INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 14, No. 4, p. 107-117, 2019
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Spatio-temporal variation of equity in warabandi irrigation system: An analysis of pehur main canal system, Khyber Pakhtunkhwa, Pakistan

Muhammad Siyar*[1], Fazlur Rahman[2], Iffat Tabassum[2], Fazlul Haq[3]

[1]*Department of Geography, Government Post Graduate College, Swabi, Khyber Pakhtunkhwa, Pakistan*

[2]*Department of Geography, University of Peshawar, Pakistan*

[3]*Department of Geography, GC University, Faisalabad, Pakistan*

Article published on April 28, 2019

Key words: Canal irrigation system, Agricultural practices, Cropping seasons, Traditional water management, Equity issues.

Abstract

This paper explores the variation of equity of water distribution in Pehur Main Canal (PMC) irrigation system in the context of time and space. This canal operates under warabandi scheduling of water supply with the aim of achieving social justice. The data for this study was collected from the *Mogawar,* official outlet-wise register. The equity is measured on a scale of 0-1, 1 for complete equity and 0 for complete inequity. The data analysis shows most of values closer to 0. Temporally equity in Rabi season is better than the summer (early Kharif) season. The spatial distribution of equity during both Rabi and summer seasons is random in majority of secondary canals. Most of secondary canals have better equity in their middle and tail sections then their respective head and mid-sections. This situation points to lack of operational maintenance of irrigation system.

***Corresponding Author:** Muhammad Siyar ✉ Say_yaar@yahoo.com

Introduction

The rational distribution of water in an irrigation scheme depends on the water delivery and management system. Most of the irrigation schemes of Pakistan are operated under the Warbandi system of water distribution which was introduced at the end of nineteenth century (Malhotra, 1982, Latif and Sarwar, 1994). The objective of social justice in irrigation system is the most important cornerstone of the Warbandi in the regions where the sustainability of livelihood of masses is dependent on the irrigation supplies. The allocation of water resources should be on the equitable basis to achieve social justice. Abernethy, (1993) and Khepar *et al.*, (2000) have proposed the water distribution on equitable basis as a prerequisite for obtaining maximum output. These researchers are convinced that water users in the upper reaches of the irrigation schemes normally over irrigate their crops to increase productivity but in fact excess water will minimize it. The extra water can be given to parts of irrigation system receiving less than recommended water to realize maximum production so the overall productivity can be increased. Gorantiwar, (1995) and Kalu *et al.*, (1995) argue that whenever water supply is in shortage and is managed efficiently then the equity and productivity become contradictory issues. Hussain, *et al.*, (2011) and Seckler, *et al.*, (1988) argue that surface irrigation resources of Pakistan can provide only for 30 percent requirements of the irrigation. Water supply is lower than average when the outlet is situated at the tail distributary canal or the field is at the tail of water course (World Bank, 2002). This shortage of water has to be mitigated by equitable rationing of water to irrigate the entire Cultivable Command Area. To achieve the goal of equity water has to be allocated rationally throughout the system without giving preferences to areas having more productive lands over less productive ones.

