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Water Use Efficiency and Rotational Water Supply at the Farm Level: Certain Results from an Experimental Pilot Project in Gujarat State, India

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ABSTRACT

Delivering a fixed quantum of water on an area basis in accordance with crop water requirements by turns to the farmers' fields in the command of each outlet in the surface irrigation projects in India is known as rotational water supply at the farm level. This is essentially a software application since it does not require any heavy investments. It has been found in an experimental pilot project to have yielded considerable savings in water giving rise to a higher water use efficiency, apart from favorable economic and social gains.

INTRODUCTION

Efficient water management is signified by an appropriate awareness of not only the relationship between crop yield and water applied to the soil but also the mechanism for applying water in accordance with this knowledge. Putting these vital elements into practice is known as software application as distinguished from hardware aspects which usually refer to physical infrastructure such as dams and reservoirs, main canal and subsidiary channels (Levine *et al.*, 1979).

Rotational water supply (RWS) at the farm level is essentially a software element aiming at providing correct amounts of water at predetermined intervals on an assured basis to all lands of farmers under the command of a given government outlet. It is based on scientific premises such as crop water requirements, soil characteristics and the cropping pattern prevalent in the area.

Apart from ensuring equity in the distribution of water supplies to each farmer's field regardless of his economic, social or caste background and regardless of his physical

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location whether at the upper reaches of the outlet or at the tailend (Jayaraman, 1981), RWS prevents inefficiencies of over-irrigation arising mainly from the current practices of levying water rates on the basis of crop-acreage rather than on the volume of water used, which invariably results in wastage of water and consequent damage to soil. In other words, RWS reduces water losses without having adverse yield effects (Levine *et al.*, 1976), which is likely to be reflected in a higher water use efficiency consequent to the introduction of RWS and compared to the earlier situations of almost anarchical pattern of distribution of irrigation supplies giving rise to uncertainty, inadequacy and unreliability.

The objective of this paper is to assess the water use efficiency in a pilot project area of the Mahi–Kadana irrigation project which is designed as a perennial source of irrigation to 0.5 million acres of agricultural lands in Gujarat State, India, where RWS was introduced as an experimental measure under the World Bank assisted scheme in 1978–1979.

THE PILOT PROJECT BACKGROUND

RWS is adopted essentially for the *rabi* (winter) season when there is negligible rainfall and the farmers in the irrigation project area have to depend upon only surface irrigation. In the *kharif* (monsoon) season, only if and when the *monsoon* fails or is erratic, surface irrigation assumes importance. For protecting those water intensive crops in the *kharif* season such as paddy, the branches, minors and subminors of the canal distribution system are to be operated on a rotational basis. Apart from this, no attempt is made to introduce RWS at levels below those of distributories during the *kharif* season.

In the *rabi* season, three more levels of rotation are visualized in addition to rotation at the distributory level. The first is the rotation of the outlets along a continuous flowing minor, each outlet opening once a week for a specific time. This is on the assumption that crops grown in the outlet command area require a weekly rotation of water. Crops like wheat may require a fortnight and tobacco a 3-week rotation. But it is seen that farmers find it convenient if water is delivered on the same day of the week. For those crops requiring longer intervals, rotation can be done in multiples of one week. The second level of rotation is the one among the farmers below the outlet. The third level of rotation is among the subgroups of farmers within the group below the outlet.

Figure 1 is the sketch map of the command area (557 acres) falling under the Rawalapura subminor (9.82 cusecs) presenting the details of the irrigation system with the network of watercourses and farmland under the command of each outlet (one cusec).

Before introduction of RWS, irrigation department, the chief governmental agency operating as part of the Command Area Development Authority (CADA) restored the system to good condition. Some preliminary construction was found necessary, such as erection of flow regulators within minor. Further below the outlet level, the field channels, the maintenance of which is the responsibility of the farmers, were cleared of weeds and silt. Some division boxes and drop structures were repaired or altogether replaced. Further, measuring devices at each outlet as well as the minor were installed in addition to lining the first 10–15 m of the field channel for each outlet. Furthermore, five more additional outlets were provided to bring the existing area under irrigation with a greater degree of assurance. Thus, the number of outlets was raised to 15 from 10 which was the original figure prior to RWS.

