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9. ABSTRACT

Two programs which attempted to improve water use and management in eastern India supported the proposition that more funds should be spent on upgrading existing systems in contrast to beginning large, new irrigation projects. Improvement took the form of new field channels in existing flood irrigation systems. The Sambalpur area project realized a return of 300-350 rupees per acre for an initial investment of 34 rupees per acre. The Raipur area project had a much lower profit potential due to high investment costs. The need for technically trained persons and low-cost design is emphasized.

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Field Channels: A Key to Better Indian Irrigation

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Two different programs which attempted to improve water use and management were evaluated in eastern India. The improvement was through the installation of field channels in existing flood irrigation projects. The channels gave farmers better control over water on each field. The analysis highlights the importance of technically trained people and low-cost project designs in making projects viable. Annual net returns of 300–350 rupees per acre were obtained in the Sambalpur villages with investment costs of only 34 rupees per acre. The contrasting pilot project in Raipur had a much lower profit potential due to high investment costs. The analysis adds support to the proposition that India should spend more public funds on modest improvements in existing flood irrigation systems and much less on large new irrigation projects.

Sizable investments have been made in India to develop the irrigation potential. By 1968–1969 the net irrigated area was approximately 71 million acres, or about 21% of the net area sown. The 1968–1969 level of irrigation was 17% above the 1960–1961 level and 38% greater than in 1950–1951. There is wide variation in the type and quality of irrigation in India, with irrigated acreage fluctuating from year to year, depending on the quantity and timing of rainfall. Approximately only 8% of the irrigated area is under tube well irrigation, and 37% under government canals. The remaining acreage is irrigated by private canals, other wells, and small reservoirs [*Irrigation Commission*, 1972].

With the introduction of high-yielding varieties (HYV) of wheat and the increased use of fertilizer the returns to irrigation water increased sharply and led to a rapid expansion of private tube well irrigation, particularly in northwestern India. The later spread of HYV of rice and the continued population pressure and rising prices have pushed up the returns to irrigation even in many of the high rainfall areas of eastern India. Here the irrigation is used to supplement rainfall during the wet or monsoon season (June–December) and is necessary during the dry season (January–March) for the production of crops.

In eastern India, canal irrigation is dominant, with water flooding from field to field where farmers have little control over the flow of water. Once the water is in the main channel, the outlets are usually never closed, and so water flows continuously through the fields, and the water distribution is quite uneven. The continuous flow through ungraded terraces with different shapes and sizes of plots generally causes heavy percolation loss of irrigation water. In fact, water may not always reach those at the end of the service area or at the end of the canal. The main channels are provided by the government but those channels beyond the outlets are the responsibility of the farmers. If field channels are to be constructed, the farmer must build them. Yet without technical assistance and the agreement of the other farmers served by the same outlet, the individual farmers cannot construct the field channels. Thus field channels are almost nonexistent in eastern India [*National Commission on Agriculture*, 1973; *Williams*, 1970].

This article considers two different programs which attempt to improve water use and management in eastern India. One is located in the Hirakud project, which irrigates 282,000 acres in Sambalpur district of Orissa; the other is in Raipur district just west of Sambalpur in the state of Madhya Pradesh. Both programs attempt to improve the water use and management of existing irrigation by installing field channels to give farmers better control over water on each field. The main emphasis is on the Sambalpur case, since benefit data are not available for Raipur. The latter was included to bring out the importance of investment costs. The analysis highlights the importance of technically trained people and alternative project designs in making the projects viable [*Batra and Easter*, 1972; *Easter*, 1972].

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PROJECT DESIGN

In the case of Sambalpur the Intensive Agricultural District Program (IADP) staff introduced a program of installing field channels and demonstrating their use in two villages. The basic idea was to provide a small unlined channel from the canal outlet along the field levees to each farmer's plot, thus giving each farmer control over the flow of water onto his fields. Placing the channels along the levees minimizes the quantity of land taken out of production. Initially, a major extension effort was needed to get the approval of the entire village, since a few farmers living near the canal outlets could prevent the installation of the field channels by refusing to allow them to pass along or through their fields. After several villages were improved, other villages became interested, and village approval is now easier to get.