The distribution of irrigation water amongst the co-users needs some mechanism for equitable appropriation. The most widely used method of water appropriation in the canal irrigated areas is warbandi. Sharma & Oad, (1990) define the warbandi system as allocation of irrigation time in proportion to the size of landholdings. Zardari & Cordery, (2010) propose the objective of warbandi to be the water distribution on equitable basis over the largest possible area. Seckler, *et al.*, (1988) describe the stated aim of warbandi as provision of irrigation water in such a way that each farmer on average will irrigate one-third of his land four times in a season. The researchers have defined it differently depending upon the prevailing system and their own perspective of equity. According to Abernethy, (1986) equity is the uniform spatial distribution of water and he also holds the equity as one of the basic objective of the warbandi distribution systems. Chambers (1988) takes the equity as not only equality in the distribution of resources to water users temporally but equity also means to maintain fairness, equality and impartial dealing in the appropriation of irrigation water. Equity is the water distribution amongst its users (Sam-Amoah & Gowing, 2001, Qureshi *et al.*, 1994, Arshad *et al.*, 2009). Sampath, (1988) and Kalu *et al.*, (1995) defined the equity as distribution of water on fairness and Oad & Sampath, (1995) defined the equity of water sharing between a range of allocation units in an irrigation system as the water deliveries based on spatial uniformity. Although the equity appears to be a simple phenomenon, in reality it is a complex issue. As the scientists differ in their views toward equity its performance measure is also the source of argument and is multifaceted as equity is dependent upon one's perception of fairness, fairness for whom, and fairness in what way, and this might differ widely in the irrigation system. According to Sampath, (1988) the perception of equity appears to be simple as it appeals to the ordinary idea of equality but it proves very complicated to be measured. The equity is described as a tool to rectify social injustice and its measurement becomes a multifaceted problem that defy easy formulations but in everyday life it can be examined in the background of rationing meager resources (Young, 1994).According to Abernethy, (1989) equity is multidimensional, which is dependent on various circumstances of water users such as the land holding size, type of soil or land

values, its proximity to the headwork and many more. The equity with respect to one parameter (family size) might be inequity in relation to another parameter (landholding size). In case of equity in irrigation water delivery it becomes very difficult to assess due to involvement of multiple factors in determining what is "fair share" (Molden & Gates, 1990, Maskey *et al.*,1994). There are many methods in statistics and economics that are supposed to measure equity (Cowell, 2011, Shah *et al.*, 2016). The problems related to equity do not end with the complexity of concepts in equity. There are many methods and indicators to calculate equity. On the basis of circumstances found in the irrigation system, a comprehensive definition of equity can be 'to distribute the input resources in an irrigation system (water and land) among the allocation units in a way to realize fair distribution of output in the form of crop produce or monetary benefits to achieve the stated objectives of social justice in the irrigation system'. Equity or fairness of water distribution to the water users throughout the irrigation system always remain top priority of the management strategy in irrigation system.

Material and methods

Study Area

The Pehur Main Canal (PMC) in District Swabi of Khyber Pakhtunkhwa was selected for this study (Fig. 1). It is a gravity driven irrigation system taking off from Ghazi barrage (GoKP. 2011). The irrigation season extend from the 1st March to 15th January of next year. The system remains close from 16th January to 28th of February for desiltation and necessary repairs. The irrigation year is divided into three separate growing seasons (GoNWFP. 1987). These are winter cropping season (Rabi), dry summer season (early Kharif) and rainy season (Kharif). In Rabi season little rainfall is received and the loss of water through evapotranspiration is small so the demand for irrigation remains low.

The rainfall is low in the summer season while the consumptive loss of water is high due to evapotranspiration so cropping is restricted and that's too requires frequent irrigation. During Kharif season maximum rainfall is received from monsoon. Since abundant rainfall in this part of the year, the crops does not need frequent irrigation only one or two protective irrigations are sometime required. The dams are filled to their capacity and the rivers are often flooded so the rainy Kharif season is not included in this study. Consequently, the Rabi and summer (early Kharif) crops were considered for the assessment of equity (Renault & Vehmeyer, 1999). In Rabi season the irrigation interval is from 07 to 14 days and one week or 07 days in summer season. A total of 262 outlets distribute water to farmers throughout the system (GoP. 2000).

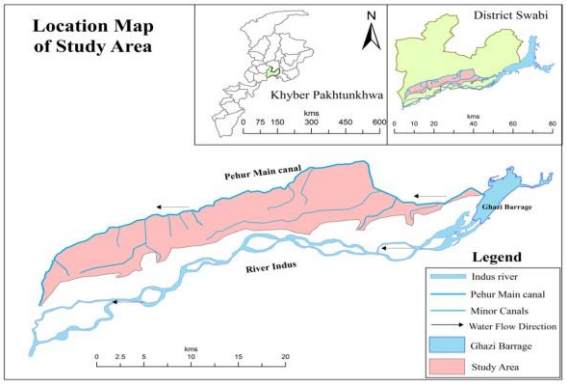

Fig. 1. Map.

