-	3.76	6.25	13.24	14.97	-	-	-
DPAP	-	-	-	-	-	-	63.39	-	-	-
DDP	-	-	-	-	-	-	-	44.83	-	-
IWDP	-	-	-	-	-	-	49.5	-	-	-
EAP	-	-	-	-	-	-	-	-	-	225.33

Upto the year 1994-95. All figures represent the actual expenditure.

Table 38 Area treated (lakh hectares) under different watershed development programs

Programmes	Upto VII FYP	A.P, 1990/91	A.P, 1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	VIII Plan total	Grand Total
NWDPRA	-	-	-	-	-	-	-	-	-	25.50
RVP	23.95	0.90	1.41	1.27	1.41	1.33	1.50	1.50	7.01	33.28
FPR	3.65	0.43	0.66	1.09	0.63	0.65	0.81	0.75	0.88	3.67
WDPSCA	-	-	-					-	-	-
DPAP	-	-	-	-	-	-	-	-	-	-
DDP	-	-	-	-	-	5.15*			-	-
IWDP	-	-	-	-	-	4.00		-	-	-
EAP	-	-	-	-	-	10.04	-	-	-	

Source: Report of Working Group on Soil and Water Conservation for the formulation of Ninth FYP, Dept. of Agriculture and Cooperation, Ministry of Agriculture, April 30th, 1996.

Table 39 State-wise problem area treated and the balance yet to be treated on a watershed basis (Lakh ha)

States	Total problem area	Programmes			Balance area	Cost in Rs per ha (NWDPRA estimate)	Total estimated cost in lakh Rs
		RVP/ FPA/ SWC-C+S	NWDPRA	DPAP/ DDP IWDP			
Andhra Pradesh	122.31	13.59	1.77	11.81	95.14	2891	275076
Arunachal Pradesh	26.54	0.33	0.02	0.01	26.18	5097	133458
Assam	29.99	2.30	0.70	0.06	26.93	2253	60679
Bihar	65.52	15.45	0.23	3.01	46.83	2507	117424
Gujrat	125.86	25.85	2.93	7.38	89.70	1899	170405
Haryana	41.62	7.19	0.20	1.61	32.62	2422	79010
Himachal Pradesh	19.14	3.42	0.34	0.76	14.62	3082	45063
Jammu & Kashmir	8.93	2.94	0.14	1.47	4.38	2918	12783
Karnataka	114.03	37.09	4.85	11.92	60.17	2090	125761
Kerala	19.35	4.79	0.88	0.29	13.39	3389	45380
Madhya Pradesh	207.17	48.89	6.60	6.53	145.15	1960	284538
Maharashtra	198.46	106.56	8.80	10.57	72.53	1877	136162
Manipur	7.34	1.16	0.09	0.32	5.77	4018	23200
Meghalaya	11.02	1.23	0.03	0.01	9.75	4658	45427
Mizoram	6.10	0.22	0.18	0.04	5.66	4552	25756
0galand	10.38	1.06	0.15	0.45	8.72	4389	38296
Orissa	78.03	8.41	2.95	3.80	62.87	2320	145899
Punjab	32.30	9.19	0.18	0.19	22.74	2590	58907
Rajasthan	342.21	18.66	5.48	7.89	310.18	2669	828050
Sikkim	3.03	2.18	0.08	0.42	0.35	4755	1682
Tamil Nadu	38.22	17.35	1.73	3.56	15.58	2229	34736
Tripura	2.79	1.59	0.08	0.01	1.11	3271	3641
Uttar Pradesh	131.15	38.03	3.04	9.97	80.11	2898	232212
West Bengal	43.03	4.47	1.57	3.42	33.57	1240	41652
Goa	2.00	0.17	0.02	0.00	1.81	1262	2282
UT's	3.50	1.48	0.02	0.01	2.02	7776	6254.
ALL INDIA	1690	373	43	86	1187	NA	2973665

Note: (1) Schemes like FVP & RVP are under soil & water conservation division of the MOA. Data is up to 1995. (2) NWDPRA is under the MOA and the data is up to 1997. (3) Schemes like DPAP, DPP & IWDP are under the MRAE . The data for DPAP& DDP are up to the year 1995 and the data for IWDP is up to 1998. Source: Report of Working Group on Soil and Water Conservation for the formulation of Ninth FYP, Dept. of Agriculture and Cooperation, Ministry of Agriculture, April 30th, 1996.

watershed treatment, which varies from Rs 1240 in West Bengal to Rs 7776 in Union Territories as projected by NWDPRA.

Out of the balance area of 1187.15 ha to be treated, it is proposed to cover 634 lakh ha during the IX FYP to XIII FYP (Table. 40). Projected cost for watershed treatment varies from Rs 5000 per ha in IX FYP to Rs 20000 per ha in XIII FYP.

Table 41 quantifies some of the tangible benefits arising from selected watersheds managed by different agencies. Box 1 outlines the investments and impacts in few selected watersheds.

Table 40 Area proposed for watershed treatment for next 25 years

Plan	Area proposed for treatment (Mha)	Per Ha cost ('000 Rs)	Total cost of treatment (Crore Rs)
1X	10.0	5.0	5000
X	12.0	7.5	9000
XI	15.0	11.0	16500
XII	15.0	15.0	22500
XIII	11.4	20.0	22800

Source: Report of Working Group on Soil and Water Conservation for the formulation of Ninth FYP, Dept. of Agriculture and Cooperation, Ministry of Agriculture, April 30th, 1996.

4.2.2 Watershed Development: A multi-agency approach

Watershed development in the country involves different modes and partnerships. Till date, the government is a dominant and key player. Two central ministries i.e., the union Ministry of Agriculture (MOA) and the Ministry of Rural Areas and Employment (MRAE) are assigned the responsibility to take the lead and set the agenda for watershed development. Sizeable budgetary allocation is made to fund the watershed programmes. The Ministry of Forests and Environment (MFE) is also involved in a minor way.

Ministry of Agriculture: National Watershed Development Programme for Rainfed Areas (NWDPRA) is the major initiative. River Valley Projects (RVP) and Flood Prone Areas (FPA) are other two major programs in this ministry under the soil conservation division. Besides, a string of soil and water conservation programs exists in Central and State sector.

Ministry of Rural Areas and Employment: Drought Prone Area Programme (DPAP) and Desert Development Programme (DDP) are two major schemes that have an exclusive watershed approach. Besides, schemes such as Integrated Wasteland Development Program (IWDP) also fund the development of watersheds. While DPAP and DDP are allocation driven, IWDP is project driven.