Once a village agrees to the program, IADP provides the technical assistance needed to design the complete village system and provides the materials (rock, concrete, and pipe) needed to install the field channels. Drop structures are required to prevent erosion in places where there are significant changes in elevation, and pipes are used under road crossings. The IADP staff also demonstrates the use of HYV, fertilizers, and pesticides and assists in maintaining the newly constructed village irrigation systems. The villagers contribute the labor for digging and maintaining the channels. At the time of this study in 1971, four village systems had been completed and nine more were in progress, while a number of others were waiting for assistance [*Easter*, 1973].

The Raipur project, a cooperative project between the Ford Foundation, IADP, and the State Agricultural College, is much smaller than the average Sambalpur project and involves only 26.6 acres in a small reservoir irrigated village. It included lining a 2000-ft main channel with bricks and cement as well as 10 ft of each of 10 lateral channels. Unlined field channels were constructed from the 10 laterals to each of the farmers' fields within the 26.6-acre project area. Two surface drains,

each 2500 ft long, were constructed to drain the excess water to a main drain running along the eastern boundary [*Ford Foundation*, 1969].

Cost of improvement. In India where most of the farm land is privately owned, irrigation improvement must be financially attractive to the farmers if it is to be widely adopted. If the cost is too high in relation to returns, the project will not spread. The expansion of tube well irrigation in northern India is an example of what can happen if profits are high from private irrigation investment. Of course, there are additional problems associated with improving flood irrigation which do not plague tube well irrigation. Foremost among these is the need to organize farmers and provide them with technical assistance. In the case of tube wells, one individual can make the decision to install irrigation, but improving a flood irrigation system requires a group decision within one village or several villages as well as the support of the Irrigation Department and the agricultural officials. In Sambalpur both the Irrigation Department and IADP were involved in providing field channels. The Raipur project had the support of IADP but was not fully supported by the Irrigation Department. In all cases the villages fully supported the projects.

The cost differences between the two projects is striking, with the Raipur project costing 902 rupees per acre as compared to an average of 34 rupees per acre in Sambalpur ($1 equals about 7.5 rupees). The cost breakdown of installing field channels, in rupees per acre, is as follows:

	Sambalpur	Raipur
Construction materials	10	564
Labor	6	225
Technical assistance	18	75
Other		38
Total	34	902

The total cost of the 26.6-acre Raipur project was 24,000 rupees, only 1000 rupees less than an average Sambalpur project which covered about 750 acres. The pilot nature of the Raipur project and the fact that it is a complete irrigation system with lined channels and drainage explain some of the difference. For the Sambalpur projects, costs were held to a minimum with the hope that drainage and the lining of some channels could be done at a later date, once the benefits from the field channels had been experienced by the farmers. Thus the Sambalpur projects represent a lower bound for the cost of improving village irrigation systems, whereas the Raipur project is approaching the upper bound.

The Sambalpur IADP divides the irrigation improvement into three stages: (1) approach and survey of interested villages, (2) installation of field channels, and (3) repair and maintenance of the field channels. Once the village has been selected, the IADP water management staff starts planning the field channel system from each canal outlet. The number of outlets is determined by the physical size of the village, since each outlet irrigates 25 acres or more. The IADP staff works with the farmers in deciding on the location of the field channels and helps install the necessary structures. The cultivators are required to dig the channels, which are generally 1 ft deep, 1½ ft wide at the base, and 2 ft wide at the top. Every year the field channels need repairs, at an estimated average cost of about 6 rupees per acre, while the land is being prepared for planting. On many of the smaller farms the labor for channel repair and maintenance appears to have a low opportunity cost. Thus the above estimates based on average wage rates may be high.

Another striking difference between the two projects, besides the cost per acre, is the capital labor ratios. The Sambalpur approach is less demanding of nonlabor inputs, particularly capital. Slightly less than 30% of the Sambalpur project costs are for construction materials as compared to over 62% for construction materials in the Raipur case.