Methodology

This study is based on official data available with the irrigation department. The divisional and sub-divisional offices of Provincial Irrigation Department (PID) keep records of the irrigation activities. Among the records kept are *Mogawar* 'Outlet-wise Registers' maintained by the irrigation staff. The 'Outlet-wise Registers' refer to designed discharge, area to be irrigated, area actually irrigated, crops assessed in each growing season, water tax (*abiana*) collected in each growing season. The PMC system was divided into head, middle and tail sections. The head section of the PMC system comprised of head of main canal, Topi minor, Zarobi minor, Kotha distributary and Kaddi minor, the middle section comprised of middle part of main canal, Zaida minor, Sheikh Dhari minor, Zakarya minor and Lahore minor and the tail-section of PMC system has tail of main canal, Thanodher distributary, Bazar minor, Manki minor and Jahangira minor. In the head, middle and tail of the PMC system, the parts of main canal, minors and

distributaries were again stratified into their respective head, middle and tail segments. The data of allocation units in these segments was analyzed for the assessment of equity temporally in the summer and Rabi seasons and spatially in the head, middle and tail of main and secondary canals.

Measurement of equity

For the assessment of equity in a water distribution system, first its objective has to be defined. Equity is defined as the provision of equal depth of water delivered all over the whole irrigated area (Zardari &Cordery, 2010). Statistical methods are generally applied to evaluate the equity of schemes. Bos *et al*., (2005, p.2) describe assessment of equity performance in the irrigation system as the "observation on regular and orderly basis, recording and understanding of irrigation activities with stated aim of constant improvement". Molden and Gates, (1990) explained numerous methods of measurements for the evaluation of irrigation systems, which are performance measures related to equity, dependability, adequacy and efficiency. These measures of performance can be subdivided into management, structural and actual contribution. They are also of the view that the performance assessment of irrigation scheme is only measurable in terms of its objectives and for this purpose first the objectives of water delivery in irrigation scheme has to be defined.

The performance assessment indicators of water users organizations in the Province of Punjab has given highest weightage to the maintenance of equity by recording and monitoring of water channels and outlets (PIDA, 2008, UlHaq, 2010). This indicates that the maintenance of equity throughout the irrigation scheme is most important objective of warabandi system. Although equity remains the highest priority in warbandi system, the Department of Irrigation in Provinces does not have any systematic measurement of equity. Conversely, for the substitute measurement of equity the only available method is to gauge the water depth at the tail end of canal, called 'tail-gauge'. Irrigation staff assumes the system operation as satisfactory and equitable if the tail-end gauge shows recommended depth of flow. But the measurement of flow at the tail-end only show the amount of water reaching the tail of canal and does not give any indication that how equitable is the water distribution in the system. Awan *et al*., (2016), Clemmens & Dedrick, (1994), Clemmens & Bos, (1990) suggested measure of delivery performance ratio (the ratio of actual flow to the targeted flow of water) as a simple measurement of performance for the operation of irrigation system in a warabandi mode. In warbandi system, the targeted flow of water would be the full capacity of the irrigation channel. For a given minor or secondary canal, the desirable ratio of delivery performance would be 1.0. For a set of minors or secondary canals, the desirable average delivery performance ratio would be 1.0 and a minimum coefficient of variation or variance. Ratio of delivery performance is a key statistical method for the assessment of performance in warabandi irrigation systems.