Table. 41 Performance evaluation of selected watershed programmes in India

No	Project Location and Agro-Climatic Zone	Source	Nature of Project	Increase in Cropping Intensity (%)	Increase in productivity per hectare in percent in watershed areas	Returns per hectare (Rs./ Ha)	Rate of return
1.	Maharashtra : Western Plateau & Hill region	Saksena et al (1989)	Water Reservoir	NA	NA	Rs 3900-5000	BCR: 1.28 IRR :12.33
2.	Maharashtra: Western Plateau & Hill region	Nawadkar & Shaikh (1989)	Land shaping, contour bunding, moisture conservation	NA	NA	Rs 2455 (103 % increase)	Net sown area increased by 14%
3.	Karnataka: Southern Plateau & Hill region	Kulkarni et al. (1989)	Soil & run-off conservation	7.45	Kharif Sorghum: 3.6 Groundnut: 3.3, Chilli: 12.4, Cotton : 16.14, Rabi Sorghum: 1.44	NA	NA
4.	Karnataka: Southern Plateau & Hill region	Singh, Katar (1989)	Bunds, graded contours, farm ponds	NA	Groundnut local : 1.68, Groundnut (HYV): 1.19, Pigeon pea, ragi: 5.23, ragi (HYV): 4.42	Incremental net returns: Rs.9,170	NA
5.	Punjab; Himalayan foot hills	Singh et al (1991)	Livestock development & soil conservation	NA	NA	NA	Overall Rate of return: 12.5% on forestry: 15.27%
6.	Haryana: Himalayan foot hills	Chopra et al. (1990)	Water reservoir afforestation, creation of new institutions	NA	NA	NA	Rate of return: 19%

No	Project Location/ Agro-Climatic Zone	Source	Nature of Project	Increase in Cropping Intensity (%)	Incremental Yield percentage / quintals per hectare	Gross Return (Rs./ Ha)	Rate of return
7.	Maheswaram: semi-arid agro-climatic zone	Rao (1993)	Integrated soil & water conservation measures as horticulture, pastures & forestry development	NA	Engineering measures: Sorghum: 1.49, Castor: 0.53 Vegetative measures: Sorghum: 2.47, Castor: 0.98	Engg. measures: Sorghum: 1599 Castor: 1487 Veg. measures: Sorghum: 1763, Castor:1578	NA
8.	Matatila Nizamses Ukai	AFC, 1988	RVP. Soil conservation, mini storage structures, afforestation	85.6 to 115.4 89.6 to 114.5 89 to 100	10% to 76.2% 2.7% to 11.3% 40.3% to 74.8%	IRR: 41% 39% 43.7%	BCR: 3.8 1.25 1.36
9.	Kandi	Singh et al. (1991)	Watershed & Area development project for rehabilitation and flood protection	Orchard area increases from 28.10% to 32.07%	NA	IRR: Kinnow: 38 Mangoes: 26 Guava:44	BCR: Kinnow:2.23 Mangoes: 2.48 Guava:2.30
10.	Maharashtra (Two agro-climatic zones)	Deshpande (1997)	Land development with bunds, tree plantation on farms, pasture development, water and soil conservation	Scarcity zone: 111 to 113% Transition Zone: 126 to 130%	NA	Increase in income per ha. Scarcity zone: 45 % , transition zone:30%	NA

No	Project Location/ Agro-Climatic Zone	Source	Nature of Project	Increase in Cropping Intensity (%)	Incremental Yield percentage / quintals per hectare	Gross Return (Rs./ Ha)	Rate of return
11.	Gujarat (two regions)	Shah (1997)	Land development, Leveling, bunds, check dams, conservation measures	NA	Veg. barrires:5-6%, Land levelling:18% to 27%, Earth bunding: 21% to 22%.	NA	NA
12.	Sukhomajri (Haryana): Foothills	Grewal et al (1995)	Water Reservoir, Land improvement	NA	Kh. Maize: 6, Sorghum: 80 Scane:250 , Rabi Wheat:15	4379	BCR: 2.9
13.	Navamota (Gujrat): Semi-arid & Hill region	Kurothe et al (1997)	Dams, Plugs, Land improvement & afforestation	19	Kharif Maize: 95, Cotton:43 Pigeon pea:171 , Rabi Wheat: 65, Gram : 41	3442	BCR: 1.43
14.	Chhajawa (Rajasthan): Dry sub-humid	Prasad et al. (1996)	Graded bunds, check dams and gully control structures	41	Kh. Sorghum: 73, Gnut: 47, Soybean: 38, Rabi Wheat: 90, Chickpea:39, Mustard: 60	NA	BCR: 2.05
15.	Fakot (U.P): Lower & Middle Himalayas	Dhyani et al (1997)	Terracing, Trenches, Diversion drains & tanks.	70	Maize: 27, Wheat (RF): 12, Chillies: 6, Pulses: 9.	NA	BCR: 1.93 IRR: 20

Source: From 1 to 11, Chopra, 1998 and 12 to 15, respective references in the list.

Box 1 Performance details of selected watersheds

Sukhomajri Watershed:

Ten earthen dams costing Rs. 16.12 lakhs were constructed to provide irrigation to 181.9 ha of farmlands. Per ha cost thus works out to Rs.8862. Reduction in runoff works out be 16.7%. Cost of watershed treatment (only mechanical) is Rs.4850 per ha.

Navamota Watershed:

Four earthen dams costing Rs.15.83 lakhs were constructed to provide irrigation to 87 hectares. Per ha cost thus works out to be Rs.18195. Per ha investment for contour bunding and minor levelling is Rs.1675. Cost of constructing an earthen gully plug is Rs.300. Cost of constructing loose boulder check dams works out to be Rs.1294. Per ha cost of afforestation works out to be Rs.5471. Reduction in runoff is recorded as 21%.

Chhajawa Watershed:

Capital cost of construction works comes to Rs.1676 per ha. Overall treatment cost per ha of watershed is Rs.2350. The number of wells increased by 40. Irrigated area increased by 318 hectares. Run-off is reduced from 24.7% to 7.7%. Following the improvement in groundwater recharge, number of wells increased from 16 to 56 and gross irrigated area from 32.5 to 351.3 ha.

Fakot Watershed:

Overall treatment cost per ha of watershed is Rs.1335. Run off is reduced from 42% to 15%. Soil loss came down from 11.8 to 2 t/ha/annum.

Public Sector Research Institutions: Research institutions in the public sector such as the Indian Council of Agricultural Research (ICAR) and different State Agricultural Universities (SAUs) are also involved in the development of watersheds across states. Often, their contribution is by way of providing technical expertise, training and evaluation. Notable examples are the Central Soil and Water Conservation Research and Training Institute, Dehradun with its eight research centers across the country, Central Research Institute for Dryland Agriculture (CRIDA) and National Bureau of Soil Survey and Land Use Planning (NBSS & LUP). Other Institutes like the Water and Land Management Institutes (WALMI) also play their role. CGIAR institutes like ICRISAT have also focused research on aspects of watershed development in India.

The operational research projects (ORP's) executed by ICAR institutes need special mention. In one sense they are trendsetters for the development and diffusion of watershed approach. Sukhomajri, Mittemeri and the Nada watersheds are some of the specific examples for the successful planning and execution of watershed programmes. They have had tremendous demonstration-effect. Many watersheds were subsequently developed on these models.

Bilateral Mode: In the bilateral mode, examples are Indo-Dutch, Indo-Sweden, Indo-UK and Indo-German partnerships. The Danish government has been active in funding watersheds in the states of Karnataka, Orissa, Tamil Nadu and Madhya Pradesh. While SIDA supports watersheds in the state of Rajasthan, the German government lends its support to Maharashtra and Karnataka.