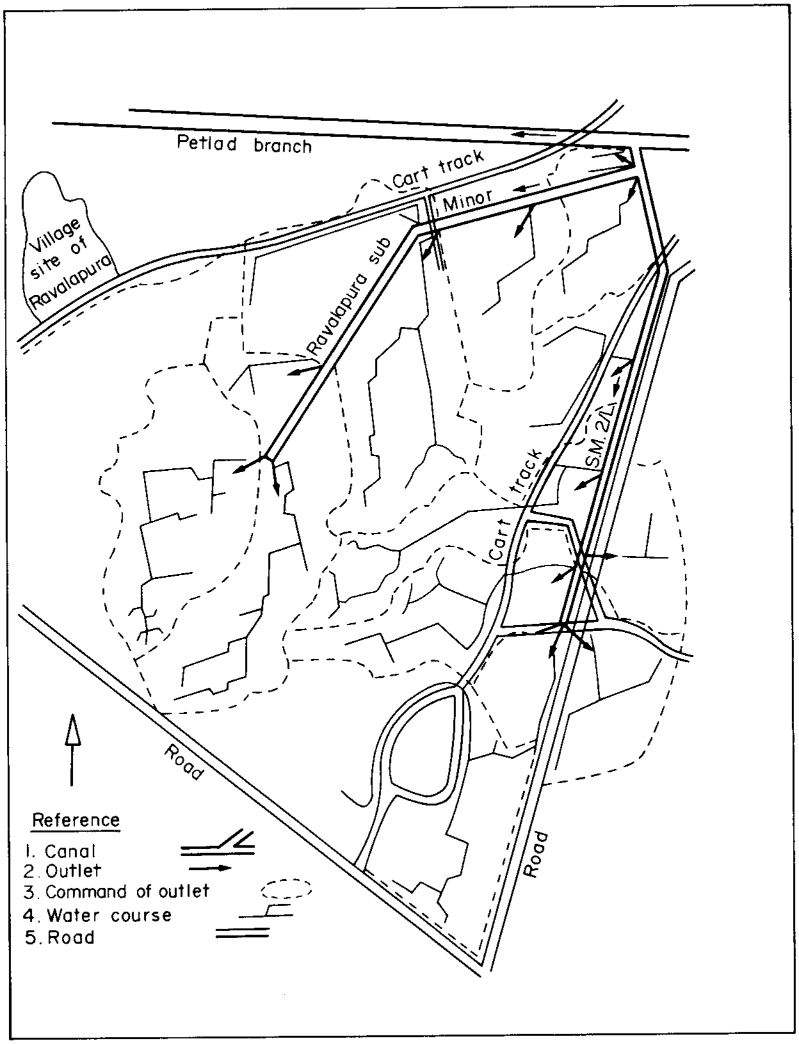

Fig. 1. Ravalapura S.M. Ex. Petlad branch, area under rotational water distribution in Rabi of 1978–1979.

Details of expenditures incurred for introduction of RWS are shown in Table 1. The per acre expenditure came to Rs 281.58 per acre.

The mechanics of RSW at and below the outlet level in the command area were worked out on the basis of crop-water requirements. Details are given in the Appendix.

Table 1 Expenditure for introduction of RWS in the pilot project area

Expenditure in rupees					
New outlets	New structures	Repairs to canals	Repairs to field channels	Total expenditure	Total expenditure per acre
5954	3000	4507	9984	23,445	281.58

Table 2. Number of irrigators and area under irrigation before and after RWS

	Before RWS (1977–1978: *Rabi*)	After RWS (1978–1979: *Rabi*)	Increase in percentage
Number of farmers	289	315	9
Total area irrigated (acres)	432.99	470.86	9
Wheat	255.12	286.62	12
Tobacco	124.50	130.75	5

While implementing RWS in the experimental area, due regard was paid to the past practices of irrigation, especially the absence of night irrigation. Therefore a more relaxed atmosphere was maintained so that ultimate acceptance of RWS was made possible. Thus only day schedules were followed and the outlets and the minor and the subminor were closed during the night, the Petlad branch serving as the night storage following the usual pattern in the Mahi–Kadana irrigation project. Similarly drawing up of time schedules during the day was left to the farmers in the subgroups to regulate among themselves without any interference from the irrigation department. These schedules written on a board with names, survey numbers, time details and the like was displayed at the head of each outlet. However, the objectives of the experimental RWS, namely; (a) to ensure each farmer was obtaining equal share of available water volume per acre based on allotted time to his field and (b) to ensure that losses occurring in the field channels are shared equally among farmers were not comprised with (Jayaraman, 1980).

