Sindh Univ. Res. Jour. (Sci. Ser.) Vol. 49 (004) 807-812 (2017)

http://doi.org/10.26692/sujo/2017.12.0062

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES

Effect of Watercourse Lining on Water Distribution (Warabandi) in the Command Area of Laiqpur Ex Ali Bahar Minor, District Sujawal, Sindh, Pakistan

N. B. BHATTI++, A. L. QURESHI, G. S. SOLANGI, S. PANHWAR

US-PCAS-W, Mehran University of Engineering & Technology (MUET), Jamshoro

Received 20rd November 2016 and Revised 07th October 2017

Abstract: A study was carried out to evaluate the impact of watercourse lining on water distribution (warabandi).For this study two watercourses, one lined (8-CL) and other unlined (11-R) of Laiqpur ex-Ali Bahar Minor were selected.The Theil's Index was calculated on the basis of various parameters such as NIA (Net Irrigated Area), NWA (Net Wetted Area), CCA (Cultivable Command Area) and frequency of irrigation, actual TWA (Total Wetted Area) and predicted TWA (Total Wetted Area) and found as 0.22 and 0.496 for lined and unlined watercourses respectively. Hence, the effectiveness of warabandi was found as 78 and 50.4% for lined and unlined water courses respectively. The Theil's Index values for head (31.07 acres), middle (31.76 acres) and tail (28.35 acres) sections of one lined and two unlined sections of the lined watercourse were determined as 0.147, 0.165 and 0.319 respectively, however for unlined watercourse, the Theil's Index values were 0.21 (head), 0.5 (middle) and 0.6 (tail). This showed that in a lined section of the watercourse No. 8-CL, the effectiveness of warabandi was 85%, at its tail section it was 68% and that for tail section of the earthen w/c was only 40%. Variation of TIC in lined and unlined watercourse was 0.17 and 0.38 respectively. The conveyance loss per 1000 ft. in lined and unlined sections of watercourse 8-CL was 1.23% and 4.92% respectively, however in watercourse 11-R that was 4.9%. The conveyance efficiency in lined and unlined sections of the lined watercourse was98.76 and 90.60% and that for earthen watercourse was 70.59% and after lining, the cropping intensity increased up to 8%.

Keywords: Watercourse Improvement, Seepage, Conveyance Efficiency, Theil's Index

1. INTRODUCTION

Land and water are two finite sources for irrigated agriculture which are globally shrinking continuously. With limited freshwater, land resources, and ever-increasing demand of these resources, irrigated agriculture being a largest consumer of global freshwater resources needs to improve its utilization of these resources (Dejen, 2015). In Sindh, Pakistan, irrigation water is generally available to canal irrigation system in a continuous delivery system. The farmers receive the share of irrigation water on a fixed rotation basis locally known as warabandi (water distribution). However, the warabandi managed jointly by stakeholders of the concerned watercourse is known as Katcha warabandi while the warabandi decided by the Irrigation or Agriculture departments is known as Pucca warabandi. The warabandi was designed by British Government; farmers are accorded the right to withdraw canal water for a period proportionate to the amount of land they own, with each farmer having an assigned warabandi turn. The actual amount of water that a farmer receives during his/her turn varies depending on the amount of water in the canal feeding to the watercourse. The warabandi may be a rotation of 10-11 days but in the present study area, the warabandi is a seven days' rotation. Each stakeholder is allocated a proprietary right for a period of time i.e. from 09.00-11.00 am every week during which farmer has a right to withdraw all the flow of the water course.

Various studies show that most of the water courses are improperly designed, poorly maintained, and carelessly operated, that results in considerably water losses (Arshad, *et al.,* 2015). About one-third of the water diverted for irrigation purposes is to be lost during conveyance (Naeem, 1991) and it is also reported that in Pakistan, the conveyance losses in watercourse occur over 40% (Anjum, 1993) however, the seepage losses in unlined irrigation system of different countries in the world vary from 25% to 50% of total diversion (Badar, 2000). The conveyance losses in 15 watercourses of KPK (Khyber Pakhtunkhwa), Pakistan were observed by (Hussain, 2000) and found about 25-45%. Also, (Khan, *et al.,* 1999) found about 27% increase in water delivery efficiency and about 53% reduction in water losses in 07 lined watercourses of KPK. Solangi *et al.,* (2017) conducted a study in the command area of Gadeji minor, Sindh, Pakistan and reported that conveyance losses at field level may be minimized by the lining of watercourses.