The agencies involved in watershed development can be broadly classified as:

1. Government — Centre and the state.
2. Public sector research institutions like the ICAR & SAU's
3. Bilateral— Indo-Dutch and Indo-German
4. Multilateral—the World Bank, FAO
5. NGO's—TBS, GPF, MYRADA, AVRD, PRIYA and DA's
6. Donor/ Philanthropic organizations— DFID & Ford Foundation
7. Peoples' initiatives: Ralegaon Siddhi, Lapodia, Gopalpura, Doodatholi

4.3 Alternate institutional models for Watershed Development

4.3.1 People's Initiative

The Backdrop

There are instances, few and far in between though, of people-led efforts in Watershed development (WSD) in India. This mode of WSD is economically, ecologically and institutionally sustainable. People-led initiatives in WSD in the country are not something new. Historically, India has had a rich experience of this mode. This mode of WSD assumes greater importance in the present socio-economic and biophysical setting. For a host of reasons, ranging from the process of colonization to the gradual erosion of moral, social and cultural fabric, informal institutions and the governmental ownership of common property resources led to the degradation of these resources. In short, the people lost confidence in the regime and also in themselves. The people became helpless with this process of confidence loss and helplessness accelerated with time. Now, one fact that of people's participation is not only clearly established but also widely acknowledged. Any program, irrespective of the source of funding or execution, depends critically on the degree of people's involvement for its success. In the past two decades, there has been sporadic but encouraging instances of the resurgence of the process of people- led initiatives in the management of natural resources. Correspondingly, the regime, both Centre and State have attempted to decentralize, empower and promote participation of people by a host of policy instruments.

The Paradigm

People's involvement is *sine-qua-non* for any program to succeed. Participatory Watershed Management (PWSM) is the cliché used to describe the people-driven WSD. For a variety of reasons, WSD in the people-led mode is not only ideal but also the most effective. Following are the major reasons for the inherent success of this paradigm. First, such programs internalize the native culture. Second, a sense of ownership and belonging is in-built —the members of the community become the stakeholders and shareholders in one stroke. Third, the institution evolving through such a process is voluntary, vibrant democratic and guarantees 'common interest'. Fourth, more often than not such a paradigm is self-sustaining—from different perspectives. The foremost being the financial angle. In programs wherein people's participation is inherent and assured, projects are often self-financed. Such projects sustain in the literal sense of the word. Continuum of the project is guaranteed in the different phases of the project —planning, implementation and maintenance. It is the last phase i.e. maintenance that is crucial and vulnerable in the other modes of WSD. Due to the factors listed above (and many other unlisted), this paradigm is not only ideal, sustainable, fitting (to our peculiarities) but comes with an element of intrinsic success as a bonus. Pre-requisite for the success and large-scale replication of such a process is only one—non-interference. If this critical necessity along with other sufficient conditions is ensured, success is inevitable.

Case Study

No literature on people-led efforts in WSD can be complete without mentioning two successful examples; Ralegan Siddhi in Maharashtra and Lapodia in Rajasthan. These are worth quoting as they fall in the chronic dry-belt of our nation. Apart from these two excellent WSD models, there are at least a dozen examples scattered across different agro-ecological regions of the country.

Located in the Parner thesil of Ahmednagar district of Maharashtra state, the Ralegan Siddhi village typifies the vast tracts of rainfed agriculture in the country. With an annual rainfall range of 50 to 700mm, it represents the archetypal drought-prone area. The PWSM experiment though involves the entire community of the village, the precursor of this process was one individual—Sri. Kishan Baburao Hazare. In other words, he catalyzed the entire process of PWSM in the village. The baseline situation (prior to 1975) of both natural resources and the social fabric was rather dismal. Groundwater table was below 20 m, only 20 ha of irrigated area, around 70 per cent of the households were living below poverty line.

In the scheme of things, utmost priority was given to the renovation, resurrection and management of four watersheds in the village. This process was initiated with a judicious mix of mechanical and vegetative structures; drainage system, trenches, check dams, drainage plugs, percolation tank and reforestation by planting 500000 saplings. Voluntary labor stands out as the major factor in this process of harvesting rain water. As a (cumulative and interactive) result of all this, the groundwater was recharged to a substantial extent and is available throughout the year at 6.5 m depth. Irrigation potential in the village has increased manifold to 2800 ha.

The PWSM centered experience in Ralegan Siddhi is holistic in its approach. There has been complete socio-economic transformation. Though, enhancement of agricultural productivity through rain-water harvesting was the driving force; the process achieved much more. Gandhian approach is the basis of the experiment. Cooperative management of natural resources, focus on women, evolution of democratic institutions, selfless leadership are unique features of this experiment. The PWSM exercise has had a string of spin-off effects such as total prohibition of alcohol and dowry, ban on open grazing and felling of tress, family planning and access to primary education.

Lapodia village is located in the Alwar district of Rajasthan state. Situated in the arid-zone, without assured irrigation source; natural resources in the village had degraded beyond recognition. The agro-pastoral economy was characterized by human and livestock migration out of compulsion to make ends meet. Water-fodder scarcity coupled with dilapidated water storage structures were the major bottlenecks faced by the villagers. In order to arrest and rejuvenate their resources, the villagers started a PWSM process in the early 90's. The process was again initialized and catalyzed by one individual—Sri. Laxman Singh. A council of village elders, Gram Sabha was conceived to formulate and enforce a strict code of conduct and regulation in the CPR's of the village.

To harvest the rain water, mechanical and vegetative measures were undertaken. De-silting and strengthening the earthen embankment of the dilapidated village tank was the first effort. The percolation tank was also subject to similar activity later. An earthen wall was constructed around the pasture land for demarcation. Reforestation was initiated on the common lands. Subsequently, a culvert was constructed on the existing percolation tank. Another percolation tank in the proximity of the existing tank was constructed. All such activities are through the contribution from the people themselves. A deep drainage channel was also constructed to divert the surface run-off of rain water. Earthen bunds ('Chaukas') and trenches ('Santra') were constructed in the pasture land. Irrigation canals were also fabricated. In sum, the soil and water conservation measures undertaken in the village have been self-financed and completely indigenous in technology.

The result of these S&W conservation measures has been reflected in the substantial rise in both production and productivity of agriculture. A 100 percent increase in Kharif production was realized. For the first time, maize and pulses were cultivated in the Rabi season also. 300 out of the total 500 ha of agricultural land started receiving assured irrigation. As in the case of Ralegan Siddhi, here too there have been tremendous spin-off effect—self-sufficiency and even surpluses in food-grains, fodder and livestock products, access to primary education and health care, empowerment of women and the democratization of political institutions at the grassroots. Such PWSM models need large-scale replication. The necessary and sufficient condition for successful replication obviously is *"peoples participation*".

4.3.2 Bilateral Partnership

The Backdrop

Recognizing the potential of WSD in ensuring all round rural development in a sustainable manner and alleviating poverty, few developed counties have chipped in with funds. Notable among these are the governments of Denmark, Germany, Sweden and United Kingdom. In the bilateral mode of WSD, the funding countries opt to have partnerships with select state governments. Often, these partnerships are based on well defined principles. Usually, these principles differ at various stages of WSD. In this WSD approach, the state governments and/or their departments play a major role. Non-governmental organizations (NGO's) also have an important role in the overall scheme of things. Budgetary allocations to WSD programs are drying up particularly at the state level. Funding from developed countries are therefore, welcome considering the current context of financial crunch.

