The Pakistan Development Review
33:4 Part II (Winter 1994) pp. 845–855

An Assessment of Warabandi (Irrigation Rotation) in Pakistan: A Preliminary Analysis*

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I. INTRODUCTION

A significant feature of Pakistan's agriculture is that it is served by the Indus irrigation system, which is one of the largest contiguous irrigation systems in the world. The system comprises of the Indus River and its tributaries, three major storage reservoirs, 19 barrages/headworks, 43 canals, and 12 link canals and 43 canals covering about 43,000 *chaks* or village settlements. The total length of the canal system is about 40,000 miles with over 80,000 water courses, field channels and ditches running for another million miles. About 100–106 million acre feet (MAF) of surface irrigation supplies are diverted annually into the canal system. Only 60 percent of this water reaches the farmgate due mainly to low efficiency in the delivery of water. The historical review of the area, production and yield trends shows that agricultural production in the past has increased mainly due to expansion in irrigated acreage while the contribution of changes in yields has been insignificant. In general, agricultural production can be increased by either expanding the irrigated cropped area or by raising the crop yields. It is highly unlikely that Pakistan will be able to satisfy the food needs of the rapidly increasing population through yield increases alone. This means that there ia a need to increase the irrigated cropped area through additional water supplies and by improving the efficiency of water use through using the water resources in a scientific manner.

The possibilities of increasing irrigated area by developing more land and new surface water supplies in the short-run are limited as it requires huge capital

*Owing to unavoidable circumstances, the discussant's comments on this paper have not been received.

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Authors' Note: We are grateful to Dr Sohail J. Malik for extensive comments on an earlier draft.

investments and strong political will. Resource constraints and the imperative of maintaining macro-stability imply low levels of public expenditure in the medium term. Until structural reforms generate additional revenue, it is imprudent to finance construction of additional storage facilities for surface water. The political controversy relating to Kalabagh Dam is indicative of the sensitive nature of building additional storage facilities for water in Pakistan. Therefore, the only feasible option for increasing the irrigated acreage is to provide additional water supplies through improved management and efficient operation of various components of the existing irrigation system.

That the Indus irrigation system is performing poorly is now conventional wisdom. The efficiency of the canal system is low and stands at about 40 percent from canal head to the root zone. Age, over-use, poor operation and maintenance and defective management of the irrigation system explain the deteriorating system efficiency. Two recent studies of the irrigated agriculture World Bank (1993) and John Mellor Associates (1993) have made a significant contribution to an improved understanding of the problems facing the irrigation system. The two studies just referred and other literature in Pakistan has concentrated on evaluating the irrigation system upwards of the watercourses and has only tangentially dealt with the issue of how far farmers have been successful in the management of on-farm distribution of water.

This paper makes a modest effort to rectify the past neglect of research relating to on-farm use of irrigation water by focussing on an analysis of the irrigation rotation system generally known as *Warabandi*. In Section II, we describe the main features of the *warabandi* system. The objectives set for the system have been culled out from the existing literature for developing an index to evaluate the performance in a quantitative manner. Section III presents the analytics of the performance index for assessing the *warabandi* system. Section IV presents the data and the findings. The last section highlights important policy implications.

II. THE *WARABANDI* SYSTEM AND ITS OBJECTIVES

The *warabandi* system was developed during British Rule in the Indo-Pak Subcontinent in the middle of the 19th century to manage the irrigation system built by them. The system serves areas in Pakistan and the states of Punjab, Haryana, Rajisthan, and Western Uttar Paradesh in India. The *warabandi* system has been explained by Malhotra (1982) and Seckler (1980).