Irrigated agriculture plays a vital role in the economy of various developing countries. The water stress among agricultural, urban, industrial and environmental sectors is increasing due to growth in population (Dawadi and Ahmad 2013) (Qaiser *et al.,* 2015) (Ghumman, *et al.,* 2014) has also reported that. As a result, per capita, water availability which was 5260m^3 in 1951 has been declined to 1032 m^3 in 2016. (Haq, 2016)

++Corresponding Author: nabibux123@gmail.com

Keeping in view the importance of water and the reduction in per capita availability, the Government has decided to improve the water courses to ensure the equal distribution of water among the stakeholders. In the command area of selected minor, there was a huge problem of seepage loss and the warabandi system was not performing well and tail end users were suffering due to a shortage of water. As there is a close relationship between watercourse lining and warabandi (Sharam, and Oad, 2015), therefore, this study was conducted to assess the effectiveness of the warabandi system in lined and unlined watercourses of Laiqpur Minor, District Sujawal, Sindh, Pakistan.

2. MATERIALS AND METHODS

2.1 The Study Area

The present study was carried out on two watercourses, one rectangular brick lined (8-CL) and the other unlined watercourse (11-R) of Laiqpur ex-Ali Bahar minor, Taluka Mirpur Bathoro, District Sujawal. The salient features of studied watercourses are described in (**Table 1)**.

Table 1. Salient features of Selected Watercourses of Laiqpur Minor

No.	Description	Data
Lined Watercourse No. 8-CL		
1.	GCA (Gross Commanded Area) (acres)	91.18
2.	CCA (Cultivable Commanded Area) (acres)	91.18
3.	Design discharge (liters/sec (LPS))	120
4.	Total length (meters)	1000
5.	Lining length (meters)	300
6.	Width (b) (meters)	0.60
7.	Depth (D) (meters)	0.65
8.	Longitudinal Slope (S)	0.0002
9.	Stakeholders (Nos.)	12
Unlined watercourse No. 11-R		
1.	Gross commanded area (GCA) (acres)	284.9
2.	Cultivable commanded area (CCA) (acres)	284.9
3.	Sanctioned discharge (LPS)	137
4.	Stakeholders (Nos.)	22

Source: Irrigation Department, District Sujawal, Sindh

2.2 Performance of Warabandi System

The performance of the warabandi system for selected two watercourses was determined using Theil's Index (Sharam, and Oad, 2015) given as:

$$TIC = \frac{\sqrt{\sum(TWA - TWA*)^2}}{\sqrt{\sum(TWA*)^2}} \quad (1)$$

Where TIC = Theil's Inequality Coefficient, TWA = Actual Total Wetted Area, and TWA* = Predicted Total Wetted Area

2.3 Equity in Water Distribution

To evaluate the equity of water distribution through the warabandi system, the TIC was calculated individually for the head, middle and tail sections of the selected watercourses. In this connection, the data such as the actual wetted area of the section predicted the wetted area of the section and frequency of irrigation was collected separately. In addition to this, the equity in water distribution among water users was determined by computing the water losses and conveyance efficiency.

The flow rate was measured by using the current meter and cutthroat flumes and following Equations 2 and 3 to determine conveyance losses and conveyance efficiency in sample watercourses.

$$\text{Conveyance Loss } (Q_L)\ (\%) = \frac{Q_i - Q_o}{Q_i} \times 100 \quad (2)$$

$$\text{Conveyance efficiency } (\%) = \frac{Q_o}{Q_i} \times 100 \quad (3)$$

Where Q_i and Q_i are inflow and outflow rates observed in ft^3/sec respectively.

3. RESULTS AND DISCUSSIONS

3.1 Performance of Water Distribution (Warabandi) System

The effectiveness of warabandi for lined watercourse was found as 78% and that for unlined watercourse (w/c) was 50.4% using Equation (1). From this it is clear that due to the lining of a watercourse, the effectiveness of warabandi increased and also due to the lining of the watercourse of the same minor, the performance of water distribution (warabandi) improved during the same crop period.

The computed TIC values of the present study are confirmed with TIC values obtained for the watercourses of Faisalabad, Punjab, Pakistan as well as India Qureshi, *et al.*, 1994) (**Table 2**).

