IWMI-Tata Water Policy Research Program

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Social Impact of Canal Irrigation

A Review of 30 Years of Research

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1.0 Introduction

Surface irrigation is of critical importance in Indian agriculture and its quest for self-dependence in meeting the countries' food requirement. With an average rainfall of 1170 mm (standard deviation of 82.63 mm) ninety percent of which is concentrated in a few days of monsoon, artificial provision of watering the crops is absolutely essential (http://www.grads.iges.org/india/partha.subdiv.html). Green revolution, which ensured self-dependence in food production for India is heavily water intensive. The pivotal role of surface irrigation projects in the strategy evolved to make India self-sufficient in food production is evident from the investments made during each of the five year plans in medium and major irrigation projects.

Table 1: Investment In Irrigation Through Plans (Rupees In Crores At Current Prices)

Plan	Major & medium	Minor	C.A.D	Flood control	Total
First plan (1951-56)	376.24	65.62	-	13.21	455.07
Second plan (1956-61)	380	161.58	-	48.06	589.64
Third plan (1961-66)	576	443.10	-	82.09	1101.19
Annual plans (1966-69)	429.81	560.93	-	41.96	1032.70
Fourth plan (1969-74)	1242.30	1173.34	-	162.04	2577.48
Fifth plan (1974-78)	2516.18	1409.58	-	298.61	4224.36
Annual plans (1978-80)	2078.58	981.90	362.96	329.96	3753.40
Sixth plan (1980-85)	7368.83	3416.82	743.05	786.85	12315.55
Seventh plan (1985-90)	11107.29	6179.30	1447.50	941.58	19675.67
Annual plans (1990-92)	5459.15	3030.07	619.45	460.64	9569.31
Eighth plan (1992-97)	20171.87	11739.36	2145.92	1691.68	36648.83
Total	52602.25	11739.36	5418.88	4856.67	91943.40
Totals At Constant Price Of 1996-97					
	132386.93	73388.66	13385.66	12222.39	231386.59

(Source: WCD Report, 2000)

India is one of the first countries where modern large-scale irrigation projects were implemented in the beginning of the nineteenth century (Postel, 1999). As of now it is second only to China in terms of the total area irrigated by surface irrigation systems. (FAO, 1987). The importance of surface irrigation systems in Indian agriculture can be ascertained from the very fact that 90% of the gross capital formation in agriculture from public accounts over the last fifty years is accounted for by the investments made in this sector (Gulati, 2000). India has a total of 4291 large dams (with height more than10 m.) built over last hundred years. Apart from these there are several diversion systems on rivers like Ganga and its tributaries that also serve large areas during kharif season. Each of these surface irrigation projects have created a huge impact on the socio-economic and environmental aspect of their environment. A surface irrigation project is a colossal socio-economic historical enterprise before which pyramids may end up looking like dwarfs (Ghose, 1989).

As a surface irrigation project grows a little old it produces its own dynamic in the social, political and economic realm of that area. In fact its influence pervades much beyond the immediate area from where it gets its endowment or the area it serves. The operation, maintenance and performance of these systems are also affected by its physical and biological environment. Thousands of studies have been done on various systems to understand the impact of canal irrigation projects. The irrigation literature in India is rich with impact studies. However, the understanding of irrigation systems and their far-reaching consequences are far from understood. It still remains a black box. (Shah, 2001). New areas, new possibilities, newer dynamic keep springing demanding still more intellectual investment to develop a better understanding of these systems and their functioning. This is what makes irrigation literature evolving and interesting and makes any review incomplete. There is always a wide scope left to capture more dimensions.

2.0 Plan of the review

The first section sets out the objectives of the review and its scope and limitations. It also describes the distinctive features of the available Indian literature on impact of irrigation. Each subsequent section dwells on one particular dimension of the overall socio-economic impact of canal irrigation.

3.0 Objectives and Scope of the review

This literature review has been carried out to explore the range of issues covered in the available literature on irrigation in India and to bring together the interesting hypotheses developed, and findings of studies done thus far so as to serve as a reference and guide for future research in this field. It would also try to highlight the important dimensions that have been overlooked or understudied in the existing literature so that further research can be taken up to plug the gap.

The review limits itself to the works on socio-economic impacts. Studies on feasibility of irrigation projects, their environmental impacts and irrigation management turnover have not been covered in the review. This is a review of studies on canal irrigation projects but a few important studies on groundwater have been referred to for comparison and facilitating a better understanding of the interrelationship between the surface and groundwater irrigation systems.

4.0 Salient features of Indian literature on impact of irrigation projects

There is a huge body of literature on the impact of irrigation projects in India. Almost each of the major and medium irrigation projects has been studied for its impact in the command area. In the initial phases of Indian irrigation literature most of the impact studies were sponsored by the implementing and the funding agencies. Studies were also carried out at the insistence of policy-making bodies like the Planning Commission. These studies generally focused on evaluating the direct and primary impacts of the irrigation projects that could be measured in monetary terms. This is part of the reason why there is such a huge body of literature that is narrow and myopic in its scope and creates a sense of déjà vu while reading.

Most of the studies focus mainly on the primary and measurable direct impacts in the command areas. We find passing references to the secondary impacts of irrigation projects but very few studies delve into detailed analysis and discussion of such impacts. The spatial coverage of most of the impact studies is limited to the command area and its adjacent landscape that serves as a benchmark for comparison. Catchment area upstream of the dam is from where the surface irrigation systems get their endowment but the impact of the irrigation projects on these areas is a completely overlooked aspect of impact literature. Large irrigation projects have influenced the lives and livelihoods of people from areas far beyond the command area by way of providing them seasonal wage employment and exposure to irrigated agriculture and its benefits. However, the existing irrigation literature doesn’t capture this extended and unintended impact of surface irrigation projects.

In spite of its narrow coverage, the Indian literature on irrigation is dynamic and organic in the sense that the dominant issues of research keep changing every few years in response to the changing socio-economic milieu.

4.1 Types of Impact Studies

The whole body of irrigation impact literature can be classified into two broad categories:

1. The in-depth studies based on primary survey of the command area. These studies cover one or a group of irrigation projects; carry out a cross-sectional comparison between the command area and the adjacent non-command areas for one reference year to evaluate the impact of the project. In most of such studies two-stage stratified random sampling is carried out. In the first stage the sample villages are divided into three spatial categories of head, mid and tail villages depending on heir distance from the canal while in the second stage random selection of farmers is carried out based on their land ownership. Detailed information is generated using questionnaires and other methods of primary survey. Simple ratio and percentage values are calculated to evaluate the impact and its differential nature across space and economic groups. Before-after comparisons in primary studies are rare due to lack of benchmark studies and reliable secondary data for pre-project years in most of the cases. Moreover, in case of longitudinal studies, researchers find it difficult to isolate the impact of irrigation from other factors of change.