Targeted resources for the measurement of Equity

Researchers have proposed measurement of equity in a variety of ways. Malhotra & Raheja, (1984) and Sampath, (1988) propose the proportion of entire irrigated area (total wetted area by each irrigation throughout the irrigation period) to entire Culturable Command Area (CCA) as the parameter for measurement. Seckler *et al*., (1988) also prefer total irrigated area measurement parameter. Bos, (1997) assumed the use of flow rates for performance measurement while El-Awad *et al*., (1991) advocates the use of volume. Bos *et al*., (1994) used flow as parameter for the measurement of equity as ratio of delivery performance. The selection of parameter has to be based on the data availability, and ease of data collection of the resource for which the equity is required, when the scheme is operational. Based on the management strategy of the irrigation system for achievement of certain objectives, equity can be for water allocation, area allocation, crop production and total economic benefits. In this study water supply is the parameter of interest in calculating equity in the irrigation system. In water allocation the parameter to be considered for equity can be volume, depth of

water applied and discharge. The discharge and depth are necessarily associated with supply duration and area therefore in this study the allocated and delivered volume was used to measure equity for allocation of water during Rabi and Summer seasons and also in the head, middle and tail sections of main, secondary and tertiary canals.

Base for measurement of equity

Equity can be measured on the basis of resources allocated (planning) and resources delivered (operation). The allocated inputs might be proportional to the size of land holding, irrigation demand of the land, land type and the family size in case of equity or may be disproportional on the basis of bias towards the certain stakeholders or under certain conditions in the irrigation scheme if the objective of the scheme may require so. The irrigation scheme in question is operated under the warbandi system and the objectives of warbandi are to distribute water among the water users, proportional to their landholdings without any bias towards or against any of the water users. In this study the measurement of equity is based on the landholding size (Malhotra & Raheja, 1984, Sampath, 1988, Seckler *et al.*, 1988, Wegerich, 2007, El-awad, *et al.*, 1991and Bos *et al.*, 1994).

Parameter for measurement of equity

According to Gorantiwar & Smout (2005) the characteristics of all allocation units (irrigation outlets) are different from each other therefore the measurement of equity directly from the quantitative parameter; i.e. volume of water is not desirable. The Cultivable command area of all outlets is dissimilar. To lessen this effect, the contribution of the volume of water towards the allocation unit in relation to the contribution of its landholding size was computed for all the allocation units. This gave us the allocation ratio which was calculated from the ratio of actual allocation and the targeted allocation proportion. So equity was actually calculated for the allocation ratio of each outlet. This process is explained in Equations (1) and (2).

Measurement of equity indicators

Although there are different concepts of equity and methods for its measurement but it should help to understand the extent of change in the water allocation and land resources to multiple units of allocation in the irrigation system and as well the disparity in allocation of these resources in various sections of the canals i.e. head, middle and tail. There are several ways to measure equity. The modified interquartile ratio which states that the "mean volume of water received by all land in the best part of the scheme, divided by the mean volume received in the poorest part of the scheme" (Abernethy, 1986 p.25). The values vary from 1 to infinity. But for the comparison and understanding of equity it should vary from 0 to 1, 1 for complete equity and 0 for complete inequity. Therefore, the modified Inter-Quartile Ratio (IQR) as Inter-Quartile Allocation Ratio (IQAR) was used to measure equity at different levels of a canal i.e. head, middle and tail during Rabi and summer seasons. The modified Inter-Quartile Allocation Ratio can be elaborated as "the mean of allocation ratio of the poorest parts divided by the mean allocation ratio of the best parts" (Gorantiwar, 2006). The proposed formulation is elaborated in Equation (4).

For thorough understanding of the concept of equity it is essential to identify its temporal and spatial variation. The variation of equity on seasonal basis and in different sections of main, secondary and minor canals is an important tool to assess distributional performance of irrigation water. For rational distribution the equity values will be closer to 1 and for irrational distribution the values will be closer to 0. The indicators for spatial and temporal measurement of equity are explained by the following equations 1-4.