Table 2. Comparison of Tic and Effectiveness of Warabandi

Parameters	Study by Qureshi, et. al. (1994)			Present Study	
	Faisalabad, Punjab, Pakistan		India	Sujawal, Sindh, Pakistan (Kharif 2012)	
	Kharif	Rabi	Crop Year	Lined Watercourse	Unlined Watercourse
Theil's Inequality Co-efficient (TIC)	0.56	0.52	0.20	0.22	0.496
Effectiveness of warabandi (%)	44.0	48.0	80.0	78.0	50.40

If TIC = 0, then the performance is 100% and if TIC=1.0, then no water is being delivered and performance is zero (0).

(Table 2) indicates that the performance of presently studied lined w/c and that of India is very close to about 80%. The effectiveness of warabandi of sample unlined w/c in Kharif season and the watercourses studied in Faisalabad, Pakistan is ranging between 44 and 50% and is almost similar.

4.2 Equity in Warabandi (Water Distribution)

The TIC was computed individually for the head, middle and tail segments of the Watercourse to determine the equity in warabandi (water distribution) among the farmers of selected watercourses. The basic data for the calculation of TIC values is described in **(Tables 3-6)** given in the appendix.

The TIC, effectiveness and other parameters for both lined and unlined watercourses are described in **(Table 3)**.

Table 3. Comparison of Cropping Intensity, TIC and Warabandi Effectiveness

Parameters	Lined Watercourse No. 8-CL			Unlined Watercourse No. 11-R		
	Head Reach	Middle Reach	Tail Reach	Head Reach	Middle Reach	Tail Reach
CCA (acres)	31.07	31.76	28.35	91.35	96.25	97.34
Irrigated Area(acres)	30.15	28.45	20.59	80.535	61.16	50.64
Cropping Intensity (%)	97.04	89.55	72.63	88.17	63.57	52.02
Theil's Inequality Coefficient (T.I.C)	0.147	0.165	0.319	0.211	0.499	0.594
Variation in T.I.C	0.172			0.383		
Effectiveness of warabandi	85.3%	83.5 %	68.10 %	78.9%	50.1 %	40.6 %

The TIC for the head, middle and tail reach of the selected one lined and two unlined reaches of the lined w/c were 0.147, 0.165 and 0.319 respectively. On the other hand, the TIC values for the head, middle and tail reaches of unlined watercourse were 0.21, 0.5 and 0.6 respectively. This indicated that the effectiveness of water distribution (warabandi) in lined and unlined reach of the improved w/c was 85% and 68%. It is evident that after lining of the watercourse, its performance was increased. This clearly indicated that lining of w/c increases the performance of warabandi of the whole w/c even it is improved up to 30%. On the other hand, the effectiveness of warabandi at the tail reach of the unlined w/c is only 40%.

The variation in TIC values in lined and unlined w/c is 0.17 and 0.38 respectively. As variation in TIC for unlined watercourse is more than double of the lined watercourse which obviously indicates that in lined w/c, the equity in water distribution is rational with the deviation of 17% only. However, in unimproved w/c the variation of water distribution is 38%, thus water is not equally distributed.

4.3 Water Losses, Conveyance Efficiency, and Cropping Intensity

4.3.1 Conveyance Losses

The water losses per 1000 ft. in the lined section of watercourse No. 8-CL were calculated using Equation (2) and found 1.23% and those in an unlined segment of the same watercourse were 4.92%. However, the losses computed for earthen watercourse were 4.9% (**Table 4**).

Table 4. Water Losses in Lined and Unlined Watercourses

No.	Watercours Section	Discharge at Inlet (Q_i) (ft^3/sec)	Discharge at Outlet (Q_o) (ft^3/sec)	Water Losses/1000ft (%)
1.	Lined (8-CL)	3.25	3.21	1.23
2.	Unlined (8-CL)	2.84	2.56	4.92
3.	Unlined (11-R)	6.80	4.80	4.90

It was observed that the losses in lined section of watercourse No. 8-CL were due to leakage from nuccas (outlets), evaporation, whereas in the unlined section, losses were due to seepage from bed and banks of the watercourse and evaporation. From these results, it is evident that on an average, loss in the unlined section is four times more than that of in the lined section.

