Research Article

Effect of Watercourse Aging on Conveyance Efficiency and Water Productivity in District Muzaffarabad, Azad Jammu and Kashmir

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Abstract | A field study was conducted to assess the ageing effect of Plain Cement Concrete (PCC) lined watercourses on conveyance losses/efficiency in district Muzaffarabad, Azad Jammu and Kashmir. Three watercourses namely, Sarai, Derkot and Mera Dadu were selected randomly on aging basis. Watercourses Sarai, Derkot and Mera Dadu were constructed in 2000, 2006-07 and 2011, respectively. Conveyance losses in the selected watercourses were determined by inflow-outflow method, wherein the flow velocity was measured using current meter. The conveyance losses were found 13.2%, 11.8% and 7.8% in watercourses Sarai, Derkot and Mera Dadu, respectively, which resulted in conveyance efficiency of 86.8%, 88.1% and 92.4%, respectively. Results showed that conveyance losses increased and conveyance efficiency decreased with the aging of watercourse. Hence, more repair and maintenance is required for aged watercourses to minimize conveyance losses. Water productivity and water management practices were computed from field observations and farmers' interviews. Water productivity of rice in the command area of selected watercourses ranged from 0.15-0.23 kgm^{-3} with average value of 0.19 kgm^{-3}, water productivity of wheat ranged from 0.77-1.48 kgm^{-3} with average of 1.18 kgm^{-3}, water productivity of maize ranged from 0.68-1.25 kgm^{-3} with average of 0.90 kgm^{-3} and average water productivity of onion crop ranged from 0.29-0.36 kgm^{-3}, with average of 0.32 kgm^{-3}. Water productivity of onion was lower compared to the values reported by FAO and others. Better watercourse maintenance and irrigation management practices were found in watercourse Sarai, whereas, watercourse Derkot had poor watercourse maintenance and field practices. Results showed that crop yields were higher in watercourses having good water management practices. It can be concluded that aging of watercourses increase conveyance losses, which can be offset by regular repair and maintenance of watercourses.

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Introduction

Nature has bestowed the Azad Jammu and Kashmir (AJK) with abundant water resources i.e. rivers, streams and springs. But due to high rainfall, steep slopes and impervious nature of the geological formations, a considerable portion of runoff goes waste without being utilized for irrigation and drinking purpose. This makes the water limiting factor in AJK and land is not being used according to its potential.

There is no big canal system in the northern areas of AJK, but for the irrigation purposes people have constructed the unlined watercourses in their respective areas since the Dogra's regime. To overcome convey-

ance losses, the Government of AJK, Government of Pakistan (GoP), and NGOs realized the importance of lining of farmer's managed small irrigation systems and carried out lining of irrigation channels in the aforementioned areas.

In the northern areas of AJK, PCC has been used for the lining of watercourses due to its cheaper cost compared to bricks masonry and PCPS and less O & M requirements. Other important reason is that the bricks masonry and PCPS is difficult to construct/install in the hilly area like north AJK.

The northern parts of AJK have abundant water resources. But due to lack of water saving practices and improvement of irrigation system, water is limiting factor for the elevated areas both for irrigation and drinking. There is no canal network existing in these areas and farmers have constructed the watercourses on natural streams on self-help basis. As most of the watercourses are earthen, a significant portion of water is lost during conveyance from source to the fields. A few watercourses are very long and more than half of their water is lost before reaching in the fields. To overcome water conveyance losses, Government of AJK and NGOs have spent hundreds of millions of rupees on lining of watercourses. All the organizations have used the PCC material for the lining because it is cheaper than brick masonry and PCPS.

Although, expected life of PCC lining is 30 years but the conveyance efficiency is not same for the whole estimated period; it deteriorates with the passage of time. A few studies have shown that life of PCC is less than brick masonry (Kahlown and Kemper, 2005). Several studies have been conducted on conveyance losses (Rahman et al., 2011; Meijeir et al., 2006; Zeb et al., 2000) but very limited work is available on the effect of watercourse aging upon conveyance efficiency. Therefore, a research study was planned to assess the effect of watercourse aging on conveyance efficiency, thus enabling us to improve technology in this field. Water productivity of major crops and water management practices in the command area of selected watercourses were also studied.

