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CONJUNCTIVE WATER MANAGEMENT IN BIHAR

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CONJUNCTIVE WATER MANAGEMENT IN BIHAR[1]

K V Raju[2] and Jeffrey D Brewer[3]

BACKGROUND

This paper attempts to define complexes of technologies, institutions, and management methods for the conjunctive management of multiple water sources - particularly surface water and groundwater–that can lead to the sustainable improvement in irrigated agricultural production while preventing or ameliorating environmental problems. It delineates the complex of technologies, institutions, and management methods in use in the selected Indian site while evaluates their effectiveness in promoting irrigated agricultural production and in preventing detrimental environmental effects such as waterlogging; salinisation, etc.

Based largely on a study carried out in 1992–93 (Raju et al. 1994) in the same area, the authors collected additional documentary evidence and interviewed (in some cases re-interviewed) government officials and farmers in the area. Detailed samples of farmers were studied in three subcommand areas over a period of a year, primarily through participant observation. Some technical studies were also carried out. In addition, various government officials were interviewed and documents collected. The findings of the earlier study were updated by a short restudy in May 1999. For the restudy, groups of farmers were interviewed in different portions of the scheme. Also relevant government officials were interviewed, both in field sites and in Patna, the capital of Bihar. Where available, appropriate records were obtained.

FEATURES OF THE STUDY AREA

The state of Bihar is the ninth largest in India, with a total area of 173,877 square kilometers and the 1996 population estimated at 93 million (Tata Services, 1998). The State includes alluvial plains of the

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1. This paper is based on a report, which was a short study of conjunctive use of surface and ground water in North Bihar, India. This report was prepared as one of four such short studies under the Conjunctive Management Project being carried out by the International Water Management Institute in collaboration with CSIRO in Australia, and PCRWR in Pakistan and funded by the Australian Council for International Agricultural Research.

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Gangetic basin in the north and Kaimur-Chotanagpur-Santhal plateau in the south. The alluvial plains are divided into two by the Ganges River flowing from west to east. The study area lies in North Bihar, which is part of the vast alluvial Gangetic Plains. The North Bihar plain was built by the rivers - principally the Gogra, Gandak, Bagamati, Kamala and Kosi - that emerge from the Himalayas and flow to the Ganga and then to the Bay of Bengal. Land in North Bihar has been created by the deposition over thousands of years of the heavy silt and detritus load brought by the rivers. This process has left very deep and potentially productive alluvial soils in the area. The whole of North Bihar is composed of young and recent alluvium soil. In building the land, the rivers have shifted channels many times. For example, it is likely that the Burhi Gandak River was once the bed of the Gandak River but the latter moved westwards. This movement of rivers has left depressed areas, known locally as *maun* or *chaur* areas, that are flooded seasonally by the rains.

The population density in the study area is very high and almost double that of the state. This is a general characteristic of North Bihar. Agriculture is the main occupation in the area. In Bihar as a whole, about 38 per cent of the working population cultivates land and another 26 per cent is primarily dependent on agricultural labour for a total of about 64 per cent of the population dependent upon agriculture. The literacy rate is low reflecting low levels of social services and social development in the area. State per capita income is very low – only Rs304. per month; the lowest in India. The all-India average is Rs588. per month. Per capita income in North Bihar is well-below the state average and is estimated at only about half of the national average (Prasad, 1993). With over half the people in the State as a whole below the Indian national poverty line, the percentage is even higher in North Bihar.[4]

Because of the high population density, the average operational farm holding is small. About three-fourth of the operational holdings are marginal (less than one hectare) in which the average size is merely 0.31 hectare (Sharma, 1998). Farm land in the area is privately owned and a significant portion is farmed by the owners. Sharecropping is common. The standard sharecropping arrangement is that the landlord provides the land while the sharecropper provides all other inputs. At the end of the

4. During the study, we found that seasonal migration in search of employment, mainly to Punjab, Assam and metropolitan cities like Delhi and Calcutta, is common. The population in the area is overwhelmingly Hindu and consists of a variety of castes, including Harijans. Multiple castes are found in all villages in the area. Caste membership remains very important for social relations in the area.

season, the sharecropper gives half the harvest to the landlord[5] Knowledgeable persons in the villages estimate that 60–75% of the farmers are sharecroppers. Land fragmentation is a widespread phenomenon.

The Eastern Gandak and Vaishali Branch Canal Commands

Major Features of the Canal System: The Gandak River flows down from the Himalayas in Nepal and joins the Ganges at Patna, the capital of Bihar. A diversion weir located at the junction of the borders of Nepal, Uttar Pradesh, and Bihar diverts water into several main canals, of which the biggest are the Western Gandak and Eastern Gandak Main Canals. About three kilometers from the river, the Eastern Gandak Main Canal splits into three. The largest branch, called the Tirhut Main Canal (TMC) continues in the southeast into Bihar. Construction of the Eastern Gandak System began in 1961 and was stopped, before completion, in 1985.

The TMC was planned to be 275 kilometers long. However, only about 240 kilometers have been constructed. The distribution system below the main canal was completed only as far as the Vaishali Branch Canal offtake, at about 169 kilometers from the TMC head; although some work has been done below that point. The total planned command area for the Tirhut Main Canal is over 600,000 hectares, with about 70 per cent having been completed. The Vaishali Branch Canal is located in the tail portion of the TMC. The VBC command lies in Vaishali and Muzaffarpur Districts.

Water Availability in the VBC Command

Climate and Rainfall: North Bihar lies in the monsoon subtropical zone. It is characterised by a wet monsoon season from June through September, followed by cooler and drier weather from October through February, and then followed by a hot summer season, with occasional thundershowers and dust storms from March to the middle of June. Normal annual rainfall in the Bihar portion of the Gangetic Plains is 1092 mm. Temperatures vary from highs of 41°C in May or early June to lows

5. We found a high proporation of sharecroppers in the area but were unable to get exact figures. The present Bihar Tenancy Act gives long term sharecroppers and leaseholders very strong rights. Hence landowners are unwilling to give land on long-term arrangements. At the same time, the state government is not capable of protecting individuals from physical violence instigated by powerful persons and groups. In this situation, many sharecroppers prefer to make private and secret arrangements that give them stability. Thus, farmers show considerable reluctance to admit to being a sharecropper.

of around freezing in January. The Gandak Command area is one of the humid areas of the state. Humidity is lowest (52%) in the months of March and April and highest (83%) during the rainy months of July and September. Over 85% of the annual rainfall falls from June through September. However, rainfall can vary markedly from year to year and from location to location.

The Gandak River: Availability of water in the Gandak River at the barrage at Valmikinagar indicates large variation in flow between the rainy and dry seasons. The capacity of the Eastern Main Canal is 443 cumecs and that of the Main Western Canal is 368 cumecs. The total is 811 cumecs. The combined capacity of these two canals is exceeded, with 75% dependability, from June through November every year. Canal water needed to meet crop requirements was assessed in 1982/83. Findings revealed that if crop water requirements as per specifications in the original design are to be fully met, then the Tirhut Main Canal would probably suffer water shortages between February and March every year assuming that all irrigation needs are met from the canal system. At the present level of development of the system, the river flow is adequate to serve the whole system (CWRS, 1993).