Allocation ratio

$$Rai = \frac{\lambda ai}{\lambda di} \qquad (1)$$

Rai is the ratio of allocation of *i*th outlet (on main and secondary canals), λai the proportion of actual allocation for *i*th outlet, λdi the proportion of planned allocation for *i*th outlet.

$$\lambda \mathrm{di} = \frac{\Delta di}{\sum_{i=1}^{na} \Delta \mathrm{di}} \qquad (2)$$

Where Δdi is the landholding size assigned to *i*th outlet; *na* total number of outlets, Δdican be equal to the cultivable command area of *i*th outlet (acres). In this case $\sum_{i=1}^{na} \Delta \mathrm{di}$ is cultivable command area of main, secondary or minor canal.

$$\lambda \mathrm{ai} = \frac{\Delta ai}{\sum_{i=1}^{na} \Delta \mathrm{ai}} \qquad (3)$$

where Δai is the allocation of water to *i*th allocation unit. Thus $\Delta ai = Vi \times Ai$ (water allocated) where Ai is the allocated area for irrigation or irrigated of *i*th outlet on main, secondary or minor canal, Vi the allocated volume of water or delivered to the *i*th outlet.

Inter-Quartile Allocation Ratio (IQAR)

$$E\mathrm{i} = \frac{R_a \mathrm{pq}}{R_a \mathrm{bq}} \qquad (4)$$

where *E*i stands for the measurement of equity for the irrigation system based on IQRA, $R_a{}^{\mathrm{bq}}$ is the mean of allocation ratios of the best part of the scheme, $R_a{}^{\mathrm{pq}}$ is the mean of allocation ratios of the poorest part of the scheme.

Equity can be measured for different sections i.e. head, middle and tail of the main, secondary and minor canals. This was done by stratifying these canals into head, middle and tail sections. The outlets were considered in these sections for analysis and also this procedure was repeated for Rabi and summer season.

Result and discussions

Equity is one of the most important objectives of the '*warabandi*' system of irrigation water distribution. It is related to social justice where the water users have to get equitable water throughout the irrigation system. The maintenance of equity is important due to the fact that the livelihood of farmers having small holdings mostly depend on the irrigation water. The equity is measured on a scale of one to zero (0-1), one (1) for complete equity and zero (0) for complete inequity. In the Pehur Main Canal system overall measure of equity indicator remains low throughout the system with exception to very few instances where it rises to reasonably high level. The Rabi season has a relatively higher equity than the summer season. Equity in different sections of the PMC system during Rabi and summer seasons is discussed below.

Equity of Pehur Main Canal system during Rabi season

Rabi cropping season extends from October to March. During this season the crop water requirement remains low due to lower evapotranspiration and the direct losses from water surface are low. The rainfall received during this season is low. The general shortage of water in this season owing to low rainfall and low level of storage in reservoirs is mitigated by extending the irrigation interval from seven (7) to fourteen (14) days. The week-wise rotation among the secondary canals improves the water supply in the system.

Equity in Head Section of Pehur Main Canal system (Rabi)

In the head section of the PMC system, the equity remains lower than the system average as whole. The only part of this section where the equity values are better than the system average value is recorded in the head of Zarobi minor (0.369). The part of the main canal included in this section has the lowest equity values in the head (0.009) and middle (0). The main and secondary canals in this section have better equity values in the tail (0.087, 0.042, 0.214, and 0.24) than the mid-section with the exception of Kaddi minor (Table 1). This indicates that the farmers in the middle reach of these canals does not receive fair share of water either because the system is operated below recommended level or some other reason. The only secondary canal in the head section having normal sequence of change is the Kaddi minor where the equity values decrease from head to tail (0.277, 0.138 and 0.125).

The inter-canal comparison shows no proper sequence of change from upper head to lower head of the system in head, middle and tail sections. The main canal included in this part of the system has lowest equity and highest by the Zarobi minor. The average equity values for the main and secondary canals in descending order from upper to lower head are (0.038, 0.052, 0.216, 0.208 and 0.18).

