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Impact of Rod Kohis improvement on water conveyance losses and wheat yield

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Abstract

Soil erosion, sedimentation and the resulting irregular surface topography of Rod Kohis are generally considered to increase water conveyance losses, which may negatively effect crop yield in their command areas. Therefore, the impact of rod kohi improvement (proper alignment, desilting, grading and compaction) on water conveyance losses and wheat yield was investigated at Rarkan in Barkhan district of Baluchistan. The experiment was conducted during two consecutive wheat crop seasons, with rod kohi under traditional farmer managed conditions during the first season and under improved condition during the second season. The results showed up to 168%, 269% and 193% increased inflow rates, 35%, 75% and 350% increased rainwater interception, 8%, 23% and 79% increased irrigated command area and 172%, 118% and 30% increased wheat yield at tail, middle and head reaches, respectively when compared with pre-improvement season. This study indicates the prospects of improved livelihood in rod kohi areas by improving and properly maintaining the rod kohis, which seems achievable through active community participation in rod kohi areas.

Keywords: Conveyance losses; Sailaba; Barkhan; Wheat yield; Catchment area.

1. Introduction

Pakistan is a major irrigated agricultural country with more than 90% crop production come coming from irrigated areas . However, the increasing demand for food due to population growth and climate change induced risks is constantly increasing the pressure on available water resources. Thus, we need to produce more with less water, which is only possible if we reduce water losses and increase crop yield and/or production area. The rain-fed areas of Pakistan is contributing far below its potential production levels. It is therefore essential to increase the production from these areas through better management systems.

Wheat is a major staple crop cultivated on 9.2 million hectare land and with total production of around 26 million tons during 2014-15 in the country. Interestingly, about one-third of the wheat crop is grown in rain-fed areas, but the yield is extremely low and even did not suffice the requirement of these areas. As wheat crop is generally preferred in rain-fed areas due to less water requirement (~400 mm per season), but the reduced wheat yield in the country in general, 2.82 ton/ha country average, demands for increasing wheat production to ensure food security. Increasing wheat production in rain-fed areas is not only essential for improving the livelihood of local farming community but also to contribute to the national economy.

The rod (channel) kohi (mountainous) irrigation system has a water potential of 14.3 million hectare-meter with total command area of ~ 41 million hectare of rain fed areas (Nespak, 1998), which is second largest after the Indus Basin. Rod Kohi system is being practiced all over Pakistan. The districts of Dera Ismail Khan in KPK, Dera Ghazi Khan and Rajanpur in Punjab covers major part of this system. In Balochistan, the Rod Kohi is named as Sailaba and is widely practiced throughout the province. The districts of Barkhan, Mousa Khel, Zhob, Bolan Lasbela, etc covers a major part of this system in the Baluchistan province. Dadu district (Khirthar range) of Sindh covers a major part of this system named as Gabarband. However, this system did not significantly contribute to the country economy in general and local community in particular. The main reasons are generally considered to be inappropriate management of rod kohi catchment, conveyance and command areas.

Most of the rod kohi areas (28.5 million hectare) lies in Baluchistan (Nespak, 1998), locally named as Sailaba, where the low rainfalls (50-250 mm) produce less runoff water, thus need more careful management for achieving greater production. The current miss management of rainwater through conventional rod kohi system reduce water availability at the tail ends of the channels. Consequently, not only crop yield is reduced but cultivated area is also negatively affected thus leading to poor livelihood (Hussain et al., 2015). Therefore, improved rod kohi system may increase water availability across the channel and may increase crop yield.

Several studies (Mishra and Fyagi, 1988; Kemper, 1976; Van Steenburgen, 1996; Tesfai and Sterk, 2002; Emami, 2005; Ahmad and Chaudhary, 2005) showed that sedimentation increase water losses in channels. Therefore, continuous rehabilitation of rod kohis is necessary to reduce the water application losses. Installation of permanent flood diversion and distribution system has been shown to reduce water losses in Eritrean spate irrigation system (Tesfai and Sterk, 2002). Therefore, proper regulatory work along with desilting, aligning, sloping and compacting practices can improve the rod kohi system performance.