Groundwater: The Gangetic plains of Eastern India-including major portions of Eastern Uttar Pradesh, Bihar, and West Bengal-have a very large groundwater potential. Because of water from the Himalayan Rivers, together with annual rainfall ranging from 1,000 mm in the west to well over 3,000 mm in the east, there is a great deal of easily accessible groundwater in the area. Also, the agricultural potential of the region is very high since the region has deep and productive soils and a generally good climate. Because of the alluvial soils and abundant groundwater in the region, development of groundwater for irrigation is both cheaper and faster than development of canal systems. The estimated groundwater availability in Bihar is 33,645.6 MCM, of which 48 per cent is located in North Bihar.

The Gangetic Plains are deep alluvial formations which attain a thickness of approximately 2500 meters in parts of North Bihar. Most of the area is underlain with aquifers at varying depths. The soil consists of various grades of sand, silt clay and kankar. The aquifers are formed by clean sand beds that constitute between 40 and 80 per cent of the soil strata. Subsurface water in North Bihar flows generally southeasterly towards the Ganges River, a pattern modified by the recharge and discharge patterns of the tributaries of the Ganges. In general, the hydraulic gradient is about 1:5000. The quality of the ground water of the aquifer system is good. To a depth of about 100 m. electrical conductivity ranges between 400 to 950 micromhos/cm indicating low salinity. The water is generally suitable for irrigation.

The aquifers are recharged mainly by the monsoon rains. The Bihar State Groundwater Directorate measures the water table before and after the monsoon every year. As shown in Table 1 for Sahebganj. Paroo. and Vaishali Blocks in the VBC area, the water table drops as low as 6.10 m below the ground surface before the monsoon and rises as high as 0.42 m below the ground following the monsoon. The fluctuations of the water table over the year are generally in the range of one to three meters.

The relationship between groundwater recharge and usage in Bihar and the Muzaffarpur and Vaishali Districts in 1991 is shown in Table1.[6] This table suggests that only 36 per cent and 48 per cent respectively of the groundwater resources of Muzaffarpur and Vaishali Districts have been developed for irrigation. Others question these figures and suggest that they may be too high. However, these figures should be viewed with caution, most professionals feel that these calculations only give the order of magnitude of the potential groundwater resources.

Table 1: Groundwater Development in Bihar and the Study Districts, 1991

(million cubic m)

	State of Bihar	Muzaffapur District	Vaishali District
1. Total replenishable groundwater	33,773	998	633
2. Utilizable for irrigation	28,706	849	530
3. Actual net draft	6,761	305	260
4. Balance	21,945	544	279
5. Level of development	24 %	36 %	48%

Source: CGWB, 1991.

6. The figures in Table 5 come from district level water balances calculated by the State Groundwater Directorate. Wet season recharge of groundwater is computed through a hydrographic analysis of data obtained from an intensive network of observation wells. An appropriate specific yield value for the material within which the water table is moving in the area represented by the observation well is applied. Dry season recharge from surface water irrigation is calculated from estimates of losses to deep percolation from canals and fields based on regional norms. The total mean annual recharge derived from these calculations is reduced by 30 per cent, to account for the uncontrollable drainage flow and transpiration by deep rooted vegetation, to obtain net recoverable recharge.

The Bihar Second Irrigation Commission (GOB, 1994) estimated that the ultimate irrigation potential from minor irrigation, including ground water irrigation, comes to 5.6 million ha out of which 3.63 million ha (2.98 million ha from groundwater and 0.65 million ha from surface water) of irrigation potential have been envisaged through completed and ongoing projects. This potential has been created through about 600,000 private borings, 1.2 million bamboo borings, 90,000 dugwells, and 5,600 state tubewells of which most are in a non-functioning state.

Irrigated Agriculture in North Bihar

Farming Seasons: Three agricultural seasons are recognised in North Bihar. The agricultural year begins with the *kharif* (rainy) season from mid-June through mid-November, followed by the *rabi* (cool) season from mid-November through the end of February or mid-March, and followed by *summer*, also called the *hot season*, from mid-March until the monsoon rains in mid-June.

Principal Crops: The Eastern Gandak Command is primarily a kharif paddy growing area. Wheat is the principal rabi crop, although significant areas are planted in other crops, including maize and barley. Mustard is the major oilseed crop and sugarcane, jute, mesta and tobacco are other important cash crops. A wide variety of other crops are also grown, including perennial crops. There has been expansion of the area under perennial crops-mostly fruit trees-in recent years because of difficulties in getting labour for seasonal crops. As mentioned earlier, many men migrate to work in Punjab and other areas with higher wage rates. Much of the land is fallow in summer, but some high value crops are grown.

Planners of the Gandak Canal System projected a cropping intensity of 180 per cent within the command, after completion of the project. The cropping intensity in the tail reach of the Gandak Command in 1984-85 was only 5 per cent more than the cropping intensity in 1966–67, before canal irrigation began, and only a little more than the cropping intensity outside the command. The most important cropping sequence is paddy in kharif, wheat in rabi, and fallow during summer. The dominance of this crop sequence will be demonstrated later.

Water Application to Crops: Paddy and wheat are grown largely in the area. With irrigation for these two crops being major concern, farmers use the check basin method of water application. In this method the field is divided into smaller units so that each unit has a near level surface. Bunds and ridges are constructed around the area to form a basin within which the irrigation water is controlled. The supply channel is aligned on the upper side of the area and there is usually one lateral channel for every two rows of check basins. The basins are filled to the desired depth and the water is retained till it infiltrates into the soil. The local agricultural university recommends irrigating paddy 20–25 times and wheat four times during the season.

For paddy, the total water requirement is 1200–1500 mm. Standing water is desired to keep weed growth down. However, the water needed to keep water in the fields may not be available. Since paddy is grown only during the rainy season, rains and the high water table can be depended upon to supply some portion of the water requirement. Hence, to ensure a good paddy crop, it is essential to provide at least four waterings during: a) transplanting, b) flowering, c) grain filling, and d) before maturity.

For wheat, the total water requirement is 240 mm. Farmers say that 3–4 irrigations is ideal. However, due to lack of water, farmers generally plan on giving water only twice during the season: a) 21 days after seeding, b) around 50 days after seeding. Each time they provide less than 50–100 mm and depend for the rest on rainfall and the high groundwater table. The first water is considered crucial, the second less important.

Every crop has its own proper water requirement and irrigation pattern. However, when considering irrigation patterns over a season, farmers describe four irrigations of all crops excluding the perennial tree crops and grass. The four irrigations pattern for paddy and wheat serves the farmers as a conceptual model for crop irrigation. The major exceptions, the perennial crops are fruit trees, timber trees, and grass. Grass is kept in very few fields for forage and generally is not irrigated, while trees, are more valuable and sometimes irrigated. However, many trees can tap the high water table directly making irrigation unnecessary even during the dry summer season.