Natural resources. The Raipur and Sambalpur projects are all in the rainfall zone, which generally permits the production of a wet season rice crop. The irrigation water supplements the rainfall and assures the production of a wet season rice crop, whereas during the dry season, crops cannot be grown without irrigation. When the rainfall is short, adequate water may not be available for the dry season.

For over 10 yr the Sambalpur farms have irrigated two crops of rice each year. Currently, the dry season crop is the more productive; insect damage has cut down on the use of HYV and has reduced production in the wet season. In contrast, the Raipur village is assured of only one rice crop, with a second crop being possible on a limited area every 2 or 3 yr.

The climate is not significantly different between the two areas. Both experience hot dry weather from April to June, followed by the monsoon, which brings heavy rains during June to September and sometimes extending into October. At least 90% of the rain falls during the monsoon and is critical for the wet season crop as well as for filling the reservoirs.

Sambalpur has four types of soils which are determined by the land slope. The upland soil is generally difficult to irrigate and is restricted to crops requiring less water than rice. The two middle-level soils are suited to growing most crops and produce a good rice crop when they are irrigated. The bottom land is the best rice-growing soil, but with the seepage caused by irrigation it is now restricted almost exclusively to rice production. Within the Raipur project there is only one type of soil, and it is suited to growing rice or other crops such as pulses, millets, or vegetables. In all cases, water is the limiting resource, not the soil [*Kumar*, 1972].

During the survey in crop year 1970–1971 the rainfall was adequate to grow a good crop of rice, and in addition, enough water was available to irrigate a dry season rice crop. Only one of the six villages surveyed in Sambalpur experienced a water shortage during the dry season, and all produced a second rice crop.

IMPACT OF FIELD CHANNELS

The only measure of the economic impact of the field channels is a comparison among Sambalpur villages, since the Raipur project was just being constructed during the survey in 1970–1971. Three types of Sambalpur villages were surveyed twice (once after each crop season) in order to examine the impact of the irrigation project currently and provide a basis for future study. The three types were (1) two villages with field channels (improved villages), (2) two villages where the channels were to be installed (improving villages), and (3) two villages which needed to install channels (control villages).

A random sample of 195 farms was taken from the six villages; it included slightly over 20% of the owner cultivators from each set of two villages. The farmers were interviewed right after each crop was harvested so that input and production information was still fresh in their minds. The sample was also drawn so that it was representative of small (3.5 acres and under), medium (3.6–7.5 acres), and large (above 7.5 acres) farms. The farm size was based on land holdings which included land rented in but excluded land rented out. Since owner cultivators accounted for almost all the land cultivated, the results are representative of the villages. The improved villages are compared with the control and improving villages to

TABLE 1. Distribution of Crops by Season for Sambalpur Villages 1970-1971

	Local Rice Varieties	HYV	Other Crops*
	Wet Season		
Improved villages	92	5	3
Control villages	94	1	4
Improving villages	90	6	4
	Dry Season		
Improved villages	27	72	1
Control villages	44	54	2
Improving villages	48	41	10

All values are given in percent. Percentages may not add to 100 due to rounding.
*Other crops included wheat, pulses, oilseeds, and vegetable crops.

measure differences in yields, input use, proportion of HYV, cropping intensity, area irrigated, and net returns, which all give an indication of the impact of the field channels on the village crop economy. Hopefully, at some later date the improving villages will be resurveyed to provide a measure of the impact of field channels over time.

The installation of field channels could increase the area irrigated and the cropping intensity within the village by improving the efficiency of water use through reduced overirrigation and reduced wastage of water near the outlet. Both seepage and surface evaporation losses would be reduced. Better control over the quantity of water applied would allow changes in the cropping patterns and improve the timeliness of both irrigation and other farming operations. Better control could also increase the use of nitrogen fertilizer by reducing the amount lost to flooding. The quantity of fertilizer lost due to flooding may be small but the belief that the fertilizer was being washed away reduced the fertilizer use in the control and improving Sambalpur villages. The more efficient application of water, by improving the production possibilities, could increase the returns from using HYV, fertilizer, and other inputs.