Importantly, irrigation system development can be more effective in mitigating rural poverty in arid and semi-arid climates as compared with any other type of development work. But potential benefits of an irrigation system can only be achievable, if it can deliver water to the beneficiaries as per demand (PWD, Lahore, Pakistan, 1963). However, the current poor irrigation performance, inefficiency and inequality negatively affects its effectiveness for mitigating rural poverty (UNDP, USA, 2006) in many countries in general and Pakistan in particular. Therefore, this research work was planned to evaluate the impact of rod kohi improvement (de-silting, aligning, sloping, compaction and diversion) on water losses and wheat crop yield along a rod kohi in rain-fed area of Baluchistan.

2. Material and methods

2.1. Description of study area

The research site was at Rarkan, a small town of district Barkhan, Baluchistan. Rarkan is located at a distance of 300 km from Quetta with longitudes 69^0 84' to $64^0$91'E and latitudes 30^0 25' to $30^0$30'N. The 5000 population of Rarkan has a total area of 81 square km (~ 62 persons per sq.km). The major source of income is Agriculture. Low annual rainfall, 50-250 mm, is the main limiting factor which negatively affect agriculture, humans and animals. Four rod kohis (a, b,c and d) irrigate about 70 % cultivated area of the Rarkan (Fig. 1). The remaining 30% area is irrigated by the khuskaba irrigation system where farming is largely dependent on incidental rainfall and localized runoff.

Fig. 1. Layout of four rod kohis (a, b, c and d) and locations of six diversion points(triangles 1 to 6) at Rarkan, Baluchistan (Google earth).

These four rod kohis were built by the irrigation department, government of Baluchistan during 1980. However, repair and maintenance of these rod kohis was never carried out. Therefore, their performance was negatively affected causing reduced rainwater harvesting and sub-optimal distribution of limited harvested water among the end users.

2.2. Data collection

The experiment commenced by selecting nine fields, three fields each at head, middle and tail section, along the rodi kohi during first wheat season (2007). The rod kohi was under farmer managed conditions during this season. After harvest of wheat crop (2007), the local community were involved for improving the rod kohi. The machinery cost was shared with community from the project. The improvement activities comprised of proper alignment, grading, de-silting, compaction and installing appropriate diversion structures. Local machinery (tractor, blade, trolley etc) and manual labour were used. The same nine fields were again selected for data collection after improvement.

The data recorded included topographic survey of selected 700 meters long rod kohi at 5 meters interval during both pre and post improvement. Six diversions were selected along the rod khoi length with two diversion points at head (1, 2), two at middle (3, 4) and two at tail section (5, 6). The experiment commenced during wheat 2007 crop season prior to improvement and completed at the harvest of wheat 2008 crop season after the improvement. Runoff data included inflow rate and duration at six diversion points located from head to tail reaches. The rod kohi discharge was calculated by using the formula (equation 1) (Michael, 1992) and continuity equation 2:

$$v = \frac{R^{2/3} . S^{1/2}}{n} \qquad (1)$$

Here,

V = Average flow velocity in rod kohi,
R = Hydraulic radius,
n = Manning's constant
S = Slope of rod kohi

$$Q = A\,V \qquad (2)$$

Where,

Q = Flow (m^3/sec)
A = Wetted Area (m^2)

The rainfall data during both seasons were monitored using manual rain gauges on five suitable positions of the catchment area for the selected rod kohi. The crop yield data was also recorded during both seasons for the nine selected fields. Same variety of wheat crop was sown and similar input (seed rate, fertilizers, etc) were applied during both seasons. The crop data for wheat were collected from nine selected fields three each at head, middle and tail reaches. The crop samples (1 m^2) each from head, middle and tail section of all nine selected fields were collected at harvest. All the data collected before improvement were repeated again on wheat crop sown during post-improvement period. The field conditions during improvement are shown in figure 2.