MANAGING THE CANAL SYSTEM FOR THE VBC COMMAND

Canal Technology: The Eastern Gandak System is a gravity canal system fed by a diversion from the Gandak River at the border of India with Nepal. The Tirhut Main Canal (TMC) starts about 3 km from the headworks and runs about 240 km to the southeast. The Vaishali Branch Canal (VBC) offtake is located about 158 km from the head of the TMC. This is in the tail reach of the Eastern Gandak System. From its headgate, the VBC runs for about 47 km, beyond which it is called the Bhagwanpur

Distributary whose length is about 33 km. The canal follows the ridge line between the Baya River and Gandak River. The designed canal network for the VBC includes two distributaries, 14 sub-distributaries, and 45 minor canals having a total length of 296 km. All are ridge canals. The VBC is designed to carry a discharge of 1,304 cusecs at the head of the canal. The canals are unlined. Control structures are of masonry construction. Most gates are screw lift gates. In almost all cases, cross-regulators have been provided below canal turnouts to provide adequate head in this flat area. As in other Indian irrigation systems, turnouts from the minor canals are called 'outlets'. In the Eastern Gandak System, outlets were designed to serve a wide range of areas from 16 ha up to 120 ha. Outlets are ungated.

It was planned that the government would construct watercourses below the outlets that carried more than 1 cusec, assuming that farmers collectively would construct smaller watercourses and field channels. But the farmers constructed only a few of the field channels. The Gandak Command Area Development Authority (GCADA) was then made responsible for constructing field channels. However, GCADA has constructed only 10 per cent of the needed field channels. Also, in many cases, outlets were not installed and farmers were forced to cut the banks to take water from the minor canals.

The designed culturable command area of the VBC is 63,289 hectares. However, when construction stopped in 1985, irrigation facilities had been completed only for 17,250 hectares. The planned total annual irrigated area was 75,946 hectares divided as follows: 44,302 hectares in kharif (70 per cent of the total); 22,151 hectares in rabi (35 per cent of the total); 50,063 hectares in summer (8 per cent of the total); and 4,430 hectares of perennial crops (7 per cent). The planned annual cropping intensity was 120 per cent. However, when construction stopped in 1985, irrigation facilities had been completed only for 17,250 hectares. Thus the irrigated area is much less than designed.

The canals and control structures are not in good condition, partly because of poor design, failure to complete construction and lack of funds for maintenance. Many gates are broken and have not been repaired for many years. For example, in 1992–93, the screw on one minor canal headgate was broken and the gate was propped open with bricks. While the VBC itself and most of the distributaries are still in relatively good condition, many of the minor canals have been damaged by farmers cutting the banks and by other changes. Table 2 shows details of 3 minor canals studied in 1992–93. From this table it can be seen that failure to construct items has led to problems.

Similarly, many watercourses and field channels constructed earlier have become inoperative because of non-use or poor maintenance. Many field channels are not in use for want of a proper linking arrangement between outlets and channels constructed by GCADA. In addition, field drainage and land leveling have not been completed in the command. These were also held to be the responsibility of the farmers. In the absence of proper on-farm development, there is considerable wastage of water.

Table 2: Details of Three Sample Minor Canals (1992)

Feature	Chakwa Minor	Madan Chapra Minor	Shampur Minor
Position on VBC	head	middle	tail
Length (meters) Designed Constructed	 396 213	 609 152	 2743 1524
Discharge (lps) Design Present*	 203 much less	 197 much less	 313 much less
Outlets No.planned No.constructed No.operational No.of bank cuts	 5 2 0 9	 3 0 - 6	 5 2 0 32
Other Problems	Broken culvert leaks water on road.		Minor not located where planned: functional length is only 900 meters.

* *There are no records of discharges at minor canal heads.*

Performance of the Vaishali Branch Canal

The VBC's design discharge is 1304 cusecs. The VBC runs at 30 to 32 per cent of design discharge at the maximum. During the last several years, maximum discharge during the kharif season has ranged between 400 and 450 cusecs. During the rabi season, it ranged between 250 and 300 cusecs. The highest discharge recorded at this regulator has been 978 cusecs during the 1978 kharif season.

At présent, because of deterioration, the carrying capacity of the canal is 500 cusecs, which though capable of irrigating 14,000 hectares, in actuality only irrigates at most 10,000 hectares during kharif. A former

Executive Engineer of the Vaishali Branch Canal and later Chief Engineer of the Gandak Project said that during his tenure between 1975 and 1978, canal discharge was 600 to 900 cusecs. It is evident that the system has deteriorated considerably through lack of adequate maintenance. Table 3 shows the areas that were, according to the plan, to be irrigated by the VBC. Actual areas irrigated are much less, because of the failure to construct the distribution system and the unreliability of the irrigation water supply.

Table 3: Planned Annual Irrigation from the Vaishali Branch Canal

Season	Area (ha)	% of CCA
Kharif	44,302	70 %
Rabi	22,151	35 %
Summer	5,063	8 %
Perennial	4,430	7 %
Total	75,946	120 %

The area irrigated by canal water as reported by the Water Resources Department at the end of a season is considered the 'achieved area' for the season. This is measured against the 'target area' fixed at the beginning of the season. The achieved area is often less than the target area. If figures for 1978-79 through 1992-93 are compared with the target areas, achievements range from 2 per cent to 120 per cent of target areas. Performance is bad even by the WRD's own standards.

Bihar Irrigation Laws and Written Policies

According to the Indian Constitution, management of water resources is a state subject. With regard to surface water, therefore, there are no binding national laws. Although there are a number of national policy statements and programmes, notably the National Water Policy (GOI, 1987), they are not binding on the state.

On the other hand, Bihar has a number of policies, laws, and regulations concerning use of surface water for irrigation and other things.[7] Rules and regulations have been formulated to implement the provisions of

7. The laws and written policies dealing with irrigation include the following: a) Bengal Canals Act, 1864; b) Bengal Irrigation Act, 1876; c) Bengal Embankment Act, 1882; d) Bihar Private Irrigation Works Act, 1922; e) Bihar Public Irrigation and Drainage Works Act, 1947; f) Bihar Emergency Cultivation and Irrigation Act, 1955; g) Bihar Lift Irrigation Act, 1956; h) Bihar Irrigation Field Channels Act, 1965; and i) Bihar State Water Policy, 1993.

these laws. Of these laws, the most comprehensive and important for irrigation management is the Bengal Irrigation Act, which along with others, have been amended several times, sometimes in major ways. Rather than attempt an analysis of these laws, we summarise the policies contained in them, including, where relevant, specific provisions that define irrigation management practices for canal systems in Bihar.

Actual Irrigation Management Policies

A basic principle incorporated into the Bengal Irrigation Act and held valid since is that the state has the legal right to assign use of all surface water in the state although it may not choose to do so. Also, incorporated into the Bengal Irrigation Act of 1876 and legally mandated until 1974 was the irrigation management system generally called the *satta* system. Under the satta system, canal officers issued permits to take water, called *satta*, on farmers' written requests. Double water rates were charged for unauthorised irrigation. One farmer per outlet was appointed as *sattadar* to oversee water distribution. He was paid 2 per cent of the canal revenue collected in his area. The canal authorities were responsible to get the water to the outlet and the sattadar managed distribution below the outlet. Village channels were constructed and maintained by villagers. Informants claim that water would be denied to a village if the village channels were not maintained properly. Alternatively, the canal authorities might carry out necessary repairs and charge the costs to the villagers. Assessment and collection of water rates was done by the revenue wing of the Irrigation Department with help from the sattadar.

After India's independence in 1947, water came to be regarded as common property which every individual had a natural right to use (GOI, 1987). The independent government came to view irrigation not as a commercial venture but as a form of welfare. This had three consequences:

- The government made an effort to spread irrigation to as many farmers as possible leading to heavy demand on the systems.
- Water rates were kept low, leading to inadequate revenues for operation and maintenance.
- Power to manage irrigation became more centralised in the state level bureaucracies and political entities. The powers of the field level officers were gradually reduced making it more difficult for them to control the system effectively and punish farmers who abused the system.