2. Secondary-data based macro level studies constitute the second category of irrigation impact studies. These studies are based on secondary data generated by organisations such as National Sample Survey organisation (NSSO), National Council of Agricultural and Economic Research (NCAER), agricultural census, fertilizer census, various irrigation departments etc. These studies use tools of multivariate data analysis to generate econometric models. These studies aim mainly at making broad policy level suggestions at regional and national level for long-term planning and resource allocation. Temporal analysis is fairly common in such studies.

4.2 Impact of Irrigation: Gleanings from the literature Review

4.2.1 Demography and occupational structure

Large canal irrigation projects bring changes in the demographic features and the occupational structure in the command area over a period of time. Several impact studies have pointed out these changes based on the inter decadal comparison between the command and the non-command areas using the census data.

For instance, R.R. Rao (1989) studied the development dynamics in command areas of major irrigation projects in Andhra Pradesh using village level data. He made cross-sectional comparisons between command and non-command villages over a long period of time using the census data. The study found that rapid urbanization had taken place in the command area. The irrigated areas became more densely populated due to the influx of people from the non-command areas and increased prosperity. Sex ratio had grown more favorable in the rice growing command areas probably due to heavy demand for female labor in rice cultivation.

The settlement pattern had also changed in the command area. Larger villages had grown at the cost of the smaller ones. The lower and the lowest order settlements showed negative growth while the higher order settlements grew further.

Caste composition had not changed in the command area significantly but the relative importance of castes changed specially in the economic sphere. This is contrary to the common sociological dictum that changes in the political sphere come more easily and rapidly than the changes in the economic sphere. Irrigated areas had registered a higher growth in the SC/ST population probably due to immigration of landless people to these areas. (Rao, 1989)

Dependency ratio (defined as number of unemployed people per 100 employed people) was found to have gone down in the command area due to increased employment opportunities created by irrigated agriculture in Tungbhadra command area studied by Rao (1989). It was 110 in the command area while 130 in the non-command area. In Chandraprabha irrigation project in Bangladesh, women and children also started working as wage laborers as labor demand increased due to increased rice cultivation with the advent of irrigation in the command area (Chowdhary, 1989).

Command areas have generally greater proportion of rural workers engaged in agriculture. In Rao's study (1989), the command areas experienced increase in proportion of agricultural workers while non-command areas experienced decline in their share. In his study of Malprabha irrigation project P.K.Vijayan (***) found that more people took up agriculture in the head and mid reaches of the canal command while in the tail reaches workers had moved out of agricultural sector. J.H. Adhvaryu and A.S. Patel, in their socio-economic evaluation of Dantiwada project in Gujarat found the percentage of people pursuing agriculture as their primary occupation to be significantly higher in the command area (Adhvaryu and Patel, 1983). Canal irrigation leads to occupational specialization in the command area. Scarlett Epstien (1962) carried out a comparative study of an irrigated and an unirrigated village in 1954 in Mandya district of Karnataka. She re-visited the area in 1971 to compare the pattern of economic development in these two villages. In the irrigated villages she observed a unilinear pattern of economic growth with agriculture as a dominant pursuit while the dry village having no irrigation sources developed into a kind of servicing center for the neighboring irrigated village and its economy got diversified. Similar type of occupational pattern was observed in Rajasthan Canal Project by T. K. Roy where18% of the total income of unirrigated households and 47% of the total income of irrigated households was coming from agriculture (Roy, 1983). K.C Alexander also observed greater occupational specialization among the irrigated households in his study in Maharashtra (Kallur, 1988).

D.V. Rao (1987) in his study “Rural development through irrigation” suggests that irrigated farming reduces child and woman labor while the demand for able-bodied adult male increases (Rao, 1987). Irrigation brings a change in the ratio of cultivators to wage laborers. With irrigation the small and marginal farmers stop doubling as wage laborers since their small land holdings become sufficient to support their livelihoods. Increased cropping intensity and labor intensiveness of irrigated farming provides them year round employment in their own farms.

4.2.2 Land ownership

1. Provision of canal irrigation brings a shift in the land-holding pattern due to immigration of farmers who are more skilled and experienced in irrigated farming. The phenomenon has been witnessed in Tungbhadra command where farmers from coastal Andhra with prior experience of irrigated farming shifted in just before the commissioning of the system. (Rao and Simdhari, 1989)

2. Canal irrigation encourages land transactions due to inability of farmers to use all irrigable land and to realize the increased value of land due to irrigation. Bellary district census handbooks of 1961 and 1971show influx of a number of enterprising farmers in the command areas from the adjoining districts. 30.8, 55.2 and 40% of households in dry cum wet (DCW), wet and perennially irrigated areas respectively were involved in land transactions of one or other kind in the district (Rao, 1974). The nature and the extent of irrigation facility determine the market value of land. In the command villages there has been a significant appreciation in the value of even the non-irrigated land. In this study the average land holding size of large landowners increased in the command area. A.S. Patel (1983) had noticed that operational land holding size was higher in the command area in Dantiwada irrigation project. The increase in operational land holding is mainly due to three sources viz. leasing in, buying and bringing additional land under cultivation.

3. M.V Reddy (1990) in his study of irrigation development in Karnataka found that the small holdings dominate both in number and area in fully irrigated holdings but their share is much lesser in the partly irrigated holdings, even lesser than in unirrigated holdings. This indicates that either the availability of irrigation has enabled households to substantially increase their size of holding acquiring even unirrigated land or large farmers tend to acquire lands expected to be irrigated by offering higher prices which is tempting for the small holders (Reddy, 1990).

4. Provision of canal irrigation brings a change in the land tenure system. There is an inverse relationship between the incidence of sharecropping and the availability of reliable irrigation. This is based on a comparison between sharecropped area/rented land area in rainfed and tank irrigated areas and assured canal-irrigated areas in Tamil Nadu by Vaidyanathan (1986). All 130 talukas were ranked first on the basis of the extent of sharecropping and secondly on the basis of reliability of irrigation (1 to every percentage point of well irrigated area, 0.7 to canal and 0.5 to tank). Then spearman's rank correlation was calculated. The coefficient was found to be –0.518, which reflects a moderately strong inverse relationship between the incidence of sharecropping and availability of assured and reliable source of irrigation. (Vaidyanathan, 1986).