Despite the departures from the rigorous norms of RWS, the results purely in terms of increase in irrigated areas under the experimental scheme are impressive as presented in Table 2.

The farmers who did not go in for *rabi* cultivation in the previous years feeling that they would not get water in an assured manner were encouraged to go in for irrigated farming. Secondly, the tailenders were given specific assurances that water supply would be strictly according to the schedule. Thirdly, as a result of RWS, over-irrigation was put to an end and additional areas came under irrigation. Thus aggregate areas irrigated went up by 9 per cent.

A detailed farm-household survey was conducted immediately after the *rabi* season to assess the socio-economic impact of RWS on farmers and farm production level. Farmers with big sized holdings preferred RWS for the reason that they did not have to quarrel among themselves for irrigation supplies, whereas the small farmers supported it for the reason that they were able to obtain their supply of water requirements in time. In regard to production level before and after RWS, it was found that RWS represented a technological improvement resulting in an upward shift of production function both in terms of average and marginal yields with respect to different inputs (Jayaraman, 1981).

The next section presents the results of the study of water use efficiency in the pilot project area.

WATER USE EFFICIENCY

Water use efficiency is defined for the purpose of our study as the ratio of water requirements of the crops to the actual amounts of water supplied. This particular definition comes near, though not very close, to the definition of overall or project efficiency (Bos, 1977). According to the latter, the overall efficiency is the ratio between the quantity of water placed in the root zone (rain deficit) and the total quantity of water supplied to the irrigated area (Bos, 1977). This particular definition is more stringent in data requirements which impose serious data collection costs not normally provided in the budget of the project authority. For the latter reason, a fairly quick and clean methodology using the aforesaid definition has been resorted to, which seems justified in the presence of financial constraints, for the purpose of rapid appraisal (Chambers, 1981). For comparison of water use efficiency indices over time, a period of 4 years is taken up which includes the 2 years prior to the introduction of RWS in 1978–1979 and one subsequent year.

In the pilot area, the *rabi* crops are wheat, tobacco, vegetables and fodder and the area under cultivation is dominated by wheat which accounts for nearly 60 per cent of the area. The variety of wheat grown in the area is the high yielding *Sonalika* whereas the tobacco grown is largely *bidi* tobacco. Vegetables are mostly seasonals such as cabbage, cauliflower and eggplant. Table 3 presents the details of the cropped area during the four year period (1976–1980) and irrigation intensity indices during the *rabi* season. The crop-water requirements of these crops have been determined by the Gujarat Agricultural University through their studies conducted at Anand campus located in the command area. They are 21 inches for wheat, 12 inches for tobacco, 21 inches for vegetables and 20 inches for fodder crops.

The *rabi* season irrigation officially starts from mid-November and ends by mid-March. Accordingly to the procedures laid down by the irrigation department and as per the canal regulations rules, the irrigators should make application to the empowered canal officer indicating the areas needing irrigation and the crops planned to be grown well before the season starts. However, due to certain reasons beyond our control, the beginning of the season gets delayed sometime as we witnessed in the year 1979–1980. During this year, there was an unseasonal rainfall in the second week of November. Sometimes it is also likely the end of the season might get extended depending upon the crop status.

The fortnightly readings of water flows at the head of the Rawalapura subminor as taken by the canal inspector (Chowkidar) during the *rabi* season for the 4 years are given in Table 4.