Consequently, farmers began paying less attention to filing applications for water knowing that if the monsoons failed they could always pressurise the government to supply water. To execute their jobs without adequate powers, field staff, including the *sattadars*, started harassing farmers. The situation eventually became unmanageable and the government abolished the *satta* system in 1974.

Under the system introduced in 1974, farmers are not required to make applications for water. Instead, areas within the commands have been designated areas of 'assured irrigation'. Farmers within the areas of 'assured irrigation' have the right to take water from the canals whenever it is available. Canal officers are responsible for preparing water schedules and informing farmers which canals are open and for what duration. Water distribution below the outlet remains the responsibility of the farmers, but the position of the *sattadar* has been abolished. Water rates are assessed on all land within the 'assured irrigation' area whether or not the land is irrigated.

This system has not been a success. Since permits are not required, there is no definition of unauthorised irrigation. Thus farmers in the upper areas can take as much water as they want irrespective of the needs of those lower down the system. In addition, the weak financial and managerial powers of the canal officers encourage abuse of water by farmers and reluctance by officers to visit the canals.

Therefore, for some time, there has been discussion about changing the law and policy, as well as some experiments. Also, Bihar constituted an Irrigation Commission to review policies, laws, actions, and other items. The Commission issued its report in six volumes in 1994 (GOB, 1994). The Commission recommended some major changes, including: a) abolition of the 'assured irrigation area' principle; it recommended requiring farmers to apply for water each season and then only charging water rates for farmers who apply, b) giving more operations and maintenance responsibilities to organised farmers.

CONJUNCTIVE MANAGEMENT IN THE VBC COMMAND

Both surface and ground water are used by farmers in the VBC Command to supplement rainfall. However, canal water is available only in part of the VBC command and also where available it is unpredictable. Water lifted from the Baya River and other drains is important to farmers in some areas. More importantly, good quality ground water is available at shallow depths everywhere and is used to supplement or replace canal water when rainfall is insufficient. The focus of conjunctive management is the individual farm. Only individual farmers have some control over which source of water they use. The key question then is: How do farmers decide what source of water to use for irrigation?

Sources of Irrigation Water

To understand how farmers use the different sources of irrigation water, we traced the sources of irrigation for the individual fields in the study area by questioning them. They were questioned on the four crop seasons: kharif 1991, rabi 1991–92, summer 1992, and kharif 1992. This led to the fact that farmers use the following terms for sources of water:

- Rain: where for a particular irrigation, a field has been entirely watered by timely rainfall.
- Canal: where a field has been irrigated entirely by canal water for a particular irrigation.
- Tubewell: where a field has been irrigated entirely by tubewell water for a particular irrigation. For this discussion no distinction is made between irrigation from the farmer's own tubewell or from someone else's tubewell.
- Canal and Rain: where for a particular irrigation, a field has been partly watered by timely rainfall and partly irrigated by canal water.
- Canal and Tubewell: where for a particular irrigation, a field has been partly irrigated by canal water, and partly with water from a tubewell.

Less important sources include: a) Dugwells, b) Hand pumps installed on a tubewell, c) Treadle pumps installed on a tubewell, d) Flooded fields: i.e. fields filled with rain water which remain over an extended period. In addition to fields irrigated by these methods, fields with unirrigated crops and fallow fields were also identified.

Sources of Water in Kharif

Paddy is by far the most important crop during kharif, in part because of the heavy rainfall in most years. Since it is the main food crop, farmers try to ensure good yields. Farmers in the study area overwhelmingly cultivate a long age paddy variety, known locally as Aghani paddy. They generally sow the seedbeds in June and harvest in November, unless delayed by lack of water at the beginning of the season.

During kharif season, paddy cultivators mainly use four sources of water: rain, canal, tubewell, and the combination of rain and canal. Tables 4, 5, and 6 show how the individual fields were watered in the three sample minors during kharif 1991. Since the farmers describe plant water needs in terms of 4 irrigations, sources of water for each of the four essential irrigations have been identified. In these tables, 'unirrigated' refers to cultivated fields that contain perennial or other crops that generally do not require human intervention for water. Kharif 1991 was considered a low rainfall season.

Chakwa Minor: As shown in Table 4, in Chakwa Minor the first irrigation depended largely upon rainfall. The first irrigation is very important for establishing the crop in the field. Canal irrigation at the beginning of the season is quite unreliable because farmers farther up the Gandak System use the canal water to establish their crops. Hence farmers depend upon rainfall - generally delaying sowing until the rains come - or tubewells.

Table 4: Chakwa Minor Sources of Water for Kharif 1991

Water Source	No. of Fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	83	88	102	41	24.7	24.4	36.0	15.0
Canal	3	16	47	109	0.8	3.3	10.7	31.3
Tubewell	56	48	7	1	21.4	20.7	3.0	0.9
Canal+Rain	14	4	-	7	2.3	0.8	-	3.2
Unirrigated	8	8	8	6	5.0	5.0	4.5	3.8
Totals	164	164	164	164	54.2	54.2	54.2	54.2

For the second irrigation in kharif 1991, the pattern was similar to that of the first irrigation. For the third irrigation, however, use of tubewell use dropped greatly as canal use rose. Canal use rose to a peak for the fourth irrigation. This change occurred because canal water became available late in the season when farmers further up the Gandak System harvested their crops. Generally, farmers in Chakwa Minor plant and harvest 2-3 weeks later than those further up the system so that they get some canal water.

Madan Chapra Minor: Table 5 shows the kharif 1991 pattern for Madan Chapra Minor. One feature immediately visible is that fields are smaller in Madan Chapra Minor than those in Chakwa Minor or, in Shampur Minor. Also tubewell water was used only for the first irrigation, rather than for the first and second irrigations as in Chakwa Minor. Compared to Chakwa Minor, there was greater use of canal water in

Madan Chapra Minor after the first irrigation. During the second and subsequent irrigations, Madan Chapra canal water users got together and assured water delivery to the minor. Farmers said, "Whenever there is a problem in canal water flow, some of us, usually youths, get together and argue with the upper reach villagers. We also fight sometimes, and bring water to our village. In fact, we have to monitor the water both during day and night for two days at least."

Table 5: Madan Chapra Minor Sources of Water for Kharif 1991

Water Source	No. of Fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	321	50	50	-	43.1	11.0	11.1	-
Canal	51	14	1	350	8.9	1.6	0.1	46.9
Tubewell	41	-	-	-	8.7	-	-	-
Canal+Rain	2	350	363	7	0.3	48.2	49.7	1.5
Other*	2	2	-	-	0.6	0.6	-	-
Unirrigated	21	22	24	81	1.9	2.1	2.6	15.1
Totals	438	438	438	438	63.5	63.5	63.5	63.5

* This includes two treadle pumps.

Shampur Minor: In Shampur Minor, as shown in Table 6, the pattern of use during kharif 1991 was similar to the pattern in the other two minors during the same season, except: a) Shampur Minor farmers depended much less upon canal water than did Madan Chapra farmers, b) a very large number of fields in Shampur Minor are planted with unirrigated crops. Shampur farmers consider both rainfall and canal water very unreliable; tubewell water is considered costly, particularly for the water-loving paddy. Hence, there has been a massive shift to crops that do not depend upon irrigation. Overall, the area planted with paddy is relatively small.