Warabandi means fixing of turns for irrigation water for each farmer on a watercourse. There are two types of *warabandi* namely "*Kacha*" and "*Pucca*". The

Kacha warabandi is arranged by the farmers themselves. Its rotation varies from 10 to 15 days depending upon the number of farms on a given watercourse. In each *chak* or village, a watch keeper used to announce to time for the benefit of each farmer through drum beating. With the passage of time, most farmers now own watches and can keep track of their turns and time. This system of water rotation has many problems. Big farmers exploit the small farmers and do not adhere to the agreed upon arrangement of water supplies. This results in conflicts and farmers get involved in time-consuming and expensive litigation. The large farmers do not care for the irrigation needs of the small farmers. The tailenders are the main losers.

To overcome this problem, on the request of any farmer who is not satisfied with the system, the canal department regulates the supply of water and fixes the turn of each farmer in a give crop year. This is called *Pucca warabandi.* If any farmer violates this arrangement, he/she is liable to prosecution under the Canal Act. The farmers who receive water from the watercourse, in the area of what is called the "*Chak*", are on a seven-day rotation schedule. Each farmer is assigned what is called a proprietary right to a period of time e.g. from 10.00 a.m. to 12.00 noon every week for which he is entitled to all of the flow in the watercourse.[1] After every year the turn of each farmer is rotated i.e. if farmer X has a turn in the day time, in the next rotation his turn is shifted to night time. In this way, this system of irrigation turns is operated without any serious problem of equity as far as irrigating one's fields during the night are concerned. The rotation's duration varies from one week to 10 days at a given watercourse in different areas. In case of canal closure, a farmer missing a turn loses his water.

In Pakistan, the irrigation system is supply-oriented and irrigation turns are not demand-oriented. The outlets from the distributory are designed to discharge a fixed supply of irrigation water whenever the distributory is running. Water keeps flowing through these outlets whenever the distributory is operating. These outlets (called "*Moghas*") are fixed open at a given discharge rate and are built of concrete and steel to avoid tampering by farmers.

The objective of the *warabandi* system is to provide only that amount of water which enables a farmer to irrigate one-third of his cultivable command area (CCA) during all season. In the central Punjab, "*Pucca warabandi*" is in vogue while in the southern Punjab and Sindh "*Kacha warabandi*" is still practiced in some areas as a majority of the big landlords reside in these areas and resort to

[1]Under the Canal Act, the sale of water is prohibited. The farmer has to use the allocated water on his farm.

tampering of outlets and exploit small and tenant farmers. This type of *warabandi* suits the irrigation needs of large farmers.

Determination of Water Allocation

The method of water allocation reflects a peculiar feature of the *warabandi* system. Officials of the irrigation department record the area to be irrigated of each farmer in a *chak*. This area is called the cultivable command area (CCA). The amount of time allocated to each farmer is calculated on the basis of a water "duty" of one cusec per 416 acres of CCA. The unique feature of this system is that this duty is sufficient only to provide adequate irrigation to one-third of each farmer's CCA in a normal weather year. On average, each farmer can only irrigate about one-third of his area. This system of water allocation in the Subcontinent was evolved to promote extensive settlement of the region and to avoid famine. The objective behind such a pattern of distribution for water was to irrigate the maximum area and service as many farmers as possible. This policy meant paying a price in terms of huge costs of constructing an extensive conveyance system and water losses through seepage along the long conveyance route. In the Indus Basin, 40 percent of water is lost through conveyance [Government of Pakistan (1992)]. On the other hand this system encouraged the efficient use of irrigation water as it had imposed scarcity on each farmer and, by doing so, had increased the shadow price of water for each farmer. Some critics have argued that *warabandi* is not cropping pattern oriented and that it does not cater to the crop water requirements especially for the high-yielding varieties (HYVs) of crops [Reidinger (1980)]. Given the water allocation, each farmer is free to choose the cropping pattern. Although this matter requires detailed empirical study, one can argue that each farmer can optimise yields by choosing the right level of crop intensity. This objection may not hold as a majority of the farmers in Pakistan have managed to switch to growing HYVs even without supplement of groundwater and yields in "*Pucca warabandi*" areas have increased after the system was adopted. For the past one decade or so the improvement of canals, distributories and watercourse through remodelling and lining coupled with precision land levelling has reduced the losses in the irrigation system. Conveyance efficiency of the irrigation system has consequently increased which has led to increased supply of water for farmers. In this paper we use an indicator of water supply based on observation of irrigated (wetted) area. The irrigated area comprised of farmer's land that is wetted by irrigation water. In the *warabandi* system, farmers rotate watering by fields, so that once the fields are measured, it is easy to ascertain the area wetted by observation. Wetted area is a rough indicator of irrigation water supplied. Its usefulness needs to be estimated by empirical validation. In our analysis the net irrigated area (NWA) is the area of land that is watered at least once in an irrigation season and total irrigated area (TWA) is the NWA *times* the frequency of irrigations that the area receives. Under the *warabandi* system the predicted outputs are: (i) NWA is equal to 33 percent of CCA; and (ii) TWA is equal to (0.33 × CCA × 4 =) 133 percent of CCA. Measuring the actual NWA and TWA and comparing it with predicted levels of irrigated areas allows us to determine whether the results of the *warabandi* system are within the acceptable range or error. However the indicators of NWA and TWA are subject to error due to ecology, soil condition and irrigation practices.