Materials and Methods

Description of the Research Area

The research was carried out in three villages of district Muzaffarabad, namely, Sarai (Tehsil Hattain), Derkot (Tehsil Pattika) and Mera Dadu (Tehsil Muzaffarabad). Source of watercourses in the selected areas are natural streams. All the watercourses lie in hilly topography and rainfed areas. Owing to hilly topography, field sizes were small. Major crops of the areas are wheat, maize, rice and vegetables.

Description of Selected Watercourses

Three watercourses were selected on the basis of aging and lining length. During the selection of watercourse, it was ensured that the age difference between the lining materials is at least 5 years and the length of lining is more than 300 m (1000 ft). All watercourses were constructed with PCC concrete material, consisting of 1:3:6 ratio and rectangular (0.30m x 0.30 m) in shape. Table 1 shows the brief descriptions of selected watercourses:

Conveyance Losses/Efficiency

Inflow-outflow method was used to find the conveyance losses. The discharge at the inlet and outlet were measured with area-velocity method using current meter. Selected length of watercourse was 305 m (1000 ft). Following equations were used to measure the conveyance losses and conveyance efficiency;

$$Q_{losses}(l/s) = Q_{in} - Q_{out}$$

$$Losses\ (\%) = (Q_{in} - Q_{out} / Q_{in}) X\ 100$$

$$E_c = (Q_{out} / Q_{in}) X\ 100$$

Where, Q_{in} =Inflow rate (Ls^{-1}), Q_{out} =Outflow rate (Ls^{-1}), E_c=Conveyance efficiency (%)

Flow/ Discharge Measurement

There are various methods to measure the flow/discharge of water; in the present research study, area-velocity method was used to determine discharge of watercourse, wherein current metering was done for the velocity measurement.

$$Q = \Sigma AV$$

Where,
Q = Flow/discharge (m^3s^{-1}),
A = Cross sectional area (m^2),
V = Velocity (ms^{-1})

Two methods are typically used to perform current metering, (a) one point method (0.6 d), (b) Two point

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method (0.2d and 0.8d). In the present study, one point method was used because water depth in selected watercourses was ≤ 0.25 m.