Table 6: Shampur Minor Sources of Water for Kharif 1991

Water Source	No. of Fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	69	31	48	3	15.4	7.1	10.4	0.4
Canal	16	9	11	38	3.3	2.3	2.7	8.7
Tubewell	1	2	-	-	0.2	0.3	-	-
Canal+Rain	3	20	14	5	0.6	4.4	2.8	1.0
Other*	-	-	1	1	-	-	0.1	0.2
Unirrigated	111	138	126	153.	32.7	38.1	36.2	41.9
Totals	200	200	200	200	52.2	52.2	52.2	52.2

* This includes one case of canal plus dugwell and one case of canal plus tubewell.

Observations on Kharif Sources of Water

Overall, the following observations can be made about kharif irrigation in the sample areas:

- During kharif season more farmers depend upon rainfall than upon any other source of water, even though paddy is the dominant crop.
- Because canal water is unavailable during the early part of the season when upstream farmers are establishing their crops, farmers in the study area often delay sowing and transplanting while waiting for heavy rains. This means that their schedule is 2–3 weeks later than upstream farmers.
- The second most important source of water during kharif is canal water, particularly during the fourth irrigation. Canal water is important for the fourth irrigation because rainfall has dropped during that period. More importantly, canal water is available late in the season because upstream users no longer need it, since drying and harvesting of their paddy crop would have begun.
- Dependence upon groundwater is low during kharif. Some farmers use tubewells for the first irrigation to establish their crops. Only the Chakwa Minor farmers were willing to use tubewells later in the season and that too only for the second irrigation.

Sources of Water in Rabi

The main crop in rabi season is wheat. In the study area, wheat is sown after the paddy harvest in December. Most fields remain moist even up to the middle of December. Ideally wheat is sown by the end of November. As pointed out earlier, farmers feel that wheat should have four irrigations but generally provide fewer, often only two irrigations. This is particularly true for wheat sown late, sometimes as late as early January because of delays in paddy cultivation. Tables 7, 8, and 9 show the sources of water used by farmers in the sample minors for rabi 1991–92. For wheat cultivation, farmers mainly use three sources of water: rainfall, canal water, and tubewell water.

Chakwa Minor: The pattern of water source use in Chakwa Minor during rabi 1991/92 is shown in Table 7. This table shows that a) a number of fields were left fallow (about 18%), b) an equal number were flooded during the rainy season - these were planted with a special paddy variety, c) a similar number of fields (around 28%) depended upon rainfall and tubewells for the first two irrigations, d) farmers did not use canal water to any signifcant extent until the last two irrigations, e) during the last irrigation, farmers used canal water in place of tubewell water.

Table 7: Chakwa Minor Sources of Water for Rabi 1991/92

Water Source	No. of Fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	45	51	60	61	12.7	15.4	18.7	25.4
Canal	3	5	14	39	0.8	1.4	3.6	10.8
Tubewell	50	41	24	1	21.4	17.2	12.4	0.9
Canal + Rain	-	-	-	-	-	-	-	-
Other*	29	29	29	29	5.3	5.3	5.3	5.3
Unirrigated	8	9	8	5	3.3	4.2	3.5	1.1
Fallow	29	29	29	29	10.7	10.7	10.7	10.7
Totals	164	164	164	164	54.2	54.2	54.2	54.2

* *All of these fields are flooded fields.*

A trend in the decreasing use of tubewells can be seen throughout the season. During the fourth irrigation, canal water was available at the right time, hence it was preferred to the more costly tubewell water.

Madan Chapra Minor: Table 8 shows the pattern of use of sources in Madan Chapra Minor during rabi 1991/92. This pattern is very different from that in Chakwa Minor. In Madan Chapra Minor: a) there were no fallow or flooded fields, b) for the first three irrigations, a large and increasing number of fields (46% – 58%) could be irrigated from canal water, c) tubewell use dropped from 27 per cent during the first irrigation to 4 per cent of the fields by the fourth irrigation as farmers replaced costly tubewell water with canal water, d) few farmers actually gave a fourth irrigation. Much of the area was planted with late sown wheat which need fewer irrigations. Late sowing of wheat was common because during kharif 1991, many farmers waited for rain to sow their paddy.

Table 8: Madan Chapra Minor Sources of Water for Rabi 1991/92

Water Source	No. of Fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	1	1	-	-	0.4	0.1	-	-
Canal	200	249	252	9	23.9	31.6	32.5	1.4
Tubewell	119	64	33	18	21.9	14.7	7.6	3.9
Canal + Rain	-	-	-	-	-	-	-	-
Other*	2	1	1	2	0.5	0.1	0.2	0.3
Unirrigated	116	123	152	409	16.8	17.0	23.2	57.9
Totals	438	438	438	438	63.5	63.5	63.5	63.5

* This includes 2 treadle pumps (first irrigation only), and four cases of canal plus tubewell.

Shampur Minor: Table 9 shows the sources used for irrigation in Shampur Minor in rabi 1991/92. This table shows that: a) just as in kharif, the major part of the area was sown with crops, mostly fruit or timber trees, which need little irrigation, , b) canal water use was very marginal throughout the season, c) tubewell use decreased over the season, d) unirrigated fields increased over the season as some short duration crops (vegetables) were harvested, e) there were no fallow fields.

Table 9: Shampur Minor Sources of Water for Rabi 1991/92

Water Source	No. of Fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	19	28	1	-	3.8	5.5	0.2	-
Canal	6	1	-	5	1.1	0.2	-	0.9
Tubewell	13	5	3	-	3.3	1.3	0.6	-
Canal+Rain	-	1	-	-	-	0.3	-	-
Other*	8	4	4	4	1.5	0.9	0.9	0.9
Unirrigated	154	161	192	191	42.5	44.0	50.5	50.4
Totals	200	200	200	200	52.2	52.2	52.2	52.2

* This includes 4 plots irrigated from dugwells throughout the season and two plots irrigated from canal plus tubewell at the first irrigation.

Observations on Rabi Sources of Water

Overall, this data indicates the following:

- As expected, rainfall alone is less important than during kharif. However, it provides the needed water for a fair number of fields, at least for two of the minors.
- Canal water was important only for one of the minors. It was the only one with reasonably abundant water supplies during rabi. This suggests that even farmers in the other two minors would make greater use of canal water, instead of depending on rain, if it were available.
- Groundwater is more important in rabi than in kharif. However, tubewell use decreases over the season.

Farmers consider the first irrigation very important. However, canal water supplies are low because farmers upstream in the system want the water for the same purpose. Hence many farmers in the sample area use tubewell water. Over the season, farmers turn to cheaper sources of water (rainfall and canal water) or do without in order to keep their production costs low.

Low Use of Groundwater: Groundwater is used far less than would be possible. Since yields are low, it would appear that more use of groundwater would improve farmer incomes by raising yields. However, the low use of groundwater is caused by the high cost of pumping. We consider the use of groundwater for both paddy and wheat cultivation to demonstrate this point.

Groundwater and Kharif Paddy Cultivation: To understand the value of groundwater, we have to consider the costs and benefits of pumping. We first note that almost all the water requirements for paddy (c. 1200 mm) can be met if rainfall is average and timely. That is, a paddy crop can be grown in North Bihar without irrigation. Irrigation of paddy serves primarily to assure water is reached at the right time.