Fig. 2. De-silting, aligning, grading and compaction work at experimental site at Rarkan, Baluchistan.

3. Results

3.1. Rainfall in catchment area

The average rainfall recorded during pre-improvement (2007) and post-improvement (2008) wheat seasons are shown in figure 3. Major rainfall events were observed in the months of July to September during both seasons. Majority of floods events were generated during July to September months. The low rainfall recorded during other months (October to June) could not produce runoff but supported crop survival in water stress periods. Although, comparison of both season showed 11% greater total annual average rainfall during first wheat season (248 mm) than the second wheat season (234 mm). But, the distribution of major rainfall events generating floods was comparable between pre and post improvement seasons.

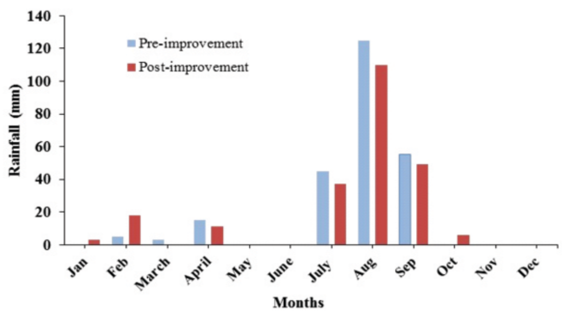

Fig. 3. Average monthly rainfall in catchment area during pre (2007) and post (2008) improvement seasons.

3.2. Rod kohi surface topography

The surface profile of the bottom of rod kohi during pre and post improvement period are given in figure 4. The surface topography was found undulated, irregular and silted during pre-improvement period. However, the surface topography of rod kohi was significantly improved after de-silting, levelling, grading and compaction.

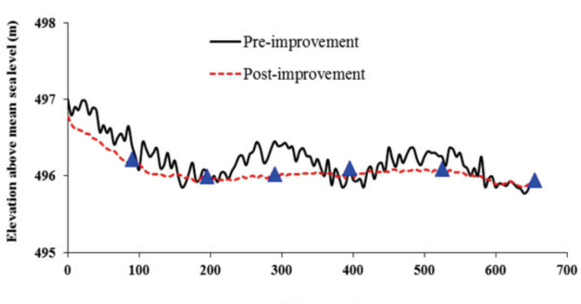

Fig. 4. Pre and post-improvement surface profile of rod kohi at six diversion points.

3.3. Rainwater harvesting

The capacity to harvest rainwater was increased after improvement. The water losses due to over topping and runoff water diversion away from rod kohi was minimised after improvement. The improvement resulted increased number of flood events interception at head (35%), middle (75%) and tail (350%). All these improvement was due to increased channel capacity and levelling activities (Fig. 5).

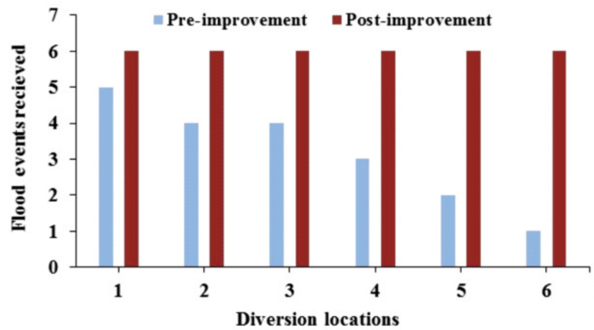

Fig. 5. No of flood events intercepted at six diversion points across rod kohi during experimental seasons.

The rod kohi improvement resulted increased inflow rates along the channel. For instance, the average water inflow rates were increased by 193%, 269%, 168% at tail, middle and head, sections respectively as given in figure 6.