The Paradigm

Bilateral mode of WSD brings with it certain advantages. First, the participating country from abroad contributes valuable financial resources. Second, monitoring—at various stages of WSD— is relatively superior. Third, more often than not the element of PWSM is ensured. Generally, the departments of respective state governments are the implementing agencies. NGO's are roped in to organize, train and motivate the farmers. Beneficiaries (farmers) are also expected to contribute 10 to 25 percent of the total cost of the project (as in the Indo-

Swedish partnership) or through labor. In the Indo-German program for example, there is an explicit emphasis on the involvement of NGOs.

An Illustration

Here we illustrate in detail the WSD experience in the bilateral mode by taking the case of Indo-Denmark partnership. Popularly known as DANIDA projects, the Danish government is implementing WSD programs in the states of Karnataka, Orissa, T.N and M.P. Specifically, the Bommasandra watershed in the Dharwad district of Karnataka state and the Canaan watershed in Brougham block of Corrupt district of Orissa state are illustrated. In Dharwad, the implementing agency is the state Department of Agriculture. Organization of the farmers is the responsibility of the junior program officers of the department. This process was initially achieved by involving youth groups in the villages. Later this process was facilitated by "link couples" in each of the villages. Hence, several watershed associations were established. Though the farmers are consulted at stage of project design, the extent of incorporation of their suggestions is rather limited. The degree of farmers' contribution varies according to the component of the WSD project. For the saplings in horticulture and forestry components, farmers have to pay for 50 percent of the total costs. Both mechanical and vegetative measures are employed. S & W conservation structures along drainage lines and extensive planting of vetiver grass on field boundaries are the major treatments.

In Corrupt, the implementing agency is the state Department of Soil Conservation. Social organization is achieved by roping in NGO's. Two link workers from each village establish self-help groups (SHG's) and village level organizations. Here also the inclusion of farmers' inputs is rather limited. Farmers contribute only 10 percent of the total project cost by way of their labor. Total project area is 4052 ha. out of which 1215 ha. have been treated. The cost per hectare comes to Rs.3,500 per hectare. Treatments both mechanical and vegetative are on similar lines as in Dharwad.

Bilateral approach to WSD is important from the view-point of funding. There are certain advantages as well as shortcomings. Mutually beneficial partnerships can be made more productive if the shortcomings are overcome by learning lessons from the experiences in other countries and the people's initiative mode.

4.3.3 Multilateral Mode

The Backdrop

Multilateral institutions too lend support to WSD efforts in the country. The World Bank is a fine example of this approach. In 1990/91, an integrated WSD project (IWDP) was launched in seven states. Gujarat, Rajasthan and Orissa came under IWDP (plains) and J&K, H.P., Punjab and Haryana (Hills). The time frame for the entire project was seven years, the first three years being the pilot phase and the next four years expansion phase. As on December 1995, the world bank has treated 2.59 and 1.46 lakh hectares by spending Rs. 182.48 and Rs.187.58 lakhs in the plain and the hills respectively.

The European Economic Community (EEC) is another example for the multi-lateral approach. Three projects in the state of Uttar Pradesh are being funded ranging from 65 to 95 percent of the total cost by the EEC. The balance is borne by the state government. This project was launched in 1993 for a period of nine years with an outlay of Rs.766 million. The target area for treatment was 1.72 lakh hectares.

The Paradigm

Like the bilateral approach, the multilateral mode of WSD is welcome as they come with much needed funds. Here too the implementing agencies are the relevant state departments. PWSM is one of the major institutional objectives. NGO's cater to the need of organizing farmers. While the treatments are selected from a list of eligible treatments, beneficiaries have no choice regarding the kind of treatment. Panchayats contribute 10 percent of the costs and private land owners contribute 15 per cent of the labor cost and planting material.

An Illustration

By looking into the details of WSD programs — one each in the states of Orissa and Rajasthan, insights into the multilateral approach of WSD can be gained. The Jatni watershed is located in the Khorda district of Orissa state. The state department of soil conservation is the implementing agency. The total watershed area of 26,273 ha has 53 mini-watersheds. Loose rock check dam, bunds around the village tank and drainage lines treatment were some of the major mechanical interventions. Contour hedges, protection of pasture land and plantations are the vegetative measures. The cost per hectare works out to be Rs.3700. The village association had equitable representation in terms of the caste-composition and gender representation. In this particular watershed no costs are shared by the farmers.

In Rajasthan, Bilwara district is the choice of illustration. The entire district is divided into many macro and micro watersheds. The state watershed development and soil conservation departments are the implementing agencies. As in the other example, the treatments are based on donor-standards with little or no input from farmers. Both mechanical and vegetative treatments are undertaken. Check dams, masonry structures and dugout ponds constitute the mechanical measures. The vegetative intervention is by way of contour barriers, alley cropping and horti-silviculture plantations. The beneficiaries contribute by way of labor. Up to 10 percent of the wages are withheld as contribution. The cost per hectare works out to around Rs.7000. Village level committees take care of the CPRs and other interventions.

4.3.4 ICAR-Research Mode

The Backdrop

WSD experiences of the Indian Council of Agricultural Research (ICAR) a research organization in the public domain dates back to the decade of the 70's. Initially, under the All India Coordinated Projects on Dry land Farming (AICRIPs) the ICAR took up 23 integrated watershed development models on an experimental basis. Thereafter, 15 pilot projects were launched to disseminate water harvesting technologies. Subsequently, 42 model WSD projects were jointly developed by the ICAR and the Department of Agriculture and Cooperation in the early 80's. This was the basis for the launching of the National Watershed Development Programs (NWDPRA) in the seventh five year plan. CGIAR institutes like the ICRISAT has also undertaken substantial research work in WSD in the semi arid tropics. Few state agricultural Universities (SAUs) are involved in watershed R&D.

The Paradigm

Treatments are based on strong technical foundation and people's involvement, with an emphasis on crop production in particular and overall development of the natural resources in general. The Union Ministry of Agriculture funds WSD efforts through budgetary allocations to the ICAR. The Central Soil and Water Conservation Research and Training Institute, head-quartered at Dehradun have nine regional centres. Research staff of the centres is multi-disciplinary in character. After a thorough review of the ground situation, project staff zero-in on the kind of treatment required. Both mechanical and vegetative interventions are undertaken. Apart from rehabilitating the CPRs, the major objective is the integrated development of the farms in the watershed. Organizing the farmers is again done by the scientists themselves. In order to take stock of the initial situation and sensitize the beneficiaries, Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) techniques are employed. Ex-ante, ex-post and concurrent evaluation are often ingrained in the scheme of things.

Case Study

The ICAR-Research approach is characterized by two operational research projects (ORPs). In more ways than one the Sukhomajri example is a celebrated one. The ORP Sukhomajri was initiated by the

Chandigarh centre of the Central Soil and Water Conservation Research Training Institute (CSWTRI) in 1975. Being located in the ecologically fragile Shiwalik foothill region, Sukhomajri was no exception to the processes of deforestation, denudation of hills, overgrazing, sedimentation of water sources and associated problems relating to soil erosion.

The technological package consisted of vegetative and mechanical treatment of the catchment area, construction of earthen dams, pipe outlets, irrigation pipelines, land improvements and appropriate cropping sequences. In all, ten earthen dams were constructed in the hills in and around Sukhomajri. These dams not only stored the rainwater but also provided supplemental irrigation to farm lands. The cost per hectare (Sukhomajri II project) works out to be Rs. 4850 per hectare. Water users association (WUA) has become a reality in the watershed.