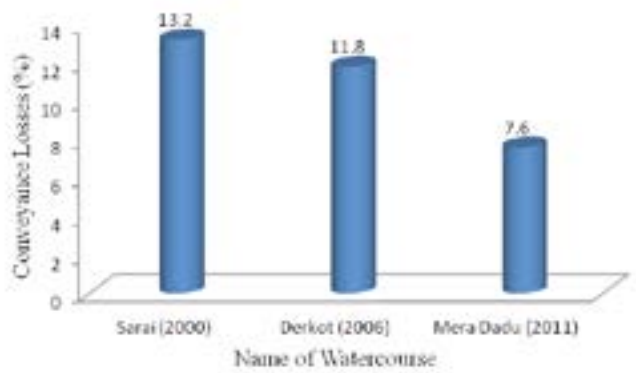

Figure 1. *Conveyance losses of selected PCC watercourses*

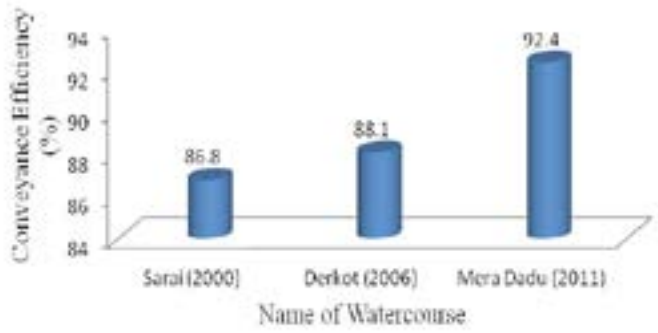

Figure 2. *Conveyance efficiency of selected watercourses*

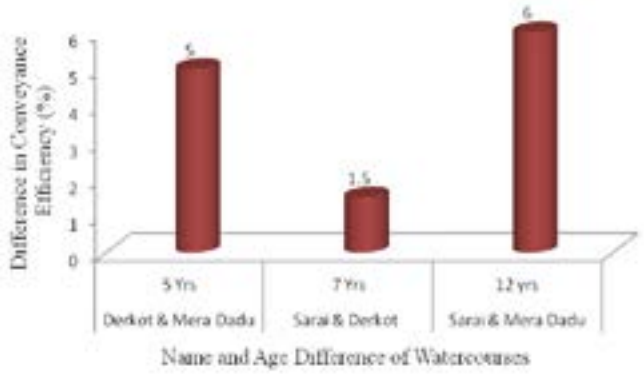

Figure 3. *Percent difference of conveyance efficiency among selected watercourses*

Water Productivity

The productivity is defined as the physical mass of production or the economic value of production measured against gross inflows, net inflow, depleted water, process depleted water, or available water (Kassam and Smith, 2001). Cai and Rosegrant (2003) reported that water productivity depend on many factors i.e. cropping pattern, climatic change, irrigation technology, field water management, soil fertility, inputs, labour, fertilizer and machinery. Data on seasonal agriculture production (kg) and total time of irrigation applied was obtained through farmers' interviews. Water inflow information was obtained through discharge measurement of selected watercourses. Total 21 beneficiaries were interviewed, 6 from watercourse Sarai, 8 from watercourse Derkot and 7 from watercourse Mera Dadu. Water productivity was determined using following equation;

$$\textit{Water Productivity} = \textit{Seasonal Agri. Production (Kg)} / \textit{Seasonal Water Inflow } (m^3)$$

Water Management Practices

A questionnaire was developed to assess the water management practices being used in the command area of selected watercourses, wherein, questions were asked about cropping pattern, cultivated area, land tenancy status, water saving, crop production, command area and operation & maintenance practices of selected watercourses. Likert scale was used to ratify the farmers of selected areas in watercourse maintenance and management practices (Likert, 1932).

Results and Discussion

Conveyance Losses/Efficiency

Figure 1 shows that average percent conveyance losses in watercourses Sarai, Derkot and Mera Dadu were 13.2%, 11.8% and 7.6%, respectively. While average conveyance losses (ls^{-1}) in watercourses Sarai, Derkot and Mera Dadu were 5.45, 4.6 and 2.35, respectively. Higher conveyance losses were found in watercourse Sarai, while lowest conveyance losses were found in watercourse Mera Dadu. Results show that water conveyance losses in older PCC are higher than the new PCC lining and the aging of lining material considerably increased the conveyance losses. Rahman et al. (2011) reported that conveyance losses in rectangular cement-concrete lining ranged from 6.58 % to 9.93% in Bogra and Godagari zone of Bangladesh. Higher conveyance losses in old lined watercourse may be due to pores formation. Meijer et al. (2006) described that concrete lining of watercourses reduced seepage losses by approx. 50%.

Figure 2 illustrates that conveyance efficiency of the selected watercourse namely, Sarai, Derkot and Mera Dadu was 86.8%, 88.1% and 92.4%, respectively. Results showed that the oldest watercourse Sarai had lowest conveyance efficiency, watercourse Derkot had moderate conveyance efficiency and newly lined wa

Table 1. *Salient features of selected watercourses*

Name of Watercourse	Year of Construction	Total Length (km)	Lined Length (km)	Source of Water
Sarai	2000	3	0.43	Sharian Nala
Derkot	2006-07	2	0.50	Mandal Canal
Mera Dadu	2011	2	0.46	Ghariduppata Nala

Table 2. *Water productivity (kgm^{-3}) of rice crop in the command area of selected watercourses*