4.2.3 Employment

Provision of irrigation leads to greater absorption of labour in agriculture at a higher wage rate in the command areas (Reddy, 1990 Kallur, 1988, Patel, 1981). Introduction of irrigation facilitates an increase in employment in agriculture in a number of different ways. Irrigation itself needs labor, and increased employment would depend on the number of waterings applied to each crop and actual area covered under different crops. Irrigation leads to shift in cropping pattern to superior cereals and cash crops, which are more labor-intensive. Use of fertilizer, insecticides and pesticides increases with irrigation leading to increased labor use. Irrigation brings additional area into cultivation by increasing the net sown area and the cropping intensity. This also generates more employment (AS Patel, l981).

The manpower use per hectare was almost three times in irrigated agriculture as compared to unirrigated agriculture (46.19 and 16.39 respectively) while gross receipts per man-day of agricultural laborers was higher by 85.2% in the irrigated areas in Rajasthan canal project area (Roy, 1983).

T. Satpathy (1984) concluded from a case study of six villages in Orissa that canal irrigation results in increase in number of man-days of employment per hectare for all farm sizes but the increment was found to be the highest for the marginal farmers.

He concluded from his study of 153 irrigated and 53 unirrigated holdings that human labor is used at sub-optimal levels in both types of farms in Orissa. Other inputs were being used at optimal levels in unirrigated farms and sub-optimal levels in irrigated farms of Orissa. This partly explains the lower irrigated yields in the state (Satpathy, 1984).

In his study of 26 medium-sized irrigation projects of Gujarat A.S.Patel (1981) found that the relative share of labor cost in the total input cost is greater in rainfed agriculture. One rupee of investment in terms of cost provides less employment to labour when irrigation is introduced on a farm than before when it was rainfed. However, overall investment in labour per unit of land increases substantially with irrigation. According to Patel's estimation one hectare of rainfed farm converted to irrigated farm would generate about 48 man-days of employment in Saurashtra and 52 man days of employment in Gujarat annually. In this way these 26 projects were expected to generate total employment of 9.3 million man-days annually. Employment will be still higher if cropping intensity and input use increases. Even at the prevailing level full round year employment will be generated for 31143 workers.

Pattern of labor employment in irrigated agriculture changes in favor of hired labor that implies occupational diversification and increased opportunity cost of leisure among the irrigated households. (Rao, 1978). Composition of manpower in crop cultivation in irrigated households was found to be heavily tilted in favor of hired labor in a study of the Rajasthan canal project by T.K.Roy (1983) also. In the study area 72.21% of total labor input came from family labor in the irrigated households while in the unirrigated households family labor accounted for 97.1% of the total labor use. Thus hiring of labor is significantly lesser in the unirrigated households.

In their study on the impact of irrigation on wealth distribution in Northern Malaysia, Jagatheesan and Zulfikili (Clive, 1982) found that each earner group (landlords, farm operators and hired laborers) gets substantial benefit (2.3 to 2.8 times) from irrigation in absolute terms. In relative terms, the relative share of the hired labor went up by 18% while that for landlord and farm operator went down by 6% and 3% respectively in the study area (Clive, 1983).

Maria Saleth (1997) points out that increased labor absorption in irrigated farming is due to increase in net and gross cropped area and change in cropping pattern towards more labor intensive crops. The initial spurt in farm employment ignited by irrigation via the area and crop pattern effects fails to be substantiated during the stage of productivity growth occurring in the mature irrigation projects. As irrigation changes from protective to productive, increased output occurs with reduced labor absorption. Increased mechanisation is one responsible factor for this trend (Maria R Saleth, 1997).

In a static framework, the employment effect of irrigation might appear very substantial however, over time the effect gets eroded as farmers begin to mechanise their farm operations. The incremental output is accompanied by much less employment. In *Ghod* command area of Western Maharashtra, the employment elasticity of output diminished from 0.62 in late sixties to 0.35 in mid seventies (Dhawan, 1985a).

5.0 Conjunctive Use in Command Areas

In the context of canal irrigation literature conjunctive use of water resources refers to the condition in which irrigation needs are met jointly from an area's surface as well as groundwater resources.

1. Dhawan (1993) identified seasonal nature of canals, low and inadequate water allowance per unit of cultivated land, precarious water supplies to farmers at the tail-end due to over appropriation by head-end farmers, farmer's eagerness to adopt HYV seeds based intensive cultivation and explicit and hidden subsidies on private groundwater irrigation as factors favoring the development of conjunctive use in the command areas.

2. The value of groundwater to a farmer in the canal command hinges on the type of canal. Evidently it will be higher if the canal supplies are of restrictive nature. For example groundwater becomes a substantial source of augmenting the meager supplies in northern India where protective principle means that hardly one-third area of a farmer can be fully irrigated with canal supplies. Even in non-protective canal of the type existing in southern India, a private well allows even the tail farmers to grow water intensive crops that will not be possible with exclusive dependence on canal supplies. This brings home an important truth that canal farmers would not invest in their own wells if they do not experience shortage of water (Dhawan, 1989).

3. M.V. Reddy (1990) carried out a detailed study of a major irrigation system to understand the drivers and constraints of conjunctive use in command areas of such systems. His study suggests that scarcity and unreliability of water supply are the main drivers of investment in wells in command areas. In his survey of the well owning farmers in the command area 88.9% respondents cited inadequacy of canal water supply, 81.5% farmers cited greater irrigation requirement for sugarcane, 77.8% cited too long gap between successive rotations, 67.4 % cited tail-end location and just 3.5% cited arresting water logging as the reasons for investment in wells in the command area.

4. Brackish ground water (67%), lack of capital (76.5%), uneconomic land-holding (70.6%), lack of technical support (52.9%), lack of power (14.7%), hard rock geology (17.7%) and restrictions from the irrigation department (52.9%) were cited as the main reasons for non-investment in wells by the non-owners (Reddy, 1990).

5. An important study of farm-level water utilization at various locations (head, mid and tail) of a canal course in Nagarjuna Sagar Project area by D Sen and Das (1986) suggests that low level of water delivery by the canal system encouraged farmers to invest into wells. They found that the quantum of water available in the farms at the head, mid and tail end was only 45.96%, 37.48% and 24.71% respectively of the localization requirements. Water delivered at the field ranged from 18.96% to 24.75% of the total water released in three years of the study. The rest of it was being lost out to seepage and evaporation. O.P. Dutta (1968) carried out a rough calculation of the amount of water entering the sub-surface table through percolation in canal irrigation systems.

According to his calculations 49.2% of the total water released at the canal head is lost to the sub-surface water table as percolation loss which is used by the wells in the command area.[1]

6. In his interim evaluation study of Borsad branch canal of Mahi-Kadana project, A.S. Patel (1988) found that since canal irrigation was inadequate, most sample households had to supplement it by resorting to tube well irrigation. Average investment in irrigation assets per household was found to be Rs. 2537 among canal irrigators while it was negligible among non-canal irrigators. Well-ownership was highest among irrigators in the head reaches followed by mid reaches, tail reaches and non-irrigators (Patel, 1988).