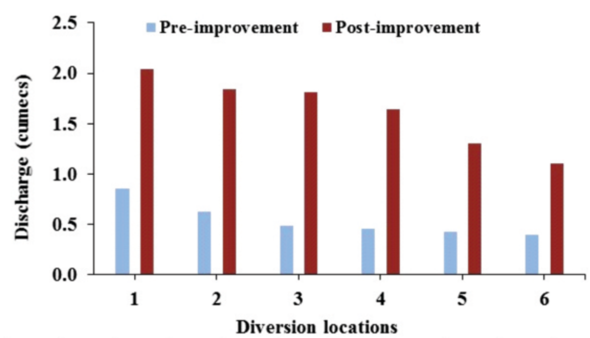

Fig. 6. Discharge (cumecs - m3/sec) of flood water intercepted at various diversion points during pre and post-improvement seasons.

The conveyance water losses along the rod kohi channel before improvement were 13% (head), 45% (middle) and 52% (tail) and after improvement were 5% (head), 15% (middle) and 41% (tail) respectively with respect to first diversion point as shown in figure 7.

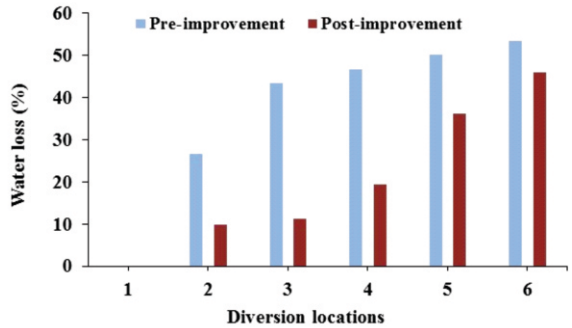

Fig. 7. Water losses at each successive diversion point with respect to first diversion point during pre and post-improvement seasons.

The increased inflow at various diversion points during post-improvement season reduced the time required to irrigate one hectare by 62%, 72% and 63% at head, middle and tail reaches respectively when compared with pre-improvement season as shown in figure 8.

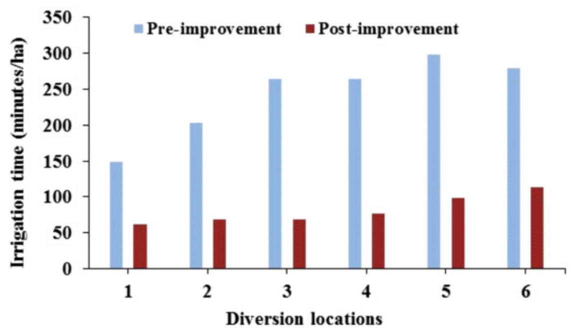

Fig. 8. Time for irrigating one hectare at various diversion pints along rod kohi during pre and post-improvement seasons.

3.4. Rod kohi command area

The improved rainwater harvesting during post-improvement season increased the irrigated command area along the rod kohi as given in figure 9. The increased command area after improvement was 7% (head), 23% (middle) and 79% (tail) respectively than pre-improvement command area.

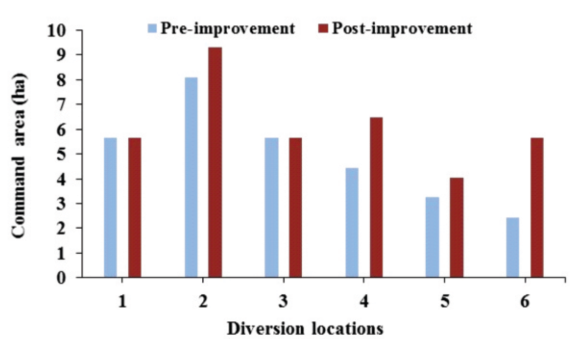

Fig. 9. Rod kohi irrigation command area during pre and post-improvement seasons.

3.5. Wheat yield

The improved irrigation water availability along the rod kohi caused increased wheat yield during post-improvement season. The average increased wheat yield was 172% (tail), 118% (middle) and 30% (head) respectively compared with pre-improvement season as given in figure 10.