III. THE ANALYTICAL FRAMEWORK

The assessment of the managerial efficiency of any management system can be made by looking at the difference between the predicted outputs of the system as specified by its objectives and the actual results. If there is no difference between the two, the system is operating with 100 percent efficiency. In a real world situation, perfection is never obtained. In the previous section, we have shown that the designers of the *warabandi* system had planned that each farmer should be able to irrigate 1/3 of his CCA in each season. Allowing for the four seasons, each farmer should be able to irrigate 133 percent of his CCA during each crop year.

Comparing actual irrigated area with the designated irrigated areas, one can get an idea about how well the system of *warabandi* has been operating. The mean value of the difference between the actual and the desired performance and coefficient of variations (CV) of the ratio for the *warabandi* system can sometimes lead to contradictory results. Mean value may be low and CV high or vice versa.

Theil's inequality coefficient (TIC) that treats positive errors and negative errors of water supply equally and penalises large errors more than small errors is a handy way of combining the mean error and the uniformity error denoting dispersion. The index given by Theil (1966) is as follows:

$$TIC = \frac{\sqrt{\sum (TWA - TWA^*)^2}}{\sqrt{\sum (TWA^*)^2}}$$

where

TWA = Actual total wetted area as defined in Section II.
TWA^* = Predicted total wetted area as defined in Section II.

When TIC = 0, performance is perfect and when TIC = 100 percent, no water is being delivered and performance is zero.

IV. SOURCES OF DATA AND FINDINGS

The data pertain to a water course randomly selected from the Tandlianwala distributory in Faisalabad district. Thirty farmers were selected at random to collect the needed data.

Information was collected for two crop seasons, namely, *Rabi* and *Kharif* for the crop year 1992-93. Data were personally collected by one of the authors.

With this basic data, a preliminary view of the *warabandi* performance of the *chak* in hand could be obtained.[2] As pointed above, one objective of the *warabandi* is that NWA should be equal to 33 percent of CCA. Table 1 shows that mean value of NWA/CCA ratio is 30.64 percent (*Rabi*: 15.98 percent and *Kharif*: 14.65 percent) with a coefficient of variation (CV) of 40 percent. The TWA provides the comprehensive picture and its ratio (TWA/CCA) should be equal to 133 percent. The actual data show that the mean value of this ratio is about 104 percent with a CV of 66 percent with a seasonal break-up of 50 percent in the *Rabi* and 54 percent in the *Kharif* season. In the *Rabi* season, water is short of crop requirement by about 35 percent and in the *Kharif* the gap is 25 percent [Hussain and Rao (1991)]. In India [Seckler (1980)] NWA/CCA and TWA/CCA ratios standing at 39 percent and 136 percent respectively. This means that the *warabandi* system is more efficient in the Indian Punjab as compared to West Punjab (Pakistan).