We will consider costs and benefits of groundwater irrigation using figures given by farmers per *katta* which is the standard land unit in the area.[8] The total per *katta* cash cost was Rs 140. His yield (after deducting harvest and threshing costs) was 25 kg per *katta* and the price was Rs 10 per kg. Therefore, the per *katta* return to his family labour and his capital, without considering irrigation costs, was: (Rs10 x 25) - Rs140 = Rs110. Farmers estimate that it takes an hour of pumping to irrigate one *katta* of paddy. If a farmer had to pay Rs40 per hour (the price that this farmer said he tried to charge others for the use of his tubewell), each irrigation lowers his returns by 36 per cent.

In fact, however, this farmer pointed out that his 1998 yield was low; in kharif 1997 he got 80 kg per *katta*. That was a very high yield. A better estimate of a normally expected yield is about 40 kg per *katta* (2.4 tons per hectare). At that yield, and using the reported costs, the farmer's return, without including the cost of irrigation is: (Rs10 x 40) - Rs140 = Rs360. In this case, each irrigation by pumping groundwater would lower returns by only 11 per cent, which, however, is still considered significant by farmers. If four irrigations were given, this would lower returns by almost half.

A second consideration is the cost of pumping. Rs40/hour (or Rs50/hour in some areas) is the 1998–99 cartel price of pumping. In fact, many water buyers pay less. This same farmer estimates that he averages Rs28 per hour from his buyers. At that rate, and using the

8. There are 24 katta per acre or 60 per hectare. In May 1998, one farmer in Madan Chapra Minor gave us the following per katta figures from 1998. Cost of a) plonghing and levelling the field: Rs 80, b) transplanting: Rs 50, c) seed: nothing, used his own seed, d) fertilizer: Rs 10, e) mid-season labour: nothing, used family labour, f) harvesting and threshing: deducted from yield so not counted.

expected yield of 40kg per *katta*, the cost of one irrigation by pumping is only 7 per cent of the returns. With our estimated operational cost of Rs21.43 per hour (which does not include depreciation and is probably a little low), the cost of each irrigation is only 6 per cent of the returns. However, even at that cost, giving four irrigations from groundwater would cost about a quarter of the returns to farming.

Thus, even tubewell owners provide all four irrigations by tubewell water to very few fields – just enough to provide rice for home consumption – even if rainfall and canal water fail. In all three sample minors, only one field during kharif 1991 and two during kharif 1992 were irrigated all four times from tube wells.

Another key consideration is the nature of the land. Basically, land in the VBC area is classified by farmers into two types: ordinary land and *chaur* land. The latter is land that is waterlogged or flooded during kharif and well into rabi seasons. There are large areas of *chaur* land in these villages; in our informant's village almost half the land is considered *chaur* land. Farmers cannot plant high yield rice varieties in *chaur* land.

Finally, as pointed out earlier, 60–70% of the farmers are sharecroppers who get only half the crop but who have to pay the full cost of cultivation. For them, the cost of pumping is doubled. During kharif 1992 – a 'drought' year – some sharecroppers abandoned their paddy crops saying that the cost of more than two irrigations from tubewells made the total cost of production greater than the potential earnings from the crop. Pumping is thus expensive, particularly when compared with rainfall, which is free, and with canal water, for which farmers have to pay a small amount even if they do not get any.

Groundwater and Rabi Wheat Cultivation

The reasons for low use of groundwater for rabi wheat cultivation are similar to those for low use of groundwater for kharif paddy cultivation. However, the average rabi rainfall is only about 53mm, far below the crop water requirement of 250mm. While residual soil moisture makes up some of the difference, unlike paddy in kharif, irrigation is essential to produce a rabi wheat crop.

A Madan Chapra Minor Farmer discussed in the previous section also gave us a rundown on rabi wheat cultivation. He listed his 1998–99 per *katta* costs, excluding irrigation.[9] His total per katta cash income was

9. Costs as follows: a) seed (2 kilograms): Rs 20, b) Fertiliser (see below): Rs 67.50, c) Ploughing: Rs 50, d) Labour during the season: No cost, used household labour, e) Harvest costs: Deducted from harvest. The 1999 sale price of wheat was Rs 6 per Kg and he got about 55 kg of wheat per katta (perhaps a bit higher than usual).

Rs330; his total per *katta* costs, excluding irrigation, were Rs137.50; a total per katta return to labour and capital was Rs192.50. According to the farmers, it is possible to irrigate a *katta* of wheat with half hour's pumping. Therefore, the cost of each irrigation and the percentage of the returns are:

- At Rs40 per hour (cartel price): Rs20 and 10 per cent
- At Rs 28 per hour (average price): Rs 14 and 7 per cent
- At Rs 21.43 (operational cost): Rs 10.72 and 6 per cent

For the usual two irrigations, the cost of irrigation for a landowner is only 12–20 per cent of his return. This is clearly worthwhile, given that farmers believe that without the first irrigation the yield would be reduced by half and that the second also should not be done away with. Farmers do not believe that the third and fourth irrigations contribute so much to the yield and can, given occasional strong winds later in the season, contribute to lodging. Thus, they are rarely willing to pay pumping costs for the second and third irrigations. However, as shown earlier, Madan Chapra Minor gets some canal water during rabi, particularly toward the end of the season, so that some farmers will give a third or fourth irrigation from the canal.

A Shampur Minor Farmer gave us a detailed breakdown of his costs and returns. This was in a group interview and the others noted that, except for certain specific features of this man's holdings, the example is representative. Our informant gave the per *katta* costs, excluding irrigation.[10] His production was 38 kg of wheat per *katta*. The farmers, after discussion decided that the normally expected yield is only about 30 kg per *katta* so this is better than the expected figure. Thus, his total return to labor and capital, excluding irrigation costs, was: (Rs6 x 38) - Rs 24 = Rs228. The irrigation costs for irrigation and percentage of returns at the various prices would be:

- At Rs50 per hour (cartel price): Rs25 and 11 per cent
- At Rs30 per hour (average price): Rs15 and 7 per cent
- At Rs21.43 per hour (operational cost): Rs10.72 and 5 per cent

For the usual two irrigations, then irrigation costs the farmer 10–22 per cent of his returns. Of course, it costs the sharecropper a much higher portion. It would be unreasonable then for the farmer to irrigate more than twice unless his yields were much higher. In Shampur Minor,

10. Costs excluding irrigation are: a) seed: No cost, used own seed, b) Fertiliser (see below): Rs 24, c) Plonghing: No cost, used own animals, d) Labour during the season: No cost, used household labour, e) Harvest costs: Deducted from harvest.

however, unlike Madan Chapra Minor, canal water is rarely available in rabi and does not offer an alternative. As with irrigation of kharif paddy, pumping groundwater is thus considered an expensive way to get irrigation water for rabi wheat.