A note of caution should be observed in this comparative analysis. There are always subtle differences between villages which cannot be controlled. These differences, such as better leadership, can equip one village for economic improvement and not another. Thus some of the changes observed in the improved villages may be due to uncontrolled variables which are not duplicated in other villages and cannot be attributed to the field channels. However, adoption rates before and after the field channels were installed indicate that the villages had very similar potentials. In addition, the increased interest of other villages in the field channel program indicates that they think the benefits are real and transferable.

One indication of the project benefits was the farmer's response to questions concerning the improved irrigation. In the improved villages, 90% of the farmers surveyed reported receiving a more dependable water supply. In addition, 87% said that they had improved water control, and an equal number reported better utilization of fertilizer. Only 28% reported a reduction in flooding, but not all farmers had a flooding problem. Flooding on rice acreage usually occurred near the outlet. Finally, diversification of cropping did not take place, which interestingly, may be partly due to the more dependable water supply. In other words, with the more dependable water supply, farmers did not have to grow crops with lower water requirements.

On the basis of the limited amount of historical data collected for the improved villages, the cropping intensity and irrigated area did increase after the field channels were installed. The proportion of the village cropland irrigated went from 84 to 97%, and cropping intensity rose from 187 to 196%. (Cropping intensity is gross acreage of crops grown annually divided by net area of cropland.) The 1970–1971 irrigated areas in the control and improving villages were only 84 and 75%, respectively, and cropping intensities were 185 and 157%. The lower irrigated area and cropping intensity in the improving villages were due to the location of one village at the end of a main canal.

The proportion of rice grown was not significantly different among the villages except for the improving villages during the dry season (Table 1). This difference was due to a shortage of water in one improving village which forced farmers to grow crops with low water requirements. The acreage of high-yielding rice varieties was significantly greater in the improved villages during the dry season, 72% as compared to 54 and 41%. This is very important because the average yields of HYV are generally 4–5 quintals per acre more than the local rice varieties (Table 2). The proportion of HYV was not significantly different among villages during the wet season because of insect problems which almost eliminated HYV during the wet season.

Even within seasons and by varieties the improved villages had significantly higher rice yields. During the wet season the mean yields were 3 and 4.9 quintals per acre higher, whereas in the dry season the difference was 3.7 and 3.5 quintals per acre for local rice varieties. For HYV the yields were 4.8 and 3.6 quintals per acre higher in the improved villages.

As would be expected, the use of purchased inputs was also significantly higher for the improved villages. The difference in fertilizer applied per acre was 5 and 18 kg per acre during the wet season and increased to 20 and 31 kg per acre in the dry season for local rice varieties. The fertilizer applied on the HYV was 24 and 22 kg greater in the improved villages (Table 3). The other major annually purchased input, plant protection materials, exhibited similar differences in use.

RATES OF RETURN

If these differences in HYV, yields, and input use are translated into costs and returns, the improved villages have significantly greater net returns for both seasons. The net returns for the year were between 300 and 350 rupees per acre higher in the improved villages as compared to the improving and control villages. The net returns do not include anything for the additional acreage irrigated in the improved villages. Therefore the net return may understate the total village

TABLE 2. Mean Rice Yields by Season and Rice Variety for Sambalpur Villages 1970-1971

	Improved Villages	Control Villages	Improving Villages
Wet season local varieties	9.2	6.2	4.3
Dry season local varieties	13.4	9.7	9.9
Dry season HYV*	18.4	13.6	15.2

The mean rice yields in the improved villages are all significantly higher than in the control and improving villages at the 1% level. All values are given in quintals per acre. One quintal equals 100 kg or 4.9 bushels of rough rice.
*Not enough HYV were grown in the wet season for a valid comparison.