Table 5 presents the detailed workings of total water required by various crops grown in the pilot project area for each of the 4 years. The water use efficiency indices in percentage terms as worked out are also presented in the Table. It may be seen that water use efficiency which was as low as 41 per cent in 1976–1977 (*rabi*) went up to a high

Table 3. Area under different crops in Rawalapura pilot project (in acres)

Year	Wheat	Tobacco	Vegetables	Fodder	Area	Cropping intensity index (percentage)
1976–1977	119.87	172.12	27.00	—	318.99	57
1977–1978	255.12	124.50	53.12	0.25	432.99	78
1978–1979	286.62	130.75	49.62	3.87	470.86	85
1979–1980	280.87	125.50	61.37	3.12	470.86	85
1980–1981	268.87	161.00	49.05	8.48	487.40	87

Table 4. Water drawn in day cusecs during Rabi *season in the pilot project area*

Fortnightly reading	(Day cusecs) 1976–1977	1977–1978	1978–1979	1979–1980
16–30 Nov.	84.50	87.30	7.17	—
1–15 Dec.	31.20	34.00	3.20	3.90
16–31 Dec.	59.40	64.00	89.76	68.46
1–15 Jan.	78.10	82.40	66.08	52.85
16–31 Jan.	99.70	102.81	98.45	84.10
1–15 Feb.	61.90	66.80	90.94	131.89
16–28 Feb.	69.40	76.45	67.75	82.93
1–15 Mar.	47.80	51.00	69.27	75.06
16–31 Mar.	—	—	38.00	—
Total	532.70	569.76	530.76	509.19

figure of 69 per cent in 1978–1979 (*rabi*) when RWS was introduced and 72 per cent when it was stabilized in 1979–1980 (*rabi*).

From the foregoing discussion it is clear that RWS, apart from raising the cropping intensity in the pilot project area under study, has also been instrumental in increasing the efficiency of water use. This is because of the discipline introduced by rotational delivery of water to farmers' fields by turns which has enabled the reduction in the wastage of water otherwise prevalent in the traditional, non-RWS areas.

Table 5. Water use efficiency in the Rawalapura pilot project area

	Year 1976–1977	1977–1978	1978–1979	1979–1980
Wheat				
Area in acres	119.87	255.12	286.62	280.87
Crop water requirement (in inches)	21	21	21	21
Total water requirement in acre feet	209.62	446.12	501.21	491.15
Total water requirement in day cusecs	105.65	224.86	252.62	247.50
Tobacco				
Area in acres	172.12	124.50	130.75	125.50
Crop water requirement (in inches)	12	12	12	12
Total water requirement in acre feet	172.23	124.58	130.83	125.58
Total water requirement in day cusecs	86.81	62.79	65.94	63.30
Vegetables				
Area in acres	27	53.12	49.62	61.37
Crop water requirement (in inches)	21	21	21	21
Total water requirement in acre feet	47.21	92.89	86.77	107.32
Total water requirement in day cusecs	23.79	46.82	43.73	54.09
Fodder				
Area in acres	—	0.10	3.35	3.05
Crop water requirement (in inches)	—	20	20	20
Total water requirement in acre feet	—	0.41	6.35	5.12
Total water requirement in day cusecs	—	0.21	3.21	2.58
Aggregate water required in day cusecs	216.25	337.68	365.49	367.53
Aggregate water supplied in day cusecs	532.70	569.76	530.62	509.19
Water use efficiency index (percentage)	41	59	69	72

However, one cannot definitely conclude that the maximum water use efficiency has been reached in the pilot area. Conceding the transmission losses in conveyance from the head reaches of the minor and other losses such as seepage, the step-up in efficiency in water use due to a manipulation in the mechanism of water delivery through introduction of rotations among the fields, which was also willingly accepted by the farmers, is impressive.

If the farmers could themselves come forward to maintain their earthen field channels by clearing off the weeds and silt, the efficiency of the conveyance system would also improve. In fact, the current poor maintenance of the watercourses below the government outlet, which is the responsibility of the farmer, has been one of the stumbling blocks towards realizing the full utilization of irrigation potential. But it has been found that the farmers do not maintain their field channels and other community oriented items such as structures for regulating the water flows in the absence of adequacy, certainty and reliability of irrigation supplies (Chambers and Wade, 1980). If RWS could instill the much needed confidence in the farmers and create a climate of trust in irrigation supplies and could inspire them to come together to organize themselves in a voluntary manner for maintenance of their commonly held watercourses, the economic and social gains will be truly remarkable. Empirically it has been found that such voluntary efforts toward farmers organizing themselves have yielded concrete results (Jayaraman, 1980). In such circumstances, the water use efficiency would register far greater advances.