4.3.2 Conveyance Efficiency

The conveyance efficiency in lined segment of the lined watercourse was 98.77% while that in the unlined segment of the same w/c was90.14% **(Table 5)**. However, the conveyance efficiency in unlined w/c was70.59% that means 29% improvement of conveyance occurred due to the lining of the watercourse.

Table 5. Conveyance Efficiency in Lined and Unlined Watercourses

S.No.	Watercourse Section	Discharge at Inlet (Q_i) (ft^3/sec)	Discharge at Outlet (Q_o) (ft^3/sec)	Conveyance Efficiency (%)
1.	Lined (8-CL)	3.25	3.21	98.77
2.	Unlined (8-CL)	2.84	2.56	90.14
3.	Unlined (11-R)	6.80	4.80	70.59

The graphical representation of water losses and conveyance efficiency of the lined and unlined watercourses is shown in (**Fig. 1)**.

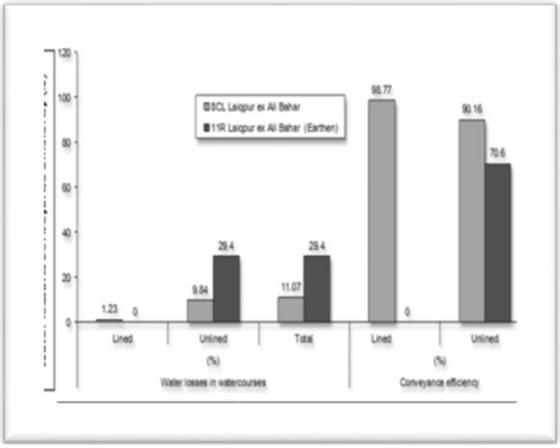

Fig. 1: Water Losses And Conveyance Efficiency Of Lined And Unlined Watercourses

4.3.3 Cropping Intensity

The cropping intensity before and after improvement of the selected watercourse was determined through field survey and interviews from farmers which are summarized (**Table 6)** and its graphical representation is shown in (**Fig. 2)**.

Table 6. Cropping Intensity before and after Improvement of Watercourses

No.	Watercourse No.	CCA (Acres)	Before Improvement		After Improvement	
			Cultivated area (acres)	Cropping Intensity (%)	Cultivated Area (acres)	Cropping Intensity (%)
1.	8-CL (lined)	91.18	72.0	79.0	80.0	87.0
2.	11-R (unlined)	284.90	192.33	67.0	-	-

The results show that cropping intensity improved after lining of the selected watercourses.

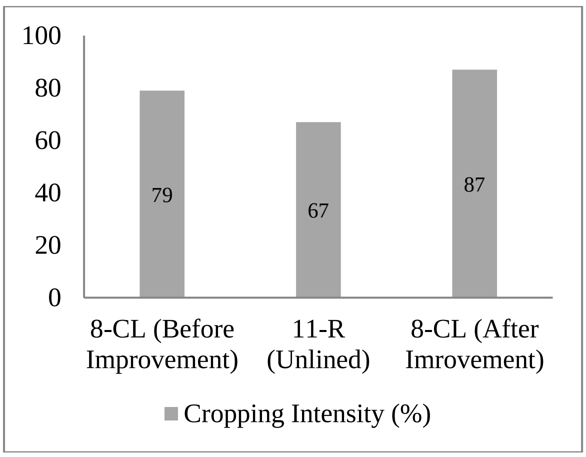

Fig. 2: Cropping Intensity (%) Before And After Improvement of Watercourse

4. CONCLUSIONS

The overall effectiveness of warabandi for lined watercourse8-CLand 11-R was determined as 78 and 50% respectively. However, in a lined section of the improved watercourse was 85% that means 30% lining has also increased warabandi performance at its tail section with the effectiveness of 73%. The effectiveness of tail section of the unimproved watercourse was 40% only. That's why it may be concluded that water distribution may be significantly improved by the lining of the watercourses.

The performance of lined watercourse (8-CL) is about 78% that is excellent. However, the performance of unlined watercourse (11-R) is only 44%, therefore, it needs improvement.

The variation in TIC values within lined watercourse is 0.17 which shows the equity within the stakeholders is balanced. However, in the case of an unlined watercourse, it is increased to 0.38.

After 30% lining of a watercourse, the cropping intensity was increased by 8% and conveyance efficiency increased by about 29% and per 1000ft length of a watercourse, water saving was determined as 4.9% and after improvement of a watercourse, no change in cropping pattern was recorded.