7. Well irrigation was found to be more important than canal irrigation even in the head reaches. Even there area irrigated exclusively by wells exceeded the canal-irrigated area. Head reaches had 43% area under exclusive well-irrigation, mid reach had 41% area under exclusive well irrigation while in the tail reaches 60% area was under well irrigation exclusively. Overall, 20.28% area was irrigated exclusively by canal, 46.26% by exclusively well and 33.46% area was irrigated partly by well and partly by canal.

8. Patel and Adhvaryu (1983) reported similar findings on dependence on wells in command area in their evaluation study of Dantiwada irrigation project. The use of groundwater was found to be dominant even in the command area. Dependence on wells and hence there number was much higher in the middle and the tail reaches as shown in the table below.

Table 2: Percentage of farmers using different sources of irrigation in Mahi-Kadana command Area.

Source of Irrigation	Upper Reach	Mid Reach	Tail Reach
Canal	22.99%	17.24%	9.63%
Well	32.16%	36.26%	78.12%
Conjunctive	44.85%	46.50%	12.25%

(Source: Patel, 1987)

9. Dantiwada project was found to have a conveyance efficiency of less than 20% in terms of water delivery at the farm gate. An analysis of time-series data of canal water release and area irrigated indicates an average duty of 181.6 Ha/MCM and 82.92 Ha/MCM for kharif and Rabi seasons respectively. Assuming overall efficiency of 17%, average delta works out to be 0.31ft. and 0.68 ft. for rabi and kharif seasons respectively. Irrigation requirements for the given cropping pattern are almost double. This implies that use of groundwater to supplement canal water is inevitable in this command area.

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[1] Transit loss = 17% (supply at canal head) + 8% (distributaries) + 20% (water courses) = 45% of supply at the canal head.
Field loss = 30% of water reaching the field = 0.3* (100-45) = 16.5%
Actual water use by crops = 55- 16.5 = 38.5% of the total water released at the canal head.
Allowing an average evaporation loss rate of 20 %, the net loss by percolation is given by
Percolation = 61.5 – (20% of 61.5%) = 49.2%

10. K. Palanisami (1984) carried out a study focusing on water distribution problems in rabi season in the Lower Bhavani project. He also found that area irrigated exclusively by canals was higher in the head reaches while canal + well-irrigated areas dominated the middle and tail reaches. In head and mid reaches wet crops were being grown mostly on canal irrigated lands that were supplemented by wells while dry crops were being grown mostly on land irrigated exclusively by canals. However, in the tail reaches of the canal system both wet and dry crops required supplementation by wells.

In this way all the studies cited above suggest that conjunctive irrigation has evolved as a practice by default in the command areas of most of the irrigation systems to support the water intensive crops and mitigate the potential negative impact of irregularity and inadequacy of canal water supplies contrary to the dominant thinking that rising groundwater levels encourage investment in well construction. . The extent of conjunctive irrigation development in an area is inversely related to the reliability and adequacy of water supplies. Therefore it is observed that number of wells increases in a command area as we move away from the reservoir.

5.1 Impact of conjunctive irrigation

1. Well owners in a command area are able to allocate more area under water intensive, highly remunerative and perennial crops like paddy and sugarcane. They cultivate their land more intensively and obtain higher yields due to better control, certainty and predictability of water availability. In head-reaches, groundwater pumping also provides vertical drainage and prevents water logging.

2. Well ownership helps reduce the head-tail disparity in cropping pattern and overall water use in command areas. In areas where water markets exist, the benefit extends even to the non-owners while in areas with poor water markets marked difference is observed among owners and non-owners in cropping pattern and crop yield. (Reddy, 1990). Analysis of cropping pattern under canal and well irrigated farms of the head, mid and tail reaches of a command area shows major spatial variation in the cropping pattern of farms irrigated exclusively by canal while farms under 'canal supported by well' have much more uniform cropping pattern across space (Mitra, 1996)

Table 3: Cropping Pattern Across Command Area

	Head Reaches		Mid Reaches		Tail Reaches	
Crop	**Well**	**Canal**	**Well**	**Canal**	**Well**	**Canal**
Jowar	16.78	27.30	15.56	33.05	19.78	37.06
Bajara	-	-	-	7.74	9.18	16.20
Wheat	19.36	25.96	15.53	16.48	9.73	15.56
G 'nut	1.89	17.14	2.30	17.33	1.65	11.18
Pulses	2.40	4.43	1.28	5.5	2.59	6.52
Sugarcane	55.46	24.51	60.66	16.28	48.52	11.44
Others	4.11	0.66	4.67	3.62	8.55	1.94

(Source: Dhawan , 1989)

3. A study by Palanisami (1984) in Lower Bhavani Project showed that spatial difference in water usage rate was much lower for farmers who had wells than those farmers who were dependent exclusively on canal for irrigation. He further found that perennial and water intensive crops were being grown only by farmers with assured supply of water through wells. Groundwater supplementation enabled the farmers to take a second paddy crop in the Rabi season.

Table 4:Difference in use of water across the command area (figures indicate delta in cm.)

Region	Source	Near outlet	Tail of outlet	Difference
Head	Canal	32.96	23.20	9.76
	Canal + Well	30.53	27.20	3.33
Mid	Canal	31.42	21.72	9.70
	Canal + Well	30.96	27.72	3.24
Tail	Canal	28.88	20.04	8.84
	Canal + Well	29.30	24.50	4.80

(Source: Palanisami, 1984)

4. In the study area, farmers practicing conjunctive irrigation reported greater input use and higher yield of paddy in all three reaches. Of 18 farmers in the high yield category, 13 had well irrigation facility. Only three well owners reported a yield less than thousand Kilogram/bigha of paddy. In the mid reaches all farmers getting high yields were practicing conjunctive irrigation. In tail reaches only well owners grew paddy and six out of nine such farmers reported more than 1000kg/bigha yield.

5. Importance of wells in the command area increases, as the system grows older especially where cash crops are being grown in the command area. For example in *Mula* command in Maharashtra, area under Sugarcane on wells supplemented by canal water has increased from 1700 Ha to 4400 Ha in a decade while Sugarcane area exclusively on canals remained stagnant at 1700 Ha. Numbers of wells have gone up from 6800 to 8200 and area under cane exclusively irrigated by wells has gone up from 1700 Ha to 5000 Ha during the same period.

5.2 Linkages between surface water and groundwater in command areas

According to B.D. Dhawan (1989) long run sustainability of much acclaimed groundwater-based agriculture in low rainfall areas of North, West and South India now hinges on seeped in waters from surface irrigation systems. He carried out a study to assess the magnitude of beneficial effects of surface irrigation development on the ground water-based farming of some groundwater short regions of India like Maharashtra, Punjab, Tamil Nadu and Western UP.