These and the intra-canal figures show that the distribution of water is irrational among the constituent canals and within their different sections.

Table 1. Equity of head-section of PMC system in Rabi season.

S. No	Name of Canal	Rabi Season			
		Head	Middle	Tail	Average
1	PMC Main(head-section)	0.009	000	0.087	0.038
2	Topi Minor	0.089	0.025	0.042	0.052
3	Zarobi Minor	0.369	0.067	0.214	0.216
4	Kotha Distributary	0.244	0.141	0.240	0.208
5	Kaddi Minor	0.277	0.138	0.125	0.18

Source: GoKP (2012)

Equity in Middle-Section of Pehur Main Canal system (Rabi)

The mid-section shows better equity than the head of the system. Although it is not up to the mark but in some parts the values rise to satisfactory level e.g. tail of Sheikh Dhari minor (0.886), head of Zakarya minor (0.78) and head of Lahore minor (0.726). The intra-canal variation of equity is not systematic in the main, Sheikh Dhari and Lahore minor. In the main canal there is successive increase in equity from upper to lower mid-section (0.143, 0.325 and 0.487), Sheikh Dhari minor has a much higher equity at the end than head and middle while Zakarya minor has low equity in the middle than the tail section (Table 2). The inter-canal variation of equity in the head, middle and tail of the constituent canals has no logical sequence. Theoretically the ideal situation would be higher equity at the upper mid-section decreasing towards the lower mid-section of the system. The average values of equity for constituent canals from upper to lower middle section of the system are (0.318, 0.24, 0.450, 0.419 and 0.528). This indicates a lack of equity among constituent canals in this part of the system.

Equity in Tail-Section of Pehur Main Canal system (Rabi)

In this section the upper and middle tail have low equity values due to less than recommended flow of water in the main canal. The lower flow of water causes irrational behavior of the outlets and secondary canals. Bazar minor has the lowest equity values in head (0.199), middle (0.078) and tail (0) in this section as it draws water from the Thanodher distributary which is already water deficient (Table 3). The Manki and Jahangira minors located at the tail of the system have better equity values. These tail end canals draw whatever water is left in system as direct outlets are unable to draw water from main canal due to their structural design. Manki minor has highest equity in the tail (0.467) than its head (0.388) and middle (0.301).

Table 2. Equity of middle-section of PMC system in Rabi season.

S. No.	Name of Canal	Rabi Season			
		Head	Middle	Tail	Average
1	PMC Main (mid-section)	0.143	0.325	0.487	0.318
2	Zaida Minor	0.565	0.109	0.046	0.24
3	Sheikh Dhari Minor	0.286	0.180	0.886	0.451
4	Zakarya Minor	0.780	0.357	0.121	0.419
5	Lahore Minor	0.726	0.316	0.543	0.528

Source: GoKP (2012)

The inter-canal comparison in this part of the system show erratic behavior having no logical sequence of change in equity from upper to lower tail. The main canal (0.144, 0.169), Thanodher distributary (0.290, 0.117) and Bazar minor (0.199, 0.078) have low equity values than the Manki (0.388, 0.301) and Jahangira minor (0.519, 0.315) in their respective head and middle sections. The values of equity for these canals in their tail-sections have a much wider range from (0.467) for Manki Minor to (0) for Bazar Minor (Table 3). These values reveal irrational distribution of water among different canals in this section.

Equity of Pehur Main Canal system during Summer Season

Pre-monsoon summer season is the hottest and driest period of the year. The rainfall is very low and evapotranspiration is very high. The high consumptive use of water for growing crops in this season coupled with losses through direct evaporation, theft and other interferences put stress on the irrigation system. Crops grown in this season like Tobacco, Watermelons and fodder are irrigation intensive. Tobacco and Watermelons are high value crops usually needs high capital investment. These conditions create an overall water shortage throughout the system.