The TWA is a better indicator of water supply than NWA which varies with soil type and other conditions stated above. For this reason, we use TWA in our analysis.

The objective function of the *warabandi* system with respect to TWA is TWA^*, with $TWA^* = 1.33 \times CCA$ for each farmer. This has been calculated for each farmer and is reported in Table 1. For perfect performance, the ratio of TWA/TWA^* should be equal to 1.00 plus or minus specified level of error. This ratio is 78 percent with CV of 66 percent showing a sub-optimal performance of the *warabandi* in Pakistan. In India the ratio is close to one (102 percent) showing relatively better performance than Pakistan.

The mean value and CV of the ratio (TWA/TWA^*) raises the issue of creating an index of managerial performance for any management system. There are two kinds of error, *firstly* the mean error (ME) or the difference between the

[2]Generalisations of findings to the entire *warabandi* system of Punjab province is hazardous. There can be large variations between canal commands and between villages within each canal command. The results should be treated as indicative. There is a need to do similar studies for different commands.

Table 1

Descriptive Statistics and Performance Indicators for Warabandi *on one Selected Water Course in Pakistan and India*

	CCA (Acres)	NWA *Rabi* (Acres)	FREQ *Rabi* (No.)	TWA *Rabi* (Acres)	NWA *Kharif* (Acres)	FREQ *Kharif* (No.)	TWA *Kharif* (Acres)	NWA/ CCA *Rabi* (%)	NWA/ CCA *Kharif* (%)	NWA for Crop Year/CCA (%)	TWA/ CCA *Rabi* (%)	TWA/ CCA *Kharif* (%)	TWA for Crop Year/ CCA (%)
PAKISTAN													
Mean	11.75	1.81	3.15	7.03	1.73	3.36	7.51	15.98	14.65	30.64	50.28	54.11	104.42
STD	6.77	1.02	1.58	6.11	1.25	1.72	7.10	5.47	7.62	12.36	27.21	44.21	69.27
CV	0.58	0.56	0.50	0.87	0.72	0.51	0.95	0.34	0.52	0.40	0.55	0.82	0.66
TIC	–	–	–	–	–	–	–	0.54	0.60	0.35	0.52	0.56	0.37
Fraction Error Due to Basis								0.57	0.67	0.05	0.83	0.63	0.02
Fraction Error Due to Difference Variation								0.67	0.13	0.00	0.09	0.04	0.28
Fraction Error Due to Difference Covariation								0.22	0.25	0.95	0.07	0.32	0.70
INDIA													
Mean										38.75			135.49
STD										18.72			45.70
CV										0.48			0.34
TIC										0.34			0.20
Fraction Error Due to Bias										0.06			0.02
Fraction Error Due to Difference Variation										0.12			0.03
Fraction Error Due to Difference Covariation										0.82			0.94

CCA: Cultivable Command Area; NWA: Net Wetted Area; TWA: Total Wetted Area; FREQ *Rabi:* No. of irrigation in *Rabi* season; FREQ *Kharif*: No. of irrigation in *Kharif* season.

mean of the objective function and the mean of the actual performance which in this case is 22 percent (100–78) in the TWA/TWA* ratio. This means that less water was delivered to the farmer than specified in the objective function. The *second* is the uniformity error (UE) or the dispersion of values around the mean. This is depicted by the CV. The high value of UE may be attributed to management errors or measurement error or exogenous factors. With these different kinds of errors, it is difficult to judge the performance of the system in an unambiguous way. Therefore, there is need to find an index which could merge these two sources of errors to a single term. The concept of TIC used in the previous section helps us to resolve the matter. The TIC for Pakistan, reported in Table 1, is 0.37 for the crop year, 0.52 for *Rabi* and 0.56 for *Kharif* seasons. The *warabandi* in this *chak* is performing at 63 percent effectiveness for the crop year, 48 percent for the *Rabi* season and 44 percent for the *Kharif* season. It should be noted that in the case of India, *warabandi* is performing at 80 percent effectiveness –a level that is significantly higher than Pakistan.