Using the farm management survey data and the talukawise statistics of Ahmednagar, he demonstrated that the rate of return on investment for dugwells in this low rainfall district (500-600mm) was substantially higher in canal command areas as compared to the non-canal areas. It averaged about 50% for canal-irrigated talukas while just 13% for non-command talukas. The difference could be attributed to two factors. First, the net irrigated area per well in the command area was75% more and second, the cropping pattern under wells in canal command was heavily tilted in favor of more remunerative crops especially sugarcane which could not be grown on seasonal wells found in the non-command talukas.

In Mula command in the same district only 22% of the water released from the reservoir reached farmer's fields and sugarcane growing was restricted. This led to investment in well irrigation in the command area. Number of wells rose by 50% in the command area after the commissioning of the canal project. Command area of each of the wells rose by an average 86% in the canal commands areas. Likewise the new cropping pattern under well also changed heavily in favor of sugarcane. Crop output based on groundwater rose from 14,000 tons in 1971 to 117,000 tons in 1982-83. This eightfold expansion in groundwater-based farming in Mula command has to be credited to the return flows from canal.

Dhawan (1989) argued that but for the return flows from canals, groundwater in much of Punjab would have been encountered at much below the current levels. To establish his contention he used the data of natural recharge and compared it against the recommended irrigation application for the paddy-wheat sequence of cropping. He found that the recommended irrigation level was 15-18 times the natural recharge rate of 12-15 cm per unit of land area. He further contended that 50-70% of the Punjab's agriculture output based on groundwater irrigation was actually due to the canal seepage. The detailed calculation is shown in the box below. Similar results have been obtained for the private tubewells in Muzaffarnagar district of western UP. While in Tamil Nadu, both canals and tanks together make substantial augmentation of its natural groundwater availability. About one fourth to two fifth of the total output of seven million tons from wells established in the state may be traced to return flows from canals and tanks, with bulk of the return flow coming mainly from the state canal network.

Punjab

- Output of well irrigated areas 14 MT
- Output of canal irrigated area 4.9 MT
- Natural Recharge 0.75 m ham
- Total Recharge 1.81 m ham
- Contribution of canals in total recharge 60%

Thus around 8.4 million tons of output in mid-eighties was being taken with the help of return flows from canals. In this way, the total (direct + indirect) output of canals is 2.5 to 3.0 times higher than that of the direct reported output.

The level of development of tubewells diminishes as we move eastwards in the vast Indo-Gangetic plains. Among several other factors that have brought about such spatial pattern in Indian tubewell irrigation is the prior development of canal irrigation. The role of canal irrigation in facilitating the rise of private tubewells needs due recognition in the irrigation discourse (Dhawan, 1982).

Seeped-in canal water improves the availability of groundwater in low rainfall regions that in turn reduces the cost water lifting and helps support many more tubewells than are feasible simply on the basis of natural groundwater recharge. (Dhawan and Satya Sai, 1988).

The prior exposure and experience with canal irrigation has proved helpful to farmers going in for their own tubewell investment. Canal irrigation leads to accumulation of savings that come handy in meeting the enhanced working capital needs of intensified farming with tubewell irrigation. Dhawan also argues that the spatial pattern of well irrigation development in India has followed canal irrigation. Moreover, it is observed that in the command areas, canal irrigated areas reap higher returns from well irrigation than the non-irrigated areas (13%vs. 50%) which provides further impetus to the development of groundwater in the command areas (Dhawan, 1989).

6.0 Stabilizing Impact of Canal Irrigation

- Irrigation leads to stabilization of cropping pattern, crop yield and total agricultural output. The output stabilizing potential of irrigation was one of the main reasons for huge investments in large canal irrigation projects during the colonial regime. First irrigation commission report, 1901 views these projects mainly as a protection against famine (Agriculture Situation in India, 1969 Vol. 24 (1).

- However, the impact of irrigation in stabilizing the crop output in the command area is contingent upon 1) seasonal character of the irrigation source, 2) the dependability of source of irrigation during drought periods, 3) the relative importance of irrigation vs. rainfall in meeting the water requirements of selected crops and 4) tolerance level to water stress of irrigated crops vis-à-vis rainfed crops. Irrigated output from summer and Rabi crops can be highly unstable if the capability of irrigation system during these seasons hinges on rainfall conditions.

- A timeline comparison of rice and wheat yields under irrigated and un-irrigated conditions in four states of Punjab, Haryana, Madhya Pradesh and Gujarat shows clear gains in yield stability of irrigated areas over un-irrigated areas.

Table 5: Comparative Stability in Wheat and Rice Crops in Selected States

	Wheat		Rice	
	CV (%)		CV (%)	
States	**Irrigated Area**	**UI area**	**Irrigated Area**	**UI Area**
Punjab	5.3	11.8	11.6	30.2
Haryana	8.1	25.6	12.9	NG
Gujarat	10.5	15.8	24.3	35.2
MP	11.3	10.2	17.8	22.5
AP	-	-	17.0	22.0

(Source: Dhawan, 1994)

- Agricultural output has stabilized due to irrigation. The percentage difference between the highest and the lowest output has come down from 30% to 12% between two quintets, 1951-56 and 1969-74 (Kathpalia).

- However, there is a second school of thought that contends that availability of irrigation makes a farmer's cropping pattern more responsive to the price changes since he has more options. Elasticity of acreage to price is found to be higher in irrigated areas especially in the low rainfall regions of India (Panda, 1985). This brings greater inter-annual variability in cropping pattern.

- An IFPRI study showed that the variability in yield had increased from 1949-50 to 1977-78. The coefficient of variation increased from 4.03% to 59 %. The variability however, was found to be positively related to the use of modern technology and inversely related to the increase in irrigated area (Mehra, 1981).

7.0 Impact of Canal Irrigation on Productivity

Irrigation leads to increase in crop yields. It helps to raise both land and labour productivity. Canal systems in India are mostly designed for providing protective irrigation to ensure output stabilization over large command areas. However, farmers have devised their ways to realize the productive potential of irrigation for their own benefit. Investment in tubewells and over appropriation of canal water by the farmers in the upper reaches of canal are such practices.

Green revolution crops (mainly wheat and rice) and cash crops like sugarcane are more sensitive to irrigation availability. That is why farmers in most of the command areas show strong preference for these crops in violation of the designed localization pattern. This leads to shrinking of the actual command area and precarious water availability to the tail-end farmers. This presents an important problem of making policy choice between water intensive crops in a smaller area or low to moderately irrigated crops in a larger area. The first option gives stronger benefits to a smaller population while the second option provides smaller benefits to a larger population. Extensive irrigation means lower per hectare irrigation cost and lower per hectare returns while intensive irrigation means higher per hectare cost of irrigation and higher returns (Nadkani, 1984).