Due to limited supply of water during this season the cropping remains confined to smaller area. The water turns on the same outlet or among different outlets are commonly exchanged between farmers to make adjustments for crop water demand. These arrangements necessarily affect the equity in different sections of the irrigation system.

Table 3. Equity of tail-section PMC system in Rabi season.

SN	Name of Canal	Rabi Season			
		Head	Middle	Tail	Average
1	PMC Main (tail-section)	0.144	0.169	0.060	0.124
2	Thanodher Distributary	0.290	0.117	0.259	0.222
3	Bazar Minor	0.199	0.078	000	0.092
4	Manki Minor	0.388	0.301	0.467	0.385
5	Jahangira Minor	0.519	0.315	0.190	0.341

Source: GoKP (2012)

Equity in Head-Section of Pehur Main Canal system (Summer Season)

The overall equity remains lower than the Rabi season in this part of the system. On individual basis only the main canal in its head and middle and Topi minor in the head show better position than the Rabi season while all other values are relatively lower than the corresponding Rabi values. Besides Kaddi minor all other canals have better equity values in the tails than the middle sections. The highest value of equity observed in the head of the system is in the head of Zarobi minor (0.232) and the lowest in the middle of Topi minor (0.009). Topi minor is located at the very head of the PMC system (Table 4).

The inter-canal variation of equity demonstrates an increasing trend from head of main to head of Kaddi minor. The middle and tail sections of these canals have haphazard values of equity indicator. The average equity values show an increase from main to Zarobi minor and then a decrease up to Kaddi minor. These variations indicate poor performance of head of the PMC system on the basis of equity indicator.

Table 4. Equity of head-section of PMC system in summer season.

SN	Name of Canal	Summer Season			
		Head	Middle	Tail	Average
1	PMC Main (head-section)	0.028	0.033	0.057	0.039
2	Topi Minor	0.147	0.009	0.036	0.064
3	Zarobi Minor	0.232	0.068	0.085	0.128
4	Kotha Distributary	0.215	0.019	0.110	0.115
5	Kaddi Minor	0.219	0.098	0.016	0.111

Source: GoKP (2012)

Equity in Middle-Section of Pehur Main Canal system (Summer Season)

The mid-section of the Pehur Main Canal system has a slightly lower equity compared to Rabi season but has a better position as compared to the head and tail sections of the system. The highest values of equity for PMC system as a whole during Summer Season are in mid-section which are (0.85) head of Zakarya minor, (0.792) head of Lahore minor and (0.721) tail of Sheikh Dhari minor (Table 5). Individually the main canal has an increasing equity from upper to lower mid-section (0.132, 0.212 and 0.382), Sheikh Dhari has higher equity in the tail than in the head and middle sections, Zakarya and Lahore minor have more equity in the tails than their respective mid-sections.

Table 5. Equity of Middle-section of PMC system in Summer Season

SN	Name of Canal	Summer Season			
		Head	Middle	Tail	Average
1	PMC Main (mid-section)	0.132	0.212	0.382	0.242
2	Zaida Minor	0.365	0.114	0.115	0.198
3	Sheikh Dhari Minor	0.318	0.130	0.721	0.390
4	Zakarya Minor	0.850	0.004	0.128	0.327
5	Lahore Minor	0.792	0.185	0.476	0.484

Source: GoKP (2012).

The inter-canal comparison shows a successive increase in the equity values from the upper to lower mid-section of the system in the head sections of constituent canals (0.132, 0.365, 0.318, 0.85 and 0.792). The middle sections of these canals record a declining trend from upper to lower mid-section of the system (0.212, 0.114, 0.13, 0.004 and 0.185) with exception to Lahore minor (Table 5). The tail sections have no logical sequence of change from upper to lower mid-section of the system (0.382, 0.115, 0.721, 0.128 and 0.476).