The Sukhomajri WSD model went to achieve all round development. The villagers became secure from different viewpoints viz., food, fodder, fuel, drought, flood, ecology and social. Cumulative and interactive benefits from the WSD process were immense. Runoff was reduced by 16.7%. Total food grain production in the village grew exponentially by about 300 percent from 45 tons per year in 1975 to 185 tons per year in 1988. Similarly, fodder output increased by 330 percent from 73 tons per year in 1975 to 317 tons in 1988. Forest area increased by 150 percent. Crop productivity registered impressive performance.

The BCR estimated at 2.9 is a reflection of the success of the project. In sum, there was a perceptible improvement in the standard of living.

The Navamota watershed is located in the Khedbrahmma Tehsil of Sabarkantha district in the state of Gujrat. The regional centre of CSWTRI in Vasad was instrumental in developing the watershed. While the comprehensive action plan was prepared by the researchers in the centre, the State Land Development Corporation was the executing authority. In 1987, a technological package combining vegetative and mechanical measures was initiated. The mechanical treatments consisted of two masonry dams, four earthen dams, 37 earthen gully plugs, 17 loose boulder check dams, contour bunding and leveling on 197 hectares. Reforestation and silvi-pasture on CPRs constituted the vegetative interventions.

An integrated development of farms via enhancing crop productivity and soil health was also an important component of the overall package. Benefits from the WSD process are manifold. Runoff was reduced by 21 percent. Irrigated area increased by 124 percent. Crop productivity recorded significant improvements ranging from 44 to 197 percent. With a BCR of 1.8, this WSD experience is hugely successful.

The University of Agricultural Sciences (UAS) Bangalore, has undertaken and successfully demonstrated WS R & D. The Mittimeri and Kabbalanala watershed ORPs are models for replication in similar agro-climatic zones.

4.3.5 The NGO's experience

The Backdrop

Non Governmental Organizations (NGOs) do play a critical role in WSD in the country. The NGOs contribute in whole or in part at different stages of WSD. The role of NGOs in WSD in general and PWSM in particular has become important in the context of shortcomings of other approaches. The problem lies either in the pre-project-phase (PPP) or at the post-operative-phase (POP). In the PPP, the involvement or rather the lack of it is a major concern and often detrimental to the success of the entire project. Maintenance of the treatments and assets created is the vital issue in the PPP. NGOs contribute substantially, especially in the PPP. *Inter alia*, insensitivity, lack of expertise, people's perception of the regime, lack of an unified command, target-orientation, and low priority on training and organizational components in the alternative modes has created a vacuum. It is this vacuum that the NGOs attempt to fill in.

The Paradigm

Generally, the NGOs organize and sensitize beneficiaries prior to the actual initiation and subsequent implementation of the WSD process. Perception has gained ground that this particular function is the core-competency of the NGOs. The NGOs may be funded by the government, bilateral & multilateral agencies, people-funded and /or self-financed. *Inter alia,* the NGOs are involved in training of trainers, networking of different organizations, arranging technical expertise and finance for WSD. Sometimes the NGOs bring in innovative approaches to WSD. The inherent advantages of the NGOs are their grass-root level contacts, network and dedication.

Recognizing and appreciating their role and potential, the government (MOA) has entered into a memorandum of understanding (MOU) with some prominent NGOs. Some state governments have also accepted the MOU. The NGOs are expected to create awareness, provide TOT, impact evaluation and monitoring from the beneficiaries perspective and enhance women's' participation.

Some Examples

There are sufficient examples of different NGOs involved in various activities of WSD in the country. Some of them include Tarun Bharat Sangh (TBS), Yug Nirman Mission, Shri.Aurobindo Mission, Institute of

Rural Development, Dr.Swaminathan Foundation of Sustainable Agriculture, Association of Voluntary Organization for Rural Development (AVARD), Youth for Action, MYRADA, Ramakrishna Kendra, Himalayan Action Research Centre, Vanavasi Sewa Ashram, Ramakrishna Mission Vidyapeeth, Bhartiya Agro-Industries Foundation (BAIF), Social Centre, SPEECH, Aga Khan Rural Support Program (AKRSP), Development Alternatives, Society for Participatory Research in Asia (PRIYA), CAPART, Peoples Science Institute, Indian Social Institute, etc.

Here, we take up few NGOs and explain their role in WSD in the nation. The Tarun Bharat Sangh, an NGO based in Rajasthan is an example of holistic PWSM. Gopalpura village in the Alwar district of Rajasthan, today is vastly different than what it used to be in the early and mid eighties. The famine of 1986/87 had devastated the village and the inhabitants had lost their source of livelihood. Against this dismal backdrop, the TBS team started to gain confidence of the villagers. The rapport and trust gained was complete and total. To augment water resources of the area by resurrecting and rejuvenating the existing water harvesting structures and techniques was the main objective. Desilting and deepening of the earthen tank bed was the first step. Labor was voluntary and spontaneous. The second step was to repair the masonry overflow and sluice system of a dilapidated dam. The cost and labor came forth. Reforestation of barren land was undertaken by the Gram Sabha. A code of conduct to manage the CPRs was also evolved. As a cumulative cum interactive effect, the groundwater level in the wells jumped from a mere 15 feet to 55 feet. Irrigated land expanded by 227 and 90 percent in the Kharif and Rabi season respectively. More than 10,000 trees are a standing testimony to the PWSM efforts. The entire process was triggered off by one individual—Shri.Rajendra Singh. Though the TBS is a dedicated team, the soul behind the success of this organization is Shri. Rajendra Singh. The overwhelming success of this effort had tremendous spin-off and demonstration effects. Villages far and near began to replicate this PWSM model.

There are certain NGOs who contribute implicitly to the WSD processes. AVRD is one such organization. It performs functions of networking the relevant actors and agencies, provides technical expertise and arranges funding for the NGOs involved in WSD. Few other NGOs provide TOT. PRIA and Indian Social Institute fall under this category. By preparing trainers' manual on integrated WS management, PRIA caters to reviving traditional and local institutions. Yet, some other NGOs like the Development Alternatives (DA) adopt a particular area and aim to develop it on a watershed basis. This organization undertook wasteland development on a watershed basis in the Datia district of M.P. from 1986 to 1990. Trenching, gully plugging and other mechanical and vegetative interventions were made. These simple but effective measures have led to the regeneration of deciduous forest in and around the area. Future plans include agro-forestry and horticultural activities within the watershed to augment the income of the farmers.

NGOs like MYRADA, adopt a holistic approach to rural development. This they attempt to attain by considering a micro-watershed as an unit of development. All their efforts—planning and implementation are centered around this unit. Certain other organizations that are not NGOs in the strictest sense but are playing a pro-active role in the WSD and PWSM processes do exist. The Participatory Watershed Management Training in Asia Program (PWMTA) is a noteworthy example. Funded by the FAO and the Netherlands government, the major objective of this program is to develop the HRD in PWSM. By preparing manuals' relating to PWSM and its numerous facets (like gender issues, ITK, experiences of other nations in WSD, resource books and packs for the trainers, policy issues, exchange of ideas between different actors), publishing a host of literature and periodicals and networking the PWMTA is playing a crucial role to develop HRD in WSD in the member countries.