The productivity potential of irrigation is unleashed when complementary inputs namely, HYV seeds and chemical fertilizers are used along with it. This raises the working capital requirement in irrigated farming and makes it more capital intensive. In most of the areas where irrigation is introduced it takes time before the farmers realize the full benefits.

Static and dynamic effects of irrigation's contribution to raising crop yields are significantly different. The static effect is the step-up in crop yield in the initial stage of irrigated farming when irrigation is a dominant farm input. At this stage, the resource poor dryland farmer is often unable to intensify input use as he changes over from rainfed to irrigated farming. So, this yield impact turns out to be modest. With the passage of time, as the system grows older, farmers begin input intensification leading to a secular rise in crop yields bridging the gap between the actual and the potential yield (Dhawan, 1989)

Neelmani Verma (1993) studied the impact of irrigation on yields of different crops in India. He established correlation between crop yield and irrigation using spearman's rank correlation method. Major states were ranked based on level of irrigation. A second set of rankings was developed based on yields of the selected crops in different states. Strong and significant correlation was found between the two rankings for rice, wheat and sugarcane. The correlation was weak but significant for coarse cereals. This shows that provision of irrigation leads to increase in crop yields. Yields of fine cereals and cash crops were found to be more sensitive to irrigation availability than that of coarse cereals, pulses and oilseeds.

In a study of ten command areas across the country by Dhawan (1989), it was found that the simple mean value of productivity of canal irrigated land was 21 quintals per hectare while the average value of rainfed yields was 8 quintals per hectare. The yield step-up is accompanied by significant decline in inter-project disparity in land productivity, because the coefficient of variation of unirrigated yields across projects is 42% while that of irrigated yield is 22%. A correlation analysis across projects showed that the level of land productivity under irrigated conditions bears positive relation with two aspects of cropping pattern, namely 1) the relative area under non-foodgrains (r = 0.32) and 2) the relative area of crops requiring kharif irrigation (r = 0.38). However, it is negatively related to the rainfall level in the command (r = -0.33). The productivity per unit-irrigated area was much greater for non-foodgrains than foodgrains. When water productivity was considered, the yield difference narrowed down considerably in most of the cases. Among non-foodgrains vegetables had the highest water productivity while sugarcane had the lowest water productivity. Oilseeds, pulses and fibres fare better than the cereals in terms of water productivity.

A similar study carried out for three states namely Gujarat, Andhra Pradesh and UP based on a survey of 4600 farmers by NCAER showed that but for in UP, medium and heavily irrigated crops had higher land and water productivity as compared to the heavily irrigated crops. The water productivity was measured in terms of output/watering in this study that doesn't account for quantum of water applied in each watering in the different categories of crops.

Table 6: Comparative Productivities of Crop Irrigated to Different Intensities[2]

States	Yield (Kg/Ha)			Yield per Watering (Kg/Ha)		
	Lightly-irrigated	Medium-irrigated	Heavily-irrigated	Lightly-irrigated	Medium-irrigated	Heavily-irrigated
AP	1321	3599	2076	486	1579	488
Gujarat	777	1970	1219	529	544	570
UP	1083	1491	2138	1072	518	898

(Source: Dhawan and Satya Sai, 1987)

[2] Coarse cereals, pulses and oilseeds are categorized as lightly irrigated while paddy, sugarcane and fruits are considered as heavily irrigated crops. Others like wheat, cotton and tobacco are considered as medium-irrigated crops.

- A recent case study on large dams in India (World Commission on Dams, 2000) shows that currently the overall irrigated yield is 2.2tons per hectare while the rainfed yield is 1.0 tons per hectare. The irrigated yield has remained substantially below the potential of 40-50 quintals per hectare as suggested by agronomical studies in India. This yield gap is accountable mainly in terms of a substantial input gap between the recommended and the actual doses of two principal inputs namely fertilizers and irrigation. The extent of under fertilization was found to be as high as 80 % in UP, 60 % in Gujarat and 33% in AP in a NCAER survey carried out in mid-seventies.

- Annual increase in irrigated yield over seventies and eighties was 41 kg. Per year while the rainfed yield increase at the rate of 11Kg per year.

- Marginal increase in productivity of land due to irrigation is higher for non-food grains by almost 100%. The improvement in productivity due to irrigation is greater in case of non-food crops as compared to the food crops (11quintals/Ha vs. 28quintals/Ha). In terms of water productivity, sugarcane ranks poorest while vegetables are the best (Source: Dhawan, 1988). Provision of groundwater irrigation creates greater productivity impact than the surface irrigation. This has been brought out by several micro and macro level comparisons of inter-source productivity. The difference in productivity among different sources is positively related to the quantum of irrigation (as indicated by number of waterings) and fertilizer use intensity.

Table 7; Comparative Performance of Surface Irrigation, GW Irrigation and Conjunctive Irrigation, 1975-76

Irrigation Category	Andhra Pradesh	Gujarat	U.P.
Surface Water			
Overall Yield (Kg/Ha)	2111	1397	1784
No. of Waterings	3.79	3.25	2.61
Output per Ha	245	939	1285
Output per watering per Ha	329	289	492
NPK (Kg/ Ha)	102	81	30
Groundwater			
Overall Yield (Kg/Ha)	2353	1898	1552
No. of Waterings	5.01	3.42	2.45
Output per Ha	1711	1553	1093
Output per watering per Ha	341	454	446
NPK per Ha	96	57	30
Conjunctive			
Overall Yield (Kg/Ha)	1935	1481	1761
No. of Waterings	4.06	3.81	2.61
Output per Ha	1721	1023	1202
Output per watering per Ha	424	269	461
NPK per Ha	98	47	54

(Source: NCAER)

8.0 Impact of irrigation on Cropping Pattern

It is generally believed that provision of irrigation leads to a shift in cropping pattern towards high-value non-food crops. However, the national level data shows that the share of foodgrains under irrigation has increased from 18.8% in 1950-51 to 32.7% in 1986-87. This uptrend in production of foodgrains under irrigated conditions has been predominantly confined to cereal crops, and little to pulses and oilseeds (Dhawan, 1994). Each point rise in the irrigation ratio for foodgrains was accompanied by a yield rise of 41 Kg per hectare area under food crops in the post HYV period (i.e. after 1967-68). Area-wise foodgrains acreage predominant in the total irrigated area in the country. In seven out of ten command areas studied by Dhawan (1989), foodgrains accounted for more than 85% of the benefited area while in other three command areas percentage share of foodgrains ranged from 61 to 68% of the command area. However, the composition of foodgrain output has considerably changed with the advent of irrigation facility. The share of fine cereals (wheat and rice) has gone up while that of coarse cereals (Jowar, maize and millets) and pulses has declined. Fine cereals have dominated the food basket because they are high yielding and high valued while coarse cereals are low yielding and low valued and pulses are low yielding and high valued. Mainly resource poor farmers and the farmers at the tail end who are not sure of canal supplies grow pulses in a command area, as it requires less irrigation and other capital-intensive inputs.