A recent study completed at the International Food Policy Research Institute (IFPRI) shows frequent water trading and selling/buying of tubewell water in Pakistan. The tailenders often sell their water rights to upstream farmers although it is legally prohibited. In this study it is shown that water markets can be especially beneficial in expanding conjunctive use of groundwater within the command canal irrigation systems [Ruth (1993)]. The poor performance of *warabandi* found by us clearly makes a case for water markets. It has been found that fellow farmers do informal trading on a common watercourse. There is a demonstrated need to re-look at the century's old *warabandi* system, to make it more flexible, demand-driven and cropping pattern-oriented. Farmers should be assigned proprietary rights to the water like land so that they can freely trade water. This should increase the allocative efficiency of irrigation water.

V. CONCLUSIONS AND POLICY IMPLICATIONS

The performance of the *warabandi* system has been evaluated on one watercourse in Faisalabad district. Data from 30 formers were collected regarding cultivable command area, net irrigated area and frequency of irrigation in both seasons namely *Rabi* and *Kharif*. Ratios of net irrigated area and total irrigated area to CCA were estimated. Theil Index (TIC) was computed to evaluate the performance of the *warabandi* system. The TWA/CCA ratios show that the system is working at 104 percent as against expected output of 133 percent. The TIC is computed at 37 percent, which implies that the system is working at 63 percent effectiveness. The comparison with an Indian study [Seckler (1980)] shows that Pakistan's *warabandi* system is less effective than that in the Indian Punjab.

The results of the study confirm the widely held belief that the system of *warabandi* in the Indus Basin is not flexible enough to use the vital water resource in an efficient manner. The institutional rigidity of the system causes large conveyance losses and hampers the consumptive needs of the crops. Farmers tend to under-irrigate the fields which, given other things, adversely affects the yields of crops. There is ample evidence of surface water trading and water markets for underground water. The system of *warabandi* needs to be modified to allow water trading and development of water markets for surface water.

The farmers should be assigned proprietary rights to irrigation so that they can use this precious resource where it has high marginal productivity. The use of this resource be demand-led than supply-driven. It should be priced at least at its marginal cost so as to generate enough resources for the proper maintenance of the canal network. This policy change will also encourage the conjunctive use of surface and underground water. Results from the IFPRI study Ruth (1993) indicate that use of groundwater in conjunction with canal irrigation increases productivity.

Based on the consumptive needs of crops and stress function, the duration of the *warabandi* may also be changed from present 7 days rotation to 15 days rotation. Accordingly allocation of water to each farmer during his turn should be increased. In this way net irrigated area can be increased and crops will get water according to the consumptive needs. This will also reduce the water losses that occur during weekly rotations.

Appendix

Appendix Table 1

Basic Data for Each Farmer Located on a Water Course in District Faisalabad for 1992-93 Crop Year