Irrigated Agricultural Strategies in the VBC Command

Low yields are a major reason that the cost of groundwater irrigation forms such a large fraction of farmers' returns to their labour and capital. However, except in *chaur* areas, the soils and climatic conditions are excellent in North Bihar. Low yields thus are a product of choices made by the farmers. The per *katta* amounts of fertiliser reportedly used in these three cases were:

- Madan Chapra Minor farmer for paddy: 2 kg urea
- Madan Chapra Minor farmer for wheat: 5 kg diammonium phosphate, 2.5 kg urea, and 0.5 kg potash; given in three applications
- Shampur Minor farmer for wheat: 2 kg diammonium phosphate, 1 kg urea, 1 kg potash, and a little zinc

These are low amounts, particularly for paddy. They indicate that the farmers have adopted a low-input low-yield strategy. In the 1992–93 study, the great majority of farmers operated on such a strategy. In our 1999 interviews they gave us the following reasons for this strategy:

- Getting good seed is costly and difficult because it is not available locally.
- Fertiliser is available locally, generally not from government sources, but only from private sources. All the farmers feel that private fertilisers are adulterated as well as more expensive than those obtained through the state government.
- Sharecroppers get such small returns that they carefully monitor every cent of expenditure and thus maintain low costs.
- Cash flow is a problem and farmers often lack cash to purchase larger amounts of fertiliser.
- There are other problems related to social conditions. In May 1999, two farmers told us that some of their fields were harvested at night by others and that, although they know who did it, they are afraid of being beaten or killed if they protest.

At least some farmers are aware of alternative farming strategies. One of our informants mentioned that he had tried high quality wheat seed one season which he had to get from Patna, the state capital. They gave excellent yields. The others indicated that with better fertiliser, for which they would have to use more water, they could get significantly better yields. However, in the present circumstances, they feel they cannot adopt such strategies.

Installing a Private Tubewell

Given that groundwater is a costly form of irrigation, even for a well owner, the question of when a tubewell is a good investment arises. Farmers told us that, at present, installing a new tubewell costs about Rs100 per foot for drilling, pipe, and fittings. Assuming that a farmer installs a new 60 foot tubewell without subsidy, it will cost him about Rs6000. An used pumpset will cost somewhat over Rs5000 for a total cost of Rs11,000. Assuming a 20 year life span, the capital cost of the well is Rs550 per year.

Let us assume that having the reliability of a groundwater supply there is an increase in paddy yields by 100 per cent-i.e. from an expected yield of 20 kg per *katta* to the presently expected yield of 40 kg per *katta* under the present low-input low-yield farming strategy. Let us also assume that a farmer would get no wheat crop without irrigation; thus all of the expected 30 kg per *katta* yield depends upon the presence of groundwater irrigation facilities. Using 1998–99 prices, this means that, for each *katta*, a tubewell would increase a farmer's cash revenue by: (paddy: Rs10 x 20) + (wheat: Rs6 x 30) = Rs380. Assuming two irrigations from ground water per season, the operating costs of the tubewell would be: (paddy: Rs21.43 x 2) + (wheat: Rs10.72 x 2) = Rs64.29 leaving an annual profit of about Rs316 per *katta* from the crops irrigated by the tubewell. Based on these figures, installation of a tubewell would be valuable for any farmer who owned at least 2 *katta* of good (i.e. not *chaur*) land.

Presently, since wells are not rare, the cost of buying a tubewell has to be weighed against the cost of purchasing water in the market. Even at a cost of Rs50 per hour (the cartel price quoted to us in Shampur Minor), the cost of giving two irrigations to each crop is only Rs150 per *katta* and thus well below the value of the additional crops. There is a third alternative, namely to plant tree crops and others that do not require irrigation (in part because of the high water table). As mentioned earlier, this is a strategy being adopted by a significant number of farmers in the Shampur Minor area because their access to cheap canal water is so bad.

Thus, while farmers want tubewells, presently they are not essential since farmers have alternative sources of water, including groundwater, and alternative cropping strategies that do not require irrigation. A big problem is cash flow. Many farmers find it very difficult to gather a lump sum needed to purchase a tubewell. Government subsidy programmes thus appear to be important not only because they lower the cost of well installation and purchase of pumpsets, but also because they allow payment over time. However, the transaction costs of getting a subsidy (farmers told us that needed bribes can cost Rs 3000 to 4000) may make it difficult to purchase a well even if one is eligible for a subsidy.

A final consideration is the benefit from selling water. Most farmers who instal a tubewell hope to sell water, at least enough to cover the costs of irrigation of their own land. However, as we have pointed out earlier, selling water is not without its troubles, particularly collection of fees, and some well owners prefer not to try. Data seem to suggest that no farmer will get rich by selling water, although another study in the same area (Shah and Ballabh, 1997) suggests that tubewells are generating significant wealth for the owners.

PERFORMANCE OF CONJUNCTIVE MANAGEMENT

Water Distribution Performance: Earlier, we documented the problems with canal management that make canal water unreliable and even unavailable to many farmers in the VBC command. Water from tubewells and from river lift pumps (where available) is highly reliable and distribution is not particularly problematic, partly because of the availability of pipes to help in distribution.

Conjunctive management in the VBC area consists of the use of tubewells (and river lift) to supplement rainfall and canal water. Tubewells are needed largely because canal water is not only unavailable in all parts of the command, because of failure to complete construction and other reasons, but also canal water is unreliable. Indeed, for many, canal water is less reliable than rainfall. On the other hand, because of social and economic conditions, farmers have adopted a low-cost low-yield farming strategy that leads them to minimise costs. In so doing, they attempt to minimise pumping of groundwater in favour of dependence on rainfall and canal water, or in favor of no irrigation. Thus, while installation of a tubewell is valuable, operation of that tubewell will be minimised. Hence, conjunctive management is a reasonable but expensive way to assure decent water distribution in the area.

Agricultural Production: We have no way to evaluate the total production of the VBC area. The sole criteria used to evaluate agricultural production in the area depends on the reported yields. Yields are low.

The yield reported in the case of the Madan Chapra Minor farmer for paddy was only 25 kilograms per katta or 1.5 tons per hectare. His yield for wheat, however, was more respectable - 3.3 tons per hectare. The Shampur Minor farmer's yield for wheat was only about 2.3 tons per hectare. These yields agree well with those reported for Bihar state as a whole. However, the low level of production is not due to failure of conjunctive management, but rather due to social and economic problems.

Environmental Management: The most important environmental problem associated with irrigation in North Bihar is waterlogging. About 900,000 hectares in Bihar suffers from waterlogging; of this nearly 800,000 hectares lie in North Bihar. Most of this is in the command areas of the Eastern Gandak, Kosi, and Western Kosi Irrigation Systems. The main causes of waterlogging include:

- high intensity of rainfall with deficient drainage capacity,
- inadequate drainage of surface water due to unfavourable drainage conditions,
- obstruction in the drainage channels by construction of fish barriers, bunds, etc.

As mentioned earlier, in two villages, one under Madan Chapra Minor and one under Shampur Minor, farmers claim that 50 per cent of the land is chaur land. Under Chakwa Minor, there are significant amounts of land that flood every monsoon season. Construction of the surface system has aggravated waterlogging in some areas. Along certain reaches of the canals, earth was removed from borrow pits to form bunds; many of these flood regularly during the monsoon. This is the primary problem in the Chakwa Minor area. In other areas, seepage from the canals adds to the already high water tables and increases the chaur areas. However, farmers believe that the biggest problem associated with the canals is that they have blocked whatever natural drainage there was, thus increasing waterlogging.