Therefore, increase in irrigation doesn't necessarily lead to a shift from food crops. HYV cereals are being grown in a large part of irrigated areas.

Table 8: Share of Different Crops in Irrigated and Unirrigated Areas

Crop Category	Percent Share in Irrigated Area	Percent Share in Unirrigated Area
Superior Cereals	66	24
Coarse Cereals	6	30
Pulses	3	17
Oilseeds	5	12
Sugarcane	5	Negligible
Others	15	17

Irrigation doesn't influence the cropping pattern in the kharif season. However, it leads to diversification of cropping pattern in Rabi.

In *Tadpatri* branch canal 51% farmers in the head end, 46% farmers in the middle and 21% farmers in the tail end introduced paddy as a new crop. The rate of innovation in cropping pattern was related to spatial location on the system but no systematic relationship was found between innovativeness and farm size. In the same system, it was observed that diversity in cropping pattern increased as one moved towards the tail end of the system. In his study of Dantiwada command, Adhvaryu and A.S. Patel (1983) found significant difference in cropping pattern of irrigated and unirrigated land within the command area itself. Fine cereals dominated the irrigated areas while coarse cereals dominated the unirrigated areas.

- Rabi crops become more important due to irrigation. Share of Rabi output has gone up to 46% in total agricultural output in 1986-87. Irrigation is majorly responsible for this phenomenon (Shah, R.B.) For Kharif; irrigation brings temporal stability in yield while it has a major productivity and area impact in Rabi and summer seasons (Pal, 1985).

- Crops like wheat and tobacco replace the lightly irrigated crops like oilseeds and pulses in rabi season with the advent of irrigation. The additional area brought under cultivation during rabi depends on the orientation of the source of irrigation towards the kharif season called K-factor. The higher the K-factor, the lower the additional area brought under cultivation during rabi (Dhawan, 1993).

- Shift from rainfed to irrigated cultivation has brought about an increase in yield by 13.3 quintals/Ha (Source: CWC, 1996). Pure yield effect in this increase is 6.9 quintals; cropping pattern effect is 2.6 quintals while interaction term is 3.8 quintals/Ha. The positive sign of the interaction term shows that irrigation leads to a change in cropping pattern towards high yielding crops. (Vaidyanathan and Minhas, 1965).

- For an individual farmer, adequacy and timeliness of water availability, relative profitability of the crop, suitability of soil and his own ability to invest into the inputs required to raise the output are the four decision variables in the decreasing order of importance in making the crop choice.

9.0 Impact of Irrigation on Cropping Intensity

Development of irrigation is perceived as the key to year- round cropping of our limited land resources. Due to the monsoon climate of India, which limits rainfall to three months in a year, irrigation becomes a pre-requisite for growing second and third crops. Conventional wisdom suggests that provision of irrigation leads to an increase in cropping intensity. This is one of the important factors that justify huge investments in the irrigation infrastructure in both public and private domains.

Overall cropping intensity in India is presently around 130 per cent which means on an average 1.3 crops are being raised on 140 million of net sown area which is currently under plough. The all India average in cropping intensity has slowly risen from 111 per cent in 1950-51 to 118 percent in 1970-71 and 127 per cent in 1987-88. This upward moving trend implies a steady annual growth of about 0.35% in cropping intensity. In the same period the gross irrigated area under crops has increased at an annual rate of 2.72 per cent (22.6 mHa to 55.6 mHa) and the irrigation ratio (defined as the ratio of gross irrigated area to net sown area) has risen at a rate of 2.32 per cent per annum. Thus we notice from the above data that irrigation ratio and cropping intensity do not have one-to-one correspondence between them or in other words, one per cent increase in irrigated area doesn't lead to one per cent rise in the cropping intensity. The beneficial role of irrigation in enhancing cropping intensity is very limited in India. The percentage of double-cropped area to the net irrigated area was only 25% in 1974-75. (Rao, 1974). The elasticity of cropping intensity with respect to increase in irrigated are is approaching zero in many Indian states which necessitates further enquiry into the relationship between cropping intensity and irrigation (Alagh, 1987). However, another school of thought says that the impact of irrigation on cropping intensity has declined from pre-HYV period to the post HYV period in Punjab and Haryana but it is not approaching zero in any case (Satya Sai, 1990).

To capture the dynamic impact of irrigation on cropping intensity Dhawan (1993) carried out a cross-sectional analysis of fourteen states of India over a period of 1950-51 to 1987-88 and a time-series analysis of all India data for the same period.

The estimated regression equation in time-series analysis was as follows:

CI = 91.21+ 0.6476 IRR+0.0925 INDEX RAIN
R^2 = 0.9758
N = 38
Where: CI = all India cropping intensity (%)
IRR = irrigation ratio (gross irrigated area as % of net sown area)
INDEX RAIN= proxy for all India rainfall index.

The coefficient of the irrigation ratio is 0.65, which implies that each percentage rise in irrigation ratio leads to a 0.65% rise in the cropping intensity.

The cross-sectional analysis of 14 states for a period of 1983-87 resulted in the following estimated equation:

CI = 66.95 + 0.46 IRR + 0.6618 Rain – 0.0015 $Rain^2$ – 15.10 K
R^2 = 0.8283
N= 70

The two regression equations here provide definite evidence of the close relationship between irrigation development and the rise in intensity of cropping at the national level. Pooled cross-sectional analysis of different quintets over the time span of 1953-54 to 1987-88 shows a more or less stable trend in the intensity impact of irrigation with weak signs of marginal improvement evident in eighties as shown in the table below.

Table 9: All-India Cross-Sectional Regression for Different Periods on Cropping Intensity

Period	n	IRR	K	R^2
1953-57	70	0.4074	27.48	0.8023
1958-62	70	0.4219	33.01	0.7866
1963-67	70	0.3911	21.10	0.7933
1968-72	70	0.3885	21.42	0.8546
1973-77	70	0.4152	21.48	0.8710
1978-82	64	0.4318	18.80	0.8506
1983-87	60	0.4555	15.10	0.8277

Dharm Narain and Shyamal Roy (1982) showed that the extent and quality of irrigation and labour availability per unit net sown area explain 80% of the interstate variation in cropping intensity in India. Interestingly, the magnitude of irrigation explained only 8% of the variation while the quality of irrigation explained 43% and labor availability explained 29% of the variation.[3] They further claimed that so far as source wise impact was concerned, tubewell irrigation has double the effect over well and canal irrigation (Narain and Roy 1982).