4.4 Summing-up

4.4.1 Watershed experience

We have several innovative models of watershed development tried out in the past. Institutional alternatives are available matching with specific resource and socio-economic situations. Technology back-up for different magnitudes of resource conservation related problems specific to the agroclimatic situation is available and continuously refined. Scattered programmes in the past have not yielded desired results covering only 30 per cent of the problem area so far. For the balance area of 119 Mha to be treated on a watershed basis, proposed plan for the next 25 years would cover 64 Mha of problem area, still leaving 46 per cent of the problem area uncovered. In the meantime degradation of the resources would continue depleting the surface flows as well as groundwater recharge with attendant implications on overall irrigation distribution. Integrating all the watershed programmes and dovetailing with irrigation water development strategies to plan for all sources and uses of water is the need of the hour.

4.4.2 Irrigation Sector: Surface water

Simultaneous existence of scarcity of water and inefficiency in its use remains a paradox. Improving efficiency in the use of irrigation water will also complement the equitable distribution of irrigation water. The national agricultural system has a strong network of institutions under both Central and State governments (Table 42) to generate water management related technologies, to impart human resource development in water management extension and to train farmers in water management activities. These institutions are regionally located with specific mandate and coverage to meet the location specific and region specific water management related requirements in agriculture sector with an annual budget outlay of Rs 6 to 31 million (1998-2000) for each of the institutions. Thus the supply side in terms of evolving appropriate water management technologies has been addressed and given a thrust since 1980s.

Table.42 Spread of selected water management related institutions in India

States/Regions	Water Management related Institutions
Southern, Eastern and Northern Regions	Water Technology Centres
UP, Punjab, Karnataka, TN, MP, Meghalaya, Haryana, Kerala, Orissa, Maharashtra, WB, J&K, HP, Assam, Rajasthan, Gujarat, Bihar,	All India Coordinated Research Project-Water Management: Directorate of Water Management Research, Patna
UP, WB, Kerala, Gujarat, Maharashtra, Orissa, MP, Bihar, AP	Water Resources Development and Training/ Management Centres; Water and Land Management/ Training & Research Institutes
Punjab, Rajasthan, TN, Haryana	Irrigation and Management Training Institutes/ Irrigation Research and Management Institute

But the demand side continues to be neglected for want of matching policy thrusts in rationalizing the water rates to reflect its physical scarcity or its economic value in its use. Pricing regime in agricultural use of water neither facilitated the demand for and adoption of water management technologies nor promoted the concept of efficiency in water use. This is true in several other uses of water also.

A comparison of water rates in surface water irrigation projects across states is given in Table 43. Despite the necessity to generate adequate revenue from irrigation users to cover the O&M expenses and also meet a part of the interest charges, revision of water rates has been infrequent, hesitant and very much less than the increase in costs (Planning Commission, 1992[1]). Water rates remained static for more than three decades in Tamil Nadu; totally abolished in Punjab since 1997; no revisions since mid 1970s in Kerala, Haryana, Jammu&Kashmir and Himachal Pradesh; revisions announced but withheld subsequently in the states of Gujarat and Karnataka. Irrigation commission's recommendation for reviewing and adjusting water rates every five years to at least cover the O&M expenses has not been accepted, much less implemented by any state in the past as observed in the Planning Commission's report

[1] Report of the Committee on Pricing of Irrigation Water, Planning Commission, Government of India, New Delhi, 1992.

referred above. Apart from low water rates, the recovery in terms of revenue collected as against revenue assessed remains low in several states ranging from 13 per cent in Orissa to 50 per cent in Haryana. Low water rates coupled with poor recovery further deprives the minimum needed maintenance of the irrigation infrastructure resulting in degradation in its functioning with attendant externalities on land and water related resources.

Table. 43 Revised agricultural water rates in India as on 1997

Name of State/ UT's	Water rates (Rs/ha)	Last date of revision
Andhra Pradesh	148.27 to 1235.55	July, 1996
Assam	75 to 375.5	June, 1992
Bihar	74.13 to 296.53	November, 1995
Goa	60 to 300	February, 1988
Gujarat	25 to 830	April, 1981
Haryana	23.96 to 119.6	September, 1995
Himachal Pradesh	6.86 to 41.09	June, 1981
Jammu and Kashmir	1.53 to 289.12	April, 1976
Karnataka	19.77 to 556	July, 1985
Kerala	17 to 99	July, 1974
Madhya Pradesh	14.83 to 296.53	October, 1994
Maharashtra	50 to 800	July, 1994
Manipur	22.5 to 75	December, 1981
Orissa	5.56 to 185.33 flow irrigation	September, 1981
	129.16 to 4984.9 lift irrigation	April, 1997
Punjab	Abolished	February, 1997
Rajasthan	19.77 to 143.32	March, 1982
Tamil Nadu	18.53 to 61.78	November, 1962
Uttar Pradesh	20 to 474	September, 1995
West Bengal	37.06 to 123	January, 1993
Dadar & Nagar Haveli	75 to 275	November, 1973
Daman & Diu	200	April, 1980
Delhi	4.22 to 237	NA

Source: Information Directorate, Central Water Commission, Sewa Bhavan, New Delhi. In case of Arunachal Pradesh, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Andaman & Nicobar islands, Lakshadweep and Pondicherry no irrigation rates is in operation

4.4.3 Irrigation Sector: Ground water

Development and utilization of ground water gained momentum with the innovation of individual farm owned pumpset technologies and rapid expansion of electrification aided by increasing flow of institutional credit starting from 1970s. The spread of ground water development beyond the green revolution areas continued during 1980s and 1990s. Lack of comprehensive policies to guide ground water development and use in a sustainable manner resulted in over exploitation of this resource in varying magnitudes in several locations. The symptoms are spreading as highlighted in Table 44.

Table.44 Spatial and temporal status of ground water exploitation in selected states

States	Ground water statistics, 1989			Ground water statistics, 1995		
	Total blocks	Grey blocks	Dark blocks	Total blocks	Over exploited	Dark blocks
Gujarat	183	13	6	184	12	14
Haryana	95	11	31	108	45	6
Karnataka	175	9	3	175	6	12
Punjab	118	18	64	118	62	8
Rajasthan	227	12	21	236	45	11
Tamil Nadu	375	66	61	384	54	43
India	3841	339	281	7063[@]	249	179

Ref: Ground water statistics, 1985 and 1989. CGWB, Ministry of Irrigation and Power, Department of Irrigation, GOI, New Delhi. Ground water resources of India, CGWB, Ministry of water resources, GOI, Faridabad.

[@] This includes blocks/mandals/watersheds/taluks for all the states. Blocks are categorized, based on the exploitation of utilizable ground water resources, as grey (65 to 85%); dark (85 to 100%) and over exploited (more than 100%).

In 1995, more than 50 per cent of the dark blocks is located in six states namely Gujarat, Haryana, Punjab, Tamil nadu, Karnataka and Rajasthan. These states, together, accounted for 90% of the over exploited blocks. Again, in these states alone, number of blocks exploiting more than 85% (dark and over exploited category) of the utilizable ground water resources has gone up by more than 70% within about five year period during 1990s.

No such over exploitation classification is available in earlier statistics (1989). The magnitude and spread of over exploited blocks in mid-1990s poses serious equity concern warranting not knee-jerk reactions but comprehensive development and management oriented policies encompassing all uses and sources of water. Like surface water, here too, abysmally low price regime (Table 45) for power neither facilitated efficiency in the use of power nor in the use of ground water.