5. ACKNOWLEDGEMENTS

Authors are thankful to NPIW (National Program for Improvement of Watercourses), Irrigation Department, District Sujawal Ex-Thatta, Sindh for providing data and IWRWM (Institute of Water Resources Engineering and Management), Mehran University of Engineering & Technology, Jamshoro, Pakistan, for logistic support regarding this study.

REFERENCES:

Arshad, I., M. M. Babar, and A. Sarki, (2015) **"**Computation of Seepage Quantity in an Earthen Watercourse by SEEP/W Simulations Case Study: "1R Qaiser Minor"-Tando Jam-Pakistan", Advanced Journal Agricultural Research, Volume 3, No. 1, 82-88.

Anjum, M. S., (1993) "Marketing Constraints and Development Strategy For Edible Oil In Pakistan", A World Bank/Minfal/PARC studies, Winrock International Islamabad,.

Ahmad, S. and D. Prashar, (2010) "Evaluating Municipal Water Conservation Policies Using A Dynamic Simulation Model", (2015) Water Resources Management, Volume 24, No. 13, 3371-3395.

Badar, H., (2000) "Sunflower Production in the Province of Punjab (Pakistan)", M.Sc Thesis, Department of Agriculture, University of Agriculture, Faisalabad.

Dejen, Z. A., (2015) "Hydraulic and Operational Performance of Irrigation Schemes in view of water saving and sustainability", Ph.D. thesis, UNESCO-IHE, Institute for Water Education Delft, Netherland,.

Dawadi S, and S. Ahmad (2013) "Evaluating the Impact of Demand-Side Management on Water Resources Under Changing Climatic Conditions and Increasing Population", J. of Environmental Management 114: 261–275,
DOI: 10.1016/j.jenvman.2012.10.015.

Ghumman, A. R., S. Ahmad, H. N. Hashmi, and R. A. Khan, (2014) "Comparative Evaluation of Implementing Participatory Irrigation Management In Punjab, Pakistan", Irrigation and Drainage, Vol. 63, 315-327.

Haq, I., (2016) "Per Capita Water Availability Decreases http://www.brecorder.com/agriculture-a-allied/183:pakistan/23847:per-capita-water-availability-decreases-in-2016?date=2016-03-09

Hussain, S. S., (2000) "Patronage of Non-Traditional Oil Seed Crops", Pakistan Agriculture Economics No.4.Agricultural Prices Commission Islamabad, Pakistan.

Naeem, A., (1991) "Sunflower Cultivation in Cotton Based Cropping System of the Punjab with Special Reference to Bahawalpur Tehsil", M.Sc Thesis, Department of Agriculture Economics, University of Agriculture, Faisalabad.

Qaiser K., S. Ahmad, W Johnson and J.Batista (2015) "Evaluating Water Conservation and Reuse Policies Using A Dynamic Water Balance Model", (Environmental 51(2): 449-458.
DOI: 10.1007/s00267-012-9965-8,.

Qureshi, S. K., Z. Hussain, and Z. Nisa, (1994) "An Assessment of Warabandi (Irrigation Rotation) In Pakistan: A Preliminary Analysis", Pakistan Development Review: 33: 4, II: 845-855.

Solangi, G. S., A. L Qureshi, and M. A. Jatoi, (2017) "Impact of Rising Groundwater on Sustainable Irrigated Agriculture in the Command Area of Gadeji Minor, Sindh, Pakistan", Mehran University Research Journal of Engineering and Technology, Jamshoro, Vol. 36, No.1, 155-166.

Sharam, D. N. and R., Oad, (2015) "Variable time model for equitable irrigation water distribution", Journal of Agricultural Water Management, Vol. 14, No.4, .367-377.

Venkatesan A K., S. Ahmad W. Johnson and J. Batista (2011) "Salinity Reduction and Energy Conservation In Direct And Indirect Portable Water Reuse", Desalination, Vol.272, No. 1–3, 120–127,

Wu G., L. Li S. Ahmad, X Chen and X. Pan, (2013) "A Dynamic Model for Vulnerability Assessment of Regional Water Resources in Arid Areas: A Case Studyof Bayingolin, China", Water Resources Vol. 27, No. 8, 3085–3101.