SUMMARY AND CONCLUSIONS

Rotational water supply (RWS) at the farm level is considered as a manipulative mechanism in the delivery of water falling under the category of software application. Though it may require certain physical inputs such as installation of measurement devices and replacement of broken structures and initial lining of watercourses, the major inputs necessary are human resources for working out the schedules based on soil–crop–water requirements and extension for persuading the farmers to abide by certain disciplines. Once the farmers accept the message and voluntarily observe the turns by themselves, the RWS becomes an effective tool of improving the water use efficiency. Further, if the farmers are convinced of the earnestness of the CADAs in maintaining the water supplies at scheduled intervals in adequate quantities in a reliable manner, they themselves would come forward to maintain the watercourses in good condition. The latter would also effectively step up the conveyance efficiency and reduce water losses in transmission, which would ultimately lead to greater water use efficiency.

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APPENDIX: DETAILS OF A HYPOTHETICAL RWS SCHEME

For working out the rotational schedule of irrigation, the following crop water requirements based on the result of research studies conducted by Gujarat Agricultural University are assumed: (a) Wheat: 7 Irrigations, each 3″ = 533 mm; (b) Tobacco: 4 Irrigations, each 3″ = 305 mm; (c) Vegetables: 7 Irrigations, each 3″ = 533 mm and (d) Others: 7 Irrigations, each 3″ = 533 mm.

It is also assumed that there are losses in transmissions: (a) losses in the field channel system (25%) and (b) losses in field application (10%). Thus, total losses amount to 35 per cent.

Suppose, there are four outlets in a group all served by a sub-minor. The areas under outlets are given below:

	Acres	Hectares
Outlet A	28	11.34
Outlet B	20	8.10
Outlet C	30	12.15
Outlet D	29	11.74
Total	107	43.33

If the cropping pattern is such that 80 per cent of the area is under wheat, 10 per cent under tobacco and another 10 per cent under vegetables, crop water requirements on hectare basis are presented in Table A.

Table A. Crop water requirements per hectare

Crops	Area percentage	Water requirement (mms)	Requirement per hectare in cubic metres
Wheat	80	533	4260
Tobacco	10	305	305
Vegetables	10	533	533
		Total	5098

Suppose, the average length of the growth period for the crops is 120 days. The flow per second per hectare is worked out as follows:

$$\frac{(5098 \text{ m}^3 \text{ per hectare})\,(1000 \text{ l})}{(120 \text{ days})\,(23 \text{ hr})\,(3600 \text{ sec})} = 0.49 \text{ l/sec/hectare.}$$

If the transmission losses are taken into account, the flow rate per second per hectare should be:

$$(0.49)\,(1.35) = 0.66 \text{ l/sec/hectare.}$$

Since a cusec equals 28.3 l/sec, the area that could be irrigated is 42.8 hectares (=28.3/0.66). As the flow is continuous in the distribution system, 168 hr per week would be available for irrigation. Thus the total flow per hectare is 168/43.33–3.88 hr per hectare per week. As there are four outlets in the group, they have the time allocations as worked out in Table B.

Table B. Time and day schedules for all outlets

Outlet	Area (hectares)	Hours per week	Schedule	
A	11.34	44	Monday Wednesday	05.00 hr to 01.00 hr
B	8.10	31	Wednesday Thursday	01.00 hr to 08.00 hr
C	12.15	47	Thursday Saturday	08.00 hr to 07.00 hr
D	11.74	46	Saturday Monday	07.00 hr to 05.00 hr

Since each outlet is going to be divided into subgroups for irrigation purposes with a view to protecting the tailenders, adjusted time allowing for line losses which is worked out for outlet A is given in Table C.

Table C. Time and day schedule for outlet A

Sub-group	Area (Ha.)	Distance from outlet	Base time hour	Adjusted field channel losses (percentage)	Adjusted time hours	Time schedule
1.	3.24	1000	13	−20	10	Mon. 0500 hr to 15.00 hr
2.	4.46	3000	17	+0	17	Mon. 15.00 hr to Tues. 08.00 hr
3.	3.64	5000	14	+20	17	Tues. 08.00 hr to Wed. 01.00 hr