A comprehensive plan for removing drainage congestion of North Bihar has been prepared and the Water Resources Department has taken up some schemes in the Gandak and Kosi Command areas. Another plan on Integrated Drainage Project has been submitted to the Central Government Planning Commission to benefit 250,000 hectares. It has been suggested that promotion of ground water irrigation could help resolve some of these problems (e.g. CWRS, 1993). However, given the limitations on pumping caused by the social and economic conditions in the area, it seems unlikely that tubewells will solve the problems.

OPPORTUNITIES TO IMPROVE THE RESULTS

As expected, the basic finding is that in the Vaishali Branch Canal command of the Eastern Gandak Irrigation System in North Bihar, conjunctive management of surface water and ground water for irrigation is being effectively carried out by individual farmers subject to several major constraints, like:

The surface water is taken from the Gandak River and is carried in a canal system. However the physical design and condition of the canals and defects and problems with the management of the canals by the Bihar State Water Resources Department and the Gandak Command Area Development Authority make canal water unreliable and canal irrigation ineffective and problematic in the study area.

Groundwater is plentiful and is available at shallow depths all year round. Also, with help from government subsidies, there has been massive development of tubewells to exploit this groundwater both in the VBC command and elsewhere in North Bihar. However, the usefulness of these tubewells is severely constrained by the economics of farming in North Bihar and by social conditions that induce farmers to follow a low-cost low-yield farming strategy.

Thus while conjunctive management makes water available to all who want it, whenever they want it, either from their own wells or from the water market, both supplementing rainfall and canal water, it does not lead to high levels of agricultural production or high levels of profitability for farmers. Also, the presence of the canals aggravate waterlogging problems in some areas while the limitations on pumping fail to reduce them. This analysis suggests the following opportunities for action to make conjunctive management more useful:

Conjunctive Management at Government Level: The canal system is a major source of water, but, unlike the tubewells, it is not under the control of the water users who alone carry out conjunctive water management for irrigation. In order to provide improved conjunctive management, there is a need to get the government agencies to take cognisance of conjunctive management. At the moment, there is no such cognisance. In the Gandak Command and in the other major irrigation systems, there is no coordination between the Water Resource officers and the Minor Irrigation officers. Staff receive orders from their respective heads and provide information to their heads. Decisions are taken independently, even though their functions are mutually dependent on the same resource base. An Executive Engineer, who has worked in both the Departments, reported, "They (the field officers) are supposed to work according to the earlier guidelines from above and are answerable only to vertical hierarchies."

The Minor Irrigation Department staff are organised on the basis of administrative boundaries (blocks and districts). Canal irrigation staff are organised according to hydraulic boundaries. Within many branch canal commands, there are large areas, like the Vaishali Branch Canal Command, that are under both surface and groundwater irrigation. Without some common basis, however, the officials in the separate departments have difficulty in cooperating.

The State of Bihar has no clear-cut policy guidelines for effective conjunctive use. Its executive agencies – the Water Resources Department (WRD) and the Minor Irrigation Department (MID) – have not spelt out the vision and action plans on a conjunctive use. Promoting conjunctive use is listed as a major function of the state Command Area Development Authorities. In practice, however, little attention has been paid to it. Worse, no state agency is monitoring the use of ground water effectively in canal systems, so that there is not only no policy but no decent information about conjunctive water use.

Recently, there has been a movement toward development of a policy. Following recommendations from the Government of India, the Minor Irrigation Department has decided to allow the installation of state tubewells within canal commands to serve areas where it is difficult to push the canal water. However, this is a very small step, particularly since the state tubewells provide a relatively small portion of the groundwater for irrigation and because they have extensive operating problems.

The Second Irrigation Commission (GOB, 1994) did no more than issue a statement that conjunctive management should be practised, without considering how to do so. Their report is almost exclusively focussed on canal irrigation. However, they did strongly urge consideration of management of water resources by basins.

Management by basins would resolve one of the current major problems, the separation of state power over water for irrigation into two independent departments: the Water Resources Department and the Minor Irrigation Department. This separation means that the personnel in neither department know about the full range of water resources being used in any one area and thus they plan investments and interventions without taking these other water resources into account.

In our opinion, it is best to keep conjunctive management for irrigation in the hands of the farmers. However, the state can provide support to the farmers in the following ways:

By monitoring and providing information on all water resources in a manner that makes all the relevant information available through a single source; i.e., data from the monitoring of ground water done by the Minor Irrigation Department (supplemented by monitoring information provided by the Central Ground Water Board) should be reported on the same basis as data from monitoring use of surface water and should be available from a single agency.

- By finding effective ways to give farmers power to jointly manage the canal systems with the government agencies.
- By providing effective support for agricultural development, including subsidies for tubewell installation, to enable farmers to make better use of groundwater resources.

An earlier study (Raju et al., 1994) on groundwater use in the Gandak Command area concluded that, there is no capacity to manage total water resources equitably, sustainably and efficiently. Distributing the same amount of surface irrigation water to areas differing in availablity of groundwater, may be neither equitable nor efficient. Within the Eastern Gandak Command, the high water table means that large areas are susceptible to waterlogging and damage from salinity and alkalinity. Neither threat can be controlled without a more coordinated effort at management of all water resources. The lack of conjunctive management at the group level in an environment of extensive conjunctive use at the individual level is somewhat like having two cooks preparing parts of the same meal; from the same limited food supply source, but without any communication, about how much of the food stock the other is using nor what type of food, nor how much of it, the other is preparing (Raju and Vermillion, 1993)

Conjunctive Management to Reduce the Waterlogging: As already pointed out, waterlogging is a major problem in North Bihar. Almost all recommendations to deal with waterlogging have focussed exclusively on improving drainage. Clearly, improved drainage is essential in North Bihar. However, properly conceived conjunctive management could play a part (cf CWRS, 1993). The theory is simple: farmers should pump their irrigation water in areas where there is value in lowering the water table. Lowering the high water table over the whole area would help in general. One could argue that it was a mistake to build canal systems in North Bihar.

However, given the present existence of the canal systems and the fact that, to farmers, they provide less expensive irrigation water than do tubewells, there is a demand for canal irrigation. The problem then has two dimensions:

- To determine and enforce the optimal pattern of providing canal water so that it does no harm.
- To develop means to encourage farmers to pump groundwater for irrigation in areas where pumping will help reduce waterlogging.

The difficulty of the latter concern is obvious: farmers prefer cheaper water when it is available. The solution lies in institutions that allow farmers to spread the costs of irrigation over both sources so that all can be served more or less fairly at similar costs. This implies that canal water rates should be raised significantly – probably possible only if canal performance is improved - and some of the funds used to subsidise groundwater irrigation in areas where pumping is desired. While this is a major institutional development problem, it could conceivably be done since similar cost and benefit sharing arrangements exist elsewhere.

Conjunctive Management for Poverty Alleviation: Although often discussed (e.g., Kahnert and Levine, 1993), this analysis suggests that the use of groundwater for irrigation, either alone or conjunctively with surface water, is not likely to serve as an engine of rural economic growth in the immediate future although it has that potential. The constraints are not water constraints: they are political, institutional, social, and economic. However, if better conjunctive management can resolve the waterlogging problem, it will certainly raise output and provide some help for the rural poor.

Ultimately, however, the state must address the underlying social and economic conditions that keep farmers from expanding their output. Examples of such reforms would be: a) Land or other reforms that reduce the percentage of sharecroppers; b) Improvement in security so that farmers need not fear theft of their crops or other such disturbances. Without such improvements, working on conjunctive management is likely to have only marginal effects.

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