TABLE 3. Total Fertilizer Nutrients Used by Season and Rice Variety for Sambalpur Villages 1970-1971

	Improved Villages	Control Villages	Improving Villages
Wet season local varieties	38	33	20
Dry season local varieties	60	40	29
Dry season HYV	80	56	58

The use of fertilizer use in the improved villages is significantly higher than in the control and improving villages at the 1% level for all cases except the wet season, where the difference between the improved and control villages is significant at the 15% level. All values are given in kilograms per acre.

returns. With the costs as low as they were in the Sambalpur project, the net returns easily cover costs. The internal rates of return are very high and exceed the rates on most other agricultural investments. Only 10–15% of the difference in net returns during 1 yr is needed to cover project costs.

In contrast, even if the same types of benefits occur in Raipur, the amount of the net returns stream is very critical. If one assumes a 10-yr project life and annual maintenance costs of 133 rupees, the net benefits per acre must exceed 150 rupees per year for the internal rate of return to reach 10%, whereas the internal rate of return will be 17% if the annual net benefits are 200 rupees per acre. Although the Sambalpur experience might be transferred to Raipur for the wet season, the same is not true for the dry season. Even with the improved irrigation system, water would be available for dry season irrigation only every second or third year. Thus annual net returns of between 200 and 250 rupees per acre are probably the upper limits for the Raipur project. For the substantial area around Raipur with irrigation only during the wet season, the annual returns, based on the Sambalpur analysis, would be in the 140–150 rupees per acre range, which suggests the need for an alternative that is less expensive than the Raipur project. If costs were cut in half by increasing the area served by the main channels and benefits were 150 rupees per acre, the internal rate of return would be almost 30%.

Prospect for Future Improvements

The Sambalpur study in eastern India points out very forcefully the possibilities for high returns from improving many of the existing flood irrigation systems in India if several crucial restraints can be eliminated. One is the technical assistance restraint which limits the Sambalpur program to only nine villages a year. At this rate it will be 40 yr before the program can reach all the irrigated villages in Sambalpur district. Farmers themselves cannot do the necessary engineering and surveying work to design even the simple Sambalpur irrigation systems. Currently in India there are unemployed engineers, but most of them do not have the desire and are not trained to do this type of irrigation work. In addition, except in a few cases such as the ones mentioned above, the programs are not available to employ engineers to help design improved irrigation systems. Thus India should increase the number of technicians who can design and maintain village irrigation systems and create the positions and employ the technicians in the irrigated rural areas.

Another restraint is the lack of institutional arrangements within villages or between villages for the maintenance of the new irrigation systems. This is particularly critical in India where low levels of farm income do not leave much for maintaining irrigation channels. An improved means of allocating water between villages is also needed. Many of the villages in Sambalpur near the head of the main canal waste water, and those near the end are able to irrigate only half of their land during the dry season. Water charges are based on a farmer's acreage so excess water does not cost him any extra. Pricing of water on the volume used and a better policing of actual water use would greatly improve the on-farm water use efficiency. In fact, it might encourage villages to devise better ways of allocating water both within and between villages.

Due to the cost and difficulty of measuring the volume of water delivered to each farmer the village might be used as the point of measurement. The government would set the charge per volume of water used but the individual farmer would still pay a rate based on the acres irrigated. The rate per acre, however, would vary depending on the volume delivered to the village. The more efficiently the village farmers used water, the smaller would be the total village charge, which would result in a lower charge per acre. This, or some variant, should be tried to see if economic incentives working through the village could improve water use.

Nothing definite can be said about the optimum design of village irrigation, although the Raipur project points out the possible danger of building a project which is too capital intensive and too costly. One must always keep in mind that for these projects to spread, the costs to the farmers must be low enough to afford high returns. In addition, if project construction and maintenance are labor intensive, the farmer's actual rupee expenditures will be low. The expansion and interest in the Sambalpur program is a clear indication of what is possible. Finally, the Sambalpur farmers should begin paying the full cost of installing the field channels, since their increased returns cover costs in the first year. This would help eliminate any financial constraint to expanding the Sambalpur program and reduce any adverse income redistributional effects.

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