Table 45 Average tariff for agriculture, 1997/98

Zero tariff	Less than Rs 0.50 per kWh	Rs 0.50 to 1.00 per kWh	More than Rs 1.00 per kWh
Punjab Tamil Nadu	Andhra Pradesh; Bihar; Gujarat; Kerala; Haryana; Jammu & Kashmir; Meghalaya; Karnataka; Rajasthan; Madhya Pradesh; Maharashtra; West Bengal	Orissa; Uttar Pradesh; Himachal Pradesh	Assam

At all India level, average power tariff for agriculture in 1997/98 was Rs 0.22 per kWh, which is one-tenth of the unit cost of power supply during the same year. Expanding gap between demand and supply for power imposes high opportunity cost of inefficiency in its use in irrigation sector. Similarly, fast depleting ground water regime imposes high social cost with the opportunity cost of inefficiency in the use of ground water at the cost of other competing uses and users both currently and in future, has serious efficiency and equity implications. Ground water over draft has resulted in fluoride contamination in north Gujarat and Rajasthan, and arsenic contamination in southern West Bengal and parts of Bangladesh endangering livelihood security.

5 CONCLUSIONS AND RECOMMENDATIONS

Irrigation retains its crucial role in productivity-led agricultural production growth, in alleviating poverty and in reducing inequality in income distribution in rural areas. Irrigation development in the past was not specifically targeted towards desired multiple impacts. Equity implications as influenced during the course of irrigation development initiatives therefore, assumes significance while formulating future water resource development strategies. Equity impacts of irrigation water distribution in India is empirically analysed at national and state level between sources covering different decades. For the country as a whole, number of small and marginal FHHs increased from 49.1 million in 1971 to 83.5 million in 1991 of which partially and wholly irrigated small and marginal FHHs accounted for 41.2 and 46.8 per cent respectively. In terms of irrigated area, irrigated small and marginal FHHs accounted for 23 per cent of the total household area of small and marginal FHHs in 1971, which increased, to 34.5 per cent in 1991.

Inter-farm inequality in irrigation distribution is measured by applying Theil's information theoretic measure based on five farm holding sizes namely; less than 1 ha; 1-2 ha; 2-4 ha; 4-10 ha; and above 10 ha. Eleven irrigation related attributes covering non-canal irrigated area (NCIA), net area sown (NAS), net irrigated area by canal (NIACAN), net irrigated area by tanks (NIATNK), net irrigated area by wells (NIAWELL), net irrigated area by tubewell (NIATW), total net irrigated area (NIATOT), gross cropped area irrigated (GCAI), gross cropped area (GCA), All flow irrigated area (ALLFLOW), and all lift irrigated area (ALLFT) are considered for different states. The analysis covered 17 states including SSUT for two time periods namely 1970/71 and 1990/91. For the absolute and relative distribution analysis of irrigation related attributes, five time periods at five year interval during the period 1970/71 to 1990/91 were covered. Following conclusions emerged from this study:

1. There exists considerable inequality in the distribution of irrigated areas across farm size holdings over time and the levels of inequality vary widely across different states.

2. Both in absolute terms and in terms of household distribution of irrigation, large farms have captured disproportionately larger share of irrigation benefits as compared to the small and marginal farms. For instance, marginal farms, accounting for 59 per cent of the total FHHs had only 21 per cent of net irrigated area and same per cent of canal irrigated area. On the contrary, large farms with more than 4 ha

holding size, accounting for 8.7 per cent of the total FHHs had 35 per cent of the net irrigated area and 36 per cent of canal irrigated area.

3. Changing towards Rawlsian distribution policy will significantly bring down the levels of inequality in the current irrigation distribution in general and canal irrigation distribution in particular.

4. Level of inequality in the distribution of most of the irrigation related attributes is less than the overall inequality in the current distribution of cultivated area.

5. Trends in the inequality with respect to most of the irrigation related attributes are mixed; declining within the decades namely 1970s and 1980s ending with 1990/91 but increasing between the decades. Such mixed trends reflect the absence of consistent policies in the past specifically designed for using irrigation distribution as a means of bringing down inequality in agricultural income and wealth.

6. Performance of existing proportional distribution policy varied widely across states but the deviation from the targeted objectives has narrowed down during the past two decades ending with 1990/91.

7. Existing distribution of farms is highly skewed in favour of small and marginal farms. They, together account for 78 per cent total FHHs in 1990/91, commanding 32 per cent of the total area operated. In such a situation, proportional distribution policy, with variable performance across states, by linking the distribution of irrigation to the proportional holding of land area, neither promotes efficiency as of now nor promotes equity as has been observed in this analysis.

8. Never in the past, integrated approach was adopted in the water sector by internalising all the sources and uses of water while designing policies. Consequently, sourcewise analysis of irrigated area exhibits mixed inequality trends in the distribution of irrigation related attributes. Mutual interdependent linkages among different uses and sources of water require designing of policies for development, management and utilization of water for the sector as a whole encompassing all uses and sources of water in a holistic manner.

9. Adhocism in the irrigation development policy also failed to consider the inter sectoral linkages and their interactions and thereby resulting in different magnitudes of positive and negative externalities which are neither quantified nor anticipated. Efficiency and equity implications get totally distorted depending upon the inter sectoral linkages. The approach, therefore, has to be holistic and not sector or sub-sector specific as has been in the past and even now, more as a rule than as an exception.

10. Shrinking resource base both in terms of quantity and quality of natural resources like soil and water available for sustaining agriculture growth and livelihood security underlines the effective targeting of socioeconomic policies in a holistic manner encompassing all uses. In the process, the impact of policies pursued in other related sectors can no longer be ignored since competition for natural resources both by present and future generation is getting increasingly complex to ignore such interactions among policies designed exogenously in other sectors as of now.

11. For instance, significant increase in the paddy area and better crop yields in the north-western region (Punjab, Haryana and eastern UP) are at the cost of over exploitation of ground water (Sharma, 1997[2]). The cycle of more and more area getting into early planting of paddy followed by the advancement of paddy procurement season by GOI by 15 days to one month (from October.1 to September.1) and consequent over drafting of ground water goes unabated with least consideration to the ground water sustainability. Advancement of paddy procurement season cannot be decided in isolation without factoring in the possible impact on ground water use related issues. It is estimated that advancing paddy planting by one month from June 16 to May 16 entails 25 to 30% more irrigation requirement (Sandhu, 1994[3]) in western region. In most of the districts falling in this region, the stage of ground water development has already crossed 100% reaching as high as 259%. With zero tariff for agricultural power and abolition of water rates for surface water or freezing it at a low level for several decades, virtually socio-economic policies are non-existent in the water sector in such of the states like Punjab and Tamil Nadu and even in many other states also.

12. Source-wise inequality analysis revealed that contribution from 'within states' is more in flow irrigated area distribution than in lift irrigated area distribution. For instance, 60.1 per cent of the inequality in NIACAN distribution comes from 'within states' source as compared to only 34.9 per cent of the inequality in NIATW distribution coming from 'within states' source. Thus to improve equity in irrigation development and distribution, improved distribution across farm size groups need to be targeted than in terms of balanced regional

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[2] B.R. Sharma, Policy Issues for Farm-Level Irrigation Water Management. National Water Policy: Agricultural Scientists' Perception, Eds. N.S. Randhawa and P.B.S.Sarma, National Academy of Agricultural Sciences, 1997.