Name of Watercourse	Discharge (m^3s^{-1})	Seasonal Irrigation Time (hrs)	Irrigation Volume (m^3)	Crop Yield (kg)	WP (kgm^{-3})
Sarai	0.036	1015	131544	23700	0.18
Derkot	0.034	607	74296	11230	0.15
Mera Dadu	0.029	706	73706	17140	0.23
Average:					0.19

Table 3. *Water productivity (kgm^{-3}) of wheat crop in the command area of selected watercourses*

Name of Watercourse	Discharge (m^3s^{-1})	Seasonal Irrigation Time (hrs)	Irrigation Volume (m^3)	Crop Yield (kg)	WP (kgm^{-3})
Sarai	0.036	47	6091	8980	1.48
Derkot	0.034	49.5	6059	4690	0.77
Mera Dadu	0.029	64	6682	8600	1.29
Average:					1.18

Table 4. *Water productivity (kgm^{-3}) of maize crop in the command area of selected watercourses*

Name of Watercourse	Discharge (m^3s^{-1})	Seasonal Irrigation Time (hrs)	Irrigation Volume (m^3)	Crop Yield (kg)	WP (kgm^{-3})
Sarai	0.036	19	2463	3060	1.25
Derkot	0.034	21.5	2632	2000	0.76
Mera Dadu	0.029	21	2192	1490	0.68
Average:					0.90

Table 5. *Water productivity (kgm^{-3}) of onion crop in the command area of selected watercourses*

Name of Watercourse	Discharge (m^3s^{-1})	Seasonal Irrigation time (hrs)	Irrigation Volume (m^3)	Crop Yield (kg)	WP (kgm^{-3})
Sarai	0.036	118	15293	5500	0.36
Derkot	0.034	104	12730	4110	0.32
Mera Dadu	0.029	87.5	9135	2680	0.29
Average:					0.32

tercourse Mera Dadu had highest conveyance efficiency.

Figure 3 shows the percent difference in conveyance efficiency among selected watercourses. Age difference between watercourse Sarai and watercourse Derkot was 7 years but percent conveyance efficiency difference was 1.5%. Age difference between watercourse Derkot and watercourse Mera Dadu was 5 years but percent conveyance efficiency difference was 5%. Likewise, age difference between oldest watercourse Sarai and youngest watercourse Mera Dadu

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was 12 years, their percent conveyance efficiency difference was 6%. Results show that conveyance efficiency difference between watercourse Sarai and watercourse Derkot is less, which should be more than watercourse Derkot and watercourse Mera Dadu. As watercourse Sarai and watercourse Derkot age difference is 7 years, while watercourse Derkot and watercourse Mera Dadu have 5 years difference. The possible reason could be that the watercourse Sarai and watercourse Mera Dadu had better watercourse repair and maintenance practices. Zeb et al. (2000) reported that major cause of conveyance losses in watercourses are depositions of sediments, cracks/breaks, high density of weeds/grasses, leakages, curves and seepages in watercourses. They concluded that watercourse repair and maintenance is important factor for reducing conveyance losses and improving conveyance efficiency.

Water productivity (WP)

Table 2 depicts water productivity of rice crop under different aged watercourses. Water productivity of rice in the command area of watercourses Sarai, Derkot and Mera Dadu was 0.18 kgm^{-3}, 0.15 kgm^{-3} and 0.23 kgm^{-3}, respectively. According to FAO (2012) reports WP of rice crop vary between 0.05-0.6 kgm^{-3}. But in the command area of selected watercourses WP of rice is slightly low. Possible reason may be the temper ature and over irrigation in the monsoon season, especially in the months of July and August; when rain water is enough for water requirement of rice crop. Lee (1993) reported that low water temperatures seriously damaged the rice crop and grain yield decreased by 9.2% to 26 %. Low temperatures causes slow vegetative growth, spike let sterility, delayed heading and poor grain filling.