Tanks have the lowest impact on cropping intensity while tubewells have the greatest impact. Canals fall between the two. Among canals, the reservoir-based systems have greater impact on cropping intensity than the diversion systems. According to Dhawan (1993), it is the seasonal character of irrigation that determines its impact on cropping intensity. He measures this seasonal character in terms of K-factor, which is the kharif orientation of the source of irrigation. Higher the K- factor of irrigation, lower the impact on cropping intensity. That is why we see that the coefficient of this K-factor has a negative sign in the cross-sectional regression. It is also observed that the value of K-factor has steadily gone down from 1953-57 to 1983-87. This is because of the tubewell revolution and increase in number of reservoir based irrigation projects in the country.

Intensity of cropping is positively related with the rainfall variable but it does not change in constancy with rainfall. An analysis by Yadav showed a quadratic relation between intensity of cropping and rainfall across Indian states. (Yadav, 1990).

10.0 Differential Nature of Impact of Irrigation

Like all public investments, impact of canal irrigation varies in its nature and extent across space, time and social classes. Effect of irrigation on development in terms of both production and distribution is linked not only to the physical characteristics but also to the socio-economic structure of the area where it is introduced (Rao, 1974).

Spatial inequity in impact of irrigation is apparent from the fact that interstate differential in farm productivity is greater in irrigated farming than the rainfed farming. Impact of irrigation is relatively less pronounced in high-rainfall areas both in terms of productivity and cropping pattern. Rainfed yield bears a positive relationship with normal rainfall while irrigated yield bears a negative relationship.

According to Dhawan's assessment, in matter of spatial equity within the command area of an irrigation system, major irrigation works of northwestern India have performed much better. The policy of under-irrigation has helped in maximum extension of the spatial coverage of the benefits while *warabandi* (a time-shared system of taking canal water by turns) has ensured better water availability to even the tail-end farmers by containing the undue appropriations by the head-end farmers. In other parts of country, undue over appropriations by farmers in the upper end have not only drastically curtailed the water supply to the tail-enders but also led to substantial shrinkage in the actual command area as against the design command area (Dhawan, 1994).

Catchment area is perhaps the most important part of the canal irrigation system since the system derives its endowment (i.e. water) from this part. However, socio-

[3] Quality of irrigation was measured in terms of irrigation intensity which is defined as gross irrigated area as a percentage of the net irrigated area. This helps to capture the seasonal character of irrigation.

economic impact of canal projects on their catchment areas has not been studied at all in Indian irrigation impact literature.

Differential impact of irrigation on different land-size classes is the most widely studied aspect of Indian irrigation impact literature. As pointed out earlier in the review, almost all impact studies analyse irrigation projects for the nature of their impact on different classes of farmers. Opinions and findings in this regard are however, widely varying.

One set of studies seem to suggest that since the benefits of irrigation are locked to land, the large public investments in this sector have benefited the traditional land owning classes of farmers only. Access to water combined with ownership of agricultural land has reinforced the functional dominance of local economy and society by the high caste, land owning agricultural classes in the command areas. (E.J. Vander Velde).

There is a second set of studies that suggest that canal projects have led to over all well being of people living in the command areas. The benefits of increased economic activity fuelled by irrigation have reached not only landowners but also the land less agricultural laborers and non-farm workers in the command area. A timeline survey carried out by T.K.Roy in rajasthan canal project command area showed a marked increase in income of non-farm households mainly due to increased economic activities in the non-farm sector resulting from high agricultural production in the irrigated land. (Roy, 1983).

According to this view canal irrigation leads to increased returns to both small and large farmers. Both gross and net returns are higher in the irrigated farming than in the unirrigated farming. However, it is observed that the net return from each irrigated hectare of land is greater for large and medium farmers as compared to the small and marginal farmers. The picture changes in favor of small and marginal farmers if net returns are calculated on paid-out costs and opportunity cost of domestic labor is not accounted in the calculation.

Fertilizer use intensity and extent of conjunctive irrigation in a command area are positively related to the farm-size. Credit offtake from institutional sources is also greater among large farmers. This helps them to realize greater benefits from irrigated agriculture. A state wise comparative analysis of net returns from irrigated agriculture shows that marginal and small farmers realize greater net benefits in Punjab and Tamil Nadu. Their fertilizer use intensity was found to be greater than the large farmers in these two states. In absence of equity in fertilizer use, benefit from irrigation is positively related to the farm size (Dhawan, 1994).

11.0 Studies on Socio-economic Impact of Canal Systems- The Way Ahead

Indian irrigation literature is replete with studies on socio-economic impact of canal irrigation projects. However, our understanding of these systems and the dynamics they set in motion in their domain is grossly inadequate. Most of the studies end up taking a myopic view often dominated by the limited philosophy that dictated the design of these systems in first place. The coverage of issues remains confined to the direct and primary impacts in the command areas only. Limited understanding leads to poor management and underutilization of resources to the detriment of the system, its environment and the beneficiaries.

- Further research on impact of canal irrigation projects should take a wider and multidisciplinary systems view that captures the dynamic interaction between social and technical factors which are so embedded in each other in irrigation systems.

- Catchment area is the source of endowment for canal systems. But it has been completely overlooked in the existing literature on socio-economic impact of irrigation projects. In India unlike in western river basins, even catchment areas are densely populated with high water requirements. Local water harvesting movement has caught up in a big way in the catchment areas of many projects in western India. These movements have a direct bearing on the performance of canal systems. However, we do not have any studies to suggest the nature and extent of impact of such developments on larger systems. Research should be undertaken to understand the impact of surface irrigation systems on their catchment areas.

- Canal irrigated areas attract migrant labor from distant regions. Over the years seasonal migrants undergo powerful learning experiences as they learn about new methods of irrigated farming used in command areas and try them out in their own fields when they go back. In this manner they extend the impact of canal systems beyond the design command to a wider 'zone of influence'. Research efforts are required to understand this dynamics better.

- Canal irrigation stimulates private well irrigation development in their command areas. Farmers invest into wells to pump out the canal return flows to increase the reliability and availability of water supply. As the system grows older, the groundwater supplies become increasingly important. This adaptive development of well irrigation in the command area offers new opportunities and avenues for managing water supply in canal systems so as to maximize positive impacts and minimize the negative outfalls. Madhya Ganga Canal Project in Western U.P. is one successful example of innovation in this field, which presents large opportunities for similar systems in a large part of North Western India. More research engagements are required in this direction to build upon such innovative experiments and ideas (Sakthivadivel and Chawla, 2001).

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