[3] Sandhu, B.S. Optimising irrigation scheduling to field crops in natural resource management for Sustainable Agriculture and Development (eds. D.L.Deb), Angkor Publishers (P) Ltd., New Delhi, 1994.

irrigation development in case of canal irrigation source. But in case of tube well irrigation as a source, balanced regional irrigation development provides more opportunities for reducing the inequality in its distribution since 'between states' accounted for nearly 2/3rd of the inequality in the distribution of NIATW.

13. Highly skewed distribution of land across rural households and the proportional distribution policy of canal irrigation contribute to the high 'within the states inequality'. This problem is further accentuated by allowing the irrigation system infrastructure to deteriorate with meager allocation of resources for operation and maintenance resulting in inefficiency in its performance and inequity in the distribution of irrigation water.

14. The irrigation systems; both major and medium, should be restored to a minimum acceptable level of performance to be agreed upon by the water user associations before effecting the transfer of operational and maintenance responsibilities. Policies shifting the management and utilization responsibilities of the irrigation system to the user groups should evolve simultaneously for ensuring physical as well as financial sustainability of the irrigation system that would promote both efficiency and equity in the long run.

15. Efficient water management at the farm level holds the key to the equitable distribution and efficient utilization of irrigated areas. This implies a paradigm shift in the policy focus from utilization gap and irrigation gap orientation towards an incentive gap orientation which addresses the gap between scarcity value of water and the value underlying the current pattern of water utilization (Saleth, 1991[4]). Reforms in the existing water laws and institutions are urgently needed to correct this incentive gap and promote ecological security, economic efficiency and social equity in every use of water.

[4] R.M.Saleth. Water Resources as Private Property: I&II, The Economic Times, June 13-14, 1991.

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Appendix. 1 Indian agriculture and shrinking resource base

Resource	Unit	1950	1960	1970	1980	1990	2000
I. For an average farm holding supporting eight persons [(1)]							
Net area sown	ha	2.63	2.43	2.05	1.63	1.35	1.12
Gross area sown	ha	2.92	2.78	2.42	2.02	1.76	1.57
Area: fodder/fuel	ha	1.10	0.69	0.51	0.38	0.29	NA
Net area irrig.	ha	0.46	0.45	0.45	0.45	0.45	NA
Gross area irrig.	ha	0.50	0.51	0.56	0.58	0.59	0.81
FG area	ha	2.16	2.11	1.81	1.48	1.21	1.05
FG production	tons	1.13	1.49	1.58	1.51	1.67	1.95
FG yield	t/ha	0.52	0.71	0.87	1.02	1.35	1.86
II. Total Factor Productivity Growth [(2)]							
Rice	%	NA	NA	1.31	0.97	NA	NA
Wheat	%	NA	NA	1.42	1.08	NA	NA
Coarse grain	%	NA	NA	1.09	0.92	NA	NA

Source: This table was constructed based on the data from different sources as follows: (1) Economic Survey (various years), Ministry of Finance, Government of India, (2) Kumar, 1996; Period 1970 refers to 1971/80 and 1980 refers to 1981/86.

Appendix. 2 Methodology for Equity Impact Analysis

Theil's entropy measure used in this analysis is outlined as follows:

$$T_1(y:x) = \sum_{i=1}^{n} y_i \ln (y_i / x_i) \qquad [1]$$

Where; x_i = relative frequency values of the households in i^{th} farm size class; and y_i = relative frequency values of the irrigation attribute in i^{th} farm size class

$$T_2 (x:y) = \sum_{i=1}^{n} x_i \ln (x_i / y_i) \qquad [2]$$

Where; x_i = total no. of households in i^{th} farm-size class as a proportion of total in the country as a whole; and y_i = irrigation attribute of i^{th} farm size class as a proportion of total in the country as a whole; I = 1,…,5 in this study.

Both [1] and [2] are Theil's two variants of the information theoretic measure, which are analogous. They differ only in terms of the weighting within-set inequalities. Following Sampath (1990), T2 is used in our analysis since our interest is in showing the extent of inequity in irrigation distribution across agricultural farm households.

Inequality decomposition can be written as follows:

$$I (x:y) = I_0 (x:y) + \sum_{g=1}^{G} X_g I_g (x:y) \qquad [3]$$

Where; X_g=g^{th} state's household share; and Y_g=g^{th} state's irrigation attribute share; $I_0(x:y)$ is the between-state inequality and $I_g(x:y)$ is the inequality within state and;

$$X_g = \sum_{i \in s_g} x_i \quad \text{and} \quad Y_g = \sum_{i \in s_g} y_i \ ; \quad g = 1, \ldots, G \qquad [4]$$

where; x_i = i^{th} farm-size class household population share of g^{th} state; y_i = i^{th} conditional irrigation attribute share; and letting Sg, g=1,….,G (=17) for the gth state.

$$I_0(x{:}y) = \sum_{g=1}^{G} X_g \ln (X_g / Y_g) \qquad [5]$$

$$I_g(x{:}y) = \sum_{i \in s_g} p_i \ln (p_i / n_i), \quad g = 1,\ldots, G \qquad [6]$$

$$p_i = x_i/X_g\,; \qquad n_i = y_i/Y_g \quad i \in s_g,\ g = 1, \ldots, G. \qquad [7]$$

Using Theil's entropy measure, inter-farm size inequality in irrigation distribution in India was analyzed at all-India level as well as at the state level.

Furthermore, the inequality at the all India level was also decomposed into its constituent parts namely 'between states' inequality and 'within states' inequality. Such an analysis will help in quantifying the sources of inequality for better irrigation policy decisions. Extending this analysis to cover more irrigation attributes will also help better understanding of inequality status in irrigation distribution with respect to different sources of irrigation. Further extension of this analysis to cover 1980s also along with 1970s will provide reasonable insight into the distribution impacts of past irrigation development strategies for better irrigation policy decision making in the future.

Rawlsian Approach (Sampath, 1992):

$$X_i^* = [X_1^*, X_2^*, \ldots\ldots, X_k^*, \ldots\ldots, X_n^*] \quad \text{and} \qquad [8]$$

$$\sum_{k=1}^{K} X_k = \overline{X}\,; \; X_1^* = L_1, X_2^* = L_2, X_{k-1}^* = L_{k-1}, X_k^* \subseteq L_k, X_{k+1}^* = 0, \ldots, X_n^* = 0.. \qquad [9]$$

$$R = [\, \Sigma(x_i^* - x_i)^2 / \Sigma (x_i^*)^2 \,]^{0.5}\ ; \qquad [10]$$

Where; $\overline{X}$ = total amount of irrigation attribute; x_i^* = proportion of irrigation attribute i^{th} farm size group is supposed to receive under Rawlsian scheme; and x_i = proportion of irrigation attribute i^{th} farm size group actually received.

Rawlsian criterion distributes the irrigation water according to lexicographic ordering starting from the smallest farm holdings, by fulfilling their needs, followed by the next smallest and so on. When every farm-size group receives (x_i) exactly the amount of water they are supposed to receive x_i^* then the value of R will be zero. In otherwords, higher the value of R, higher will be the degree of Rawlsian unfairness in distribution. Both the measures namely, the Theil's entropy measure and

Theil's forecast error measure to estimate the levels of unfairness in distribution using Rawlsian notion of fairness in distribution are used in this study.