S. No. of Farmers	CCA (Acres)	NWA *Rabi* (Acres)	FREQ *Rabi* (No.)	TWA *Rabi* (Acres)	NWA *Kharif* (Acres)	FREQ *Kharif* (No)	TWA *Kharif* (Acres)	NWA/ CCA *Rabi* (%)	NWA/ CCA *Kharif* (%)	NWA for Crop Year/CCA (%)	TWA/ CCA *Rabi* (%)	TWA/ CCA *Kharif* (%)	TWA for Crop Year/ CCA (%)
1	12.00	2.00	4.00	8.00	2.50	5.00	12.50	16.67	20.83	37.50	66.67	104.17	170.83
2	12.50	3.00	4.00	12.00	4.00	5.00	20.00	24.00	32.00	56.00	96.00	160.00	256.00
3	12.00	2.50	3.50	8.75	3.00	4.50	13.50	20.83	25.00	45.83	72.92	112.50	185.42
4	25.00	4.50	4.50	20.25	5.00	5.00	25.00	18.00	20.00	38.00	81.00	100.00	181.00
5	12.00	3.00	3.50	10.50	4.00	4.50	18.00	25.00	33.33	58.33	87.50	150.00	237.50
6	12.00	2.25	3.50	7.88	3.00	4.50	13.50	18.75	25.00	43.75	65.63	112.50	178.17
7	12.00	1.50	3.00	4.50	1.25	3.00	3.75	12.50	10.42	22.92	37.50	31.25	68.75
8	12.00	1.50	3.00	4.50	1.25	3.00	3.75	12.50	10.42	22.92	37.50	31.25	68.75
9	2.00	0.50	0.45	0.23	0.25	0.45	0.11	25.00	12.50	37.50	11.25	5.63	17.00
10	4.00	1.00	1.30	1.30	1.00	1.30	1.30	25.00	25.00	50.00	32.50	32.50	65.00
11	12.00	2.00	4.45	8.90	1.75	4.45	7.79	16.67	14.58	31.25	74.17	64.90	139.08
12	6.00	0.50	1.30	0.65	0.50	1.30	0.65	8.33	8.33	16.67	10.83	10.83	21.67
13	6.00	0.50	1.30	0.65	0.45	1.30	0.59	8.33	7.50	15.83	10.83	9.75	20.67
14	6.00	0.50	1.30	0.65	0.45	1.30	0.59	8.33	7.50	15.83	10.83	9.75	20.67
15	25.00	3.00	6.00	18.00	2.50	6.00	15.00	12.00	10.00	22.00	72.00	60.00	132.00
16	25.00	3.25	6.00	19.50	2.50	6.00	15.00	13.00	10.00	23.00	78.00	60.00	138.00
17	25.00	3.00	5.30	15.90	2.50	5.30	13.25	12.00	10.00	22.00	63.60	53.00	116.60
18	12.00	1.50	2.75	4.13	1.00	2.75	2.75	12.50	8.33	20.83	34.38	22.92	57.33
19	12.00	1.50	2.75	4.13	1.00	2.75	2.75	12.50	8.33	20.83	34.38	22.92	57.33
20	25.00	2.50	6.00	15.00	2.00	6.00	12.00	10.00	8.00	18.00	60.00	48.00	108.00
21	6.25	0.75	1.50	1.13	0.50	1.50	0.75	12.00	8.00	20.00	18.00	12.00	30.08
22	6.25	0.75	1.50	1.13	0.50	1.50	0.75	12.00	8.00	20.00	18.00	12.00	30.08
23	6.25	0.75	1.50	1.13	0.50	1.50	0.75	12.00	8.00	20.00	18.00	12.00	30.08
24	6.25	0.75	1.50	1.13	0.50	1.50	0.75	12.00	8.00	20.00	18.00	12.00	30.08
25	6.25	1.50	2.25	3.38	1.00	2.25	2.25	24.00	16.00	40.00	54.00	36.00	90.08
26	6.25	1.50	2.25	3.38	1.00	2.25	2.25	24.00	16.00	40.00	54.00	36.00	90.08
27	12.50	2.50	4.50	11.25	2.00	4.50	9.00	20.00	16.00	36.00	90.00	72.00	162.00
28	12.50	2.50	4.50	11.25	2.00	4.50	9.00	20.00	16.00	36.00	90.00	72.00	162.00
29	12.50	2.00	4.00	8.00	3.00	5.00	15.00	16.00	24.00	40.00	64.00	120.00	184.00
30	8.00	1.25	3.00	3.75	1.00	3.00	3.00	15.63	12.50	28.12	46.88	37.50	84.38

CCA: Cutivable Command Area; NWA: Net Wetted Area; TWA: Total Wetted Area; FREQ *Rabi:* No. of irrigation in *Rabi* season; FREQ *Kharif*: No. of irrigation in *Kharif* season.

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