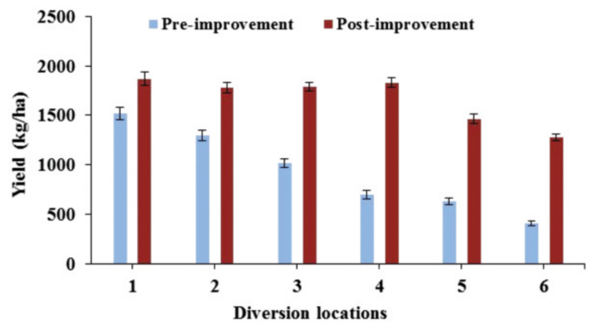

Fig. 10. Wheat crop yield at various diversion points across the rod kohi during pre and post-improvement seasons (vertical bars show standard deviation).

4. Discussion

Rod kohi systems generally deliver irrigation water instantaneously, thus water availability when required is not reliable. Moreover, the high velocities of flowing rod kohi water generally damage stream banks and degrade agricultural lands due to erosion erosion (Kamran and Shamshad, 2014). The negative impacts are generally difficult to avoid under traditional farmer managed conditions, as evidenced during the pre- improvement season. There was lack of resources and knowledge available for improvement of rod kohi in the study area, evidenced from poor surface topography, leaky earthen bunds, rodent activities and poor maintenance. Thus their farming was below subsistence level. Similarly, the unlevelled, irregular and silted channel caused hindrance in conveying the harvested rainwater from head to tail section of rod kohi. Moreover, the conventional irrigation methods practiced were less efficient, which caused larger application losses.

The application losses are generally very huge evidenced by application efficiencies in the range of 24 to 37% in rod kohi areas. Thus the water productivity and total irrigated command areas are negatively impacted, as demonstrated from this study. It has been observed that some time irrigation depth of 1.5 m is applied during a single irrigation in rod kohi areas, which exacerbate water losses (Ahmad and Choudhry, 2005). The limited water availability due to erratic rains necessitates the needs for efficient rainwater harvesting and timely frequent repair and maintenance of the rod kohis. Involvement of the local community in rehabilitation work is essential for making the rod kohi system efficient on sustainable basis. Improved rod kohis management may enhance rain water harvesting, thus can help in mitigating the drought impacts as well, frequently experienced in these remote areas (Ashraf et al., 2011). The involvement of community in the rehabilitation activities of rod kohi during the current study helped in making the study successful and the outcomes sustainable.

It was observed during the pre-improvement season that the Rod-Kohi floods were generally controlled by temporary earthen bunds, which diverted water towards the fields as already mentioned by Khan (1990). The embanked fields were flooded in sequence. In this way the fields lying nearest to the rod kohi got greater water compared with fields lying at tail ends or away from rod kohi. The increased volumetric capacity of the rod kohi and installation of proper diversion structures after improvement increased uniform distribution of flood water along the rod kohi. The increased rainwater harvesting capacity also increased the irrigated command areas and reduced the irrigation time per unit area after improvement.

Production from rod kohi areas is generally very low (Mirjat et al., 2011), as indicated by the reduced wheat yield during the pre-improvement season. Therefore, fortunes of the rod kohi farming community varies between subsistence and devastation, depending on water availability. The improved water availability and uniform distribution along the rod kohi increased wheat yield and farm income. Importantly, the increased wheat yield was positively reflected on the livelihood of local community benefitted.

5. Conclusions

Rehabilitation of rod kohi channel through appropriate aligning, de-silting, proper grading and compaction tends to increase rainwater harvesting, decrease water conveyance losses and improve water distribution uniformity across the rod kohi. This increased water availability may increase wheat yield and can lead to improved productivity and livelihood in rod kohi areas.

The active involvement of local community in the repair and maintenance of rod kohi system may enhance the performance of existing rod kohi system on sustainable basis. Moreover, the government spending should be increased for training the communities, developing infrastructure and promotion of best management practices in rod kohi areas, for increasing its contribution to the national economy in general and improving the livelihood of local communities in particular.

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