Table 3 presents water productivity wheat crop in the research areas. Water productivity of wheat crop was 1.48 kgm^{-3}, 0.77 kgm^{-3} and 1.29 kgm^{-3} in the command area of watercourses Sarai, Derkot and Mera Dadu, respectively. FAO (2012) reported water productivity of wheat crop 0.8-1.6 kgm^{-3}. Fahad (2011) also found that WP of wheat ranged 0.55-0.96 kgm^{-3}, in the command area of Warsak gravity canal Peshawar. According to farmers, yield of wheat and maize depend on cropped extent area, field maintenance and ploughing (Godi). Overall, WP of wheat and maize is reasonable but their yields were found lower compared to other provinces of Pakistan. The reason assessed from farmers' interviews was the little amount of fertilizer application.

Table 4 depicts water productivity of maize crop in selected watercourses command areas. Water productivity of maize crop was 1.25 kgm^{-3}, 0.76 kgm^{-3} and 0.68 kgm^{-3} in the command area of watercourse Sarai, Derkot and Mera Dadu, respectively. FAO (2012) reported water productivity of maize crop vary between 0.8-1.6 kgm^{-3}. Ashraf et al. (2010) found that water productivity of maize crop 0.80 kgm^{-3}. Similarly, Fahad (2011) found the WP of maize crop ranged from 0.52 to 0.90 kgm^{-3}, in the command area of Warsak gravity canal Peshawar.

Table 5 shows water productivity of onion crop. Water productivity of onion was 0.36 kgm^{-3}, 0.32$kgm^{-3}$and 0.29 kgm^{-3} in the command area of watercourse Sarai, Derkot and Mera Dadu, respectively. According to FAO (2012) reports, WP of onion crop should be 8-10 kgm^{-3}. Kumar et al (2008) reported the water productivity of onion ranged 1.54 to 2.70 kgm^{-3} in India. In general, water productivity of onion is far below as compared to FAO (2012) reported range. The water productivity was very low in the command area of watercourse Mera Dadu, because according to farmers during the last 3 years their onion crop was severely attacked by worms (wireworm, soil-dwelling larvae of click beetle), which bored the bulbs of onion and ultimately very low yield was obtained. In selected area, onion crop is grown only for domestic used not as commercial/cash crop, which could also be one of the reasons for low onion yield.

Water Management Practices

In watercourse Sarai, all beneficiaries were satisfied with the maintenance of watercourse. Mostly, the respondents were satisfied with watercourse present condition. All farmers took part in the repair and maintenance operations. Both joint and individual operations were conducted thrice or more than thrice around the year. Water User Association (WUA) was strong, well organized and active.

Repair and maintenance condition of watercourse Derkot was found poor as compared to other watercourses. Only a few respondents were satisfied with the maintenance operations and the farmers cleaned the watercourse only once annually. Generally, cleaning operation is performed individually. Water User Association (WUA) was weak and farmers did not take part actively in the watercourse maintenance operations.

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In the command area of watercourse Mera Dadu, most of the respondents reported that watercourse present condition is average. All beneficiaries took part in cleaning operation. Mixed response was received about cleaning operation. Most of the respondents reported that they clean the watercourse twice annually. Better repair and maintenance practices were performed in watercourse Sarai than watercourse Mera Dadu and watercourse Derkot. Overall, results and field observations showed that strong WUA, water management practices and field practices markedly increase the crop yield and water productivity. Results also support that watercourse Sarai with strong WUA had relatively higher values compared to Derkot and Mera Dadu.

Conclusions and Recommendations

Conveyance losses increased with the aging of watercourse lining material. Aging of lining material weakens the bond between cement, crush and sand and pores formation occurs, which eventually results in more conveyance losses and low conveyance efficiency. Regular repair and maintenance; especially older lining requires frequent repair and maintenance operations.

Generally, the water productivity of major crops (rice, wheat and maize) was reasonable. However, onion crop had very low water productivity due to the prevalence of wire-worm in the research area. In order to improve water productivity of the crops in the research areas farmers must be trained on best water management practices.

The study proved that watercourse repair and maintenance play a major role in minimizing conveyance losses and improving conveyance efficiency, regardless of the age of lining material. For better watercourse maintenance practices, strong WUAs are needed.

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