The average equity values from the upper to lower mid-section of the system are (0.242, 0.198, 0.389, 0.327 and 0.484). These irregular variations of equity values show a lack of smooth functioning of the irrigation system.

Equity in Tail-Section of Pehur Main Canal system (Summer Season)

In the tail of Pehur Main Canal irrigation system, the tail of main canal performs better than the Rabi season while the performance of secondary canals is lower than their performance of Rabi season. The worst condition of equity is observed in the middle and tail of Bazar minor (0.207, 0, and 0). This means that in the middle and tail of Bazar minor there is complete inequity. The main canal, Manki and Jahangira minor have higher equity in the middle rather than the head sections. Thanodher distributary has more equity in the tail than the head and middle (Table 6). This indicates poor operational maintenance of system inequitable distribution of water in different sections of canal.

Table 6. Equity of tail-section of PMC system in Summer Season.

SN	Name of Canal	Summer Season			
		Head	Middle	Tail	Average
1	PMC Main (tail-section)	0.164	0.202	0.071	0.146
2	Thanodher Distributary	0.171	0.105	0.211	0.162
3	Bazar Minor	0.207	0	0	0.069
4	Manki Minor	0.069	0.179	0.107	0.118
5	Jahangira Minor	0.306	0.369	0.070	0.248

Source: GoKP (2012)

The inter-canal comparison show that the heads of main and minors demonstrate an increasing trend from upper to lower tail of the system with exception to head of Manki minor (0.164, 0.171, 0.207, 0.069 and 0.306). The middle and tail sections of the main and minor does not show a proper sequence of change. The water distribution among different canals in the system is not equitable as evident from the equity values.

Conclusion

The equity indicator of performance is measured on a scale of 0-1. The 1 represents complete equity while 0 indicates complete inequity. Analysis of the data reveals that majority of the values lie closer to 0 while very small number of values is closer to 1. This situation demonstrates that water distribution throughout the irrigation system is inequitable. This means that the system is functioning in more inequity than equity. It also reveals another aspect of the equity distribution in the head, middle and tail of the PMC system and of the secondary canals. On the PMC system level the middle and tail sections are performing better than the head section of the system. On the individual basis most of the canals show better equity values in the tail than the middle sections and in some cases even better than the head sections. This situation highlights the lack of operational maintenance on behalf of the Irrigation department. The outlets at the head of canals are installed at a height from the base of canal to draw recommended volume of water when system operates at or above 70% of full capacity. When the flow in the canal drop below 70% of the capacity then these structures behave abnormally, drawing less water at the head and more in the middle and tail.

References

Abernethy CL. 1993. Indicators of the Performance Irrigation Water Distribution Systems. International Irrigation Management Institute: Colombo, Sri Lanka.

Abernethy CL. 1986. Performance Measurement in Canal Water management: A Discussion. ODI-IIMI Irrigation Management Network Paper 86/2d pp. 25.

Abernethy CL. 1989. Performance criteria for irrigation systems. In J.R. Rydzewski and K. Ward (Eds.) Proceedings on International Conference on Irrigation Theory and Practice, University of Southampton, UK, 12–15 September, 1989.

Arshad M, Ahmad N, Usman M, Shabbir A. 2009. Comparison of water losses between unlined and lined watercourses in Indus basin of Pakistan. Pakistan Journal of Agricultural Sciences **46(4),** 280-284.

Awan UK, Anwar A, Ahmad W, Hafeez M. 2016. A methodology to estimate equity of canal water and groundwater use at different spatial and temporal scales: a geo-informatics approach. Environmental Earth Sciences **75,** 409.

Bos MG. 1997. Performance indicators for irrigation and drainage. Irrigation and Drainage Systems **11,** 119-137.

Bos MG, Burton MA, Molden DJ. 2005. Irrigation and drainage performance assessment: practical guidelines. CABI, Wallingford, vol viii, 2 p.

Bos MG, Murray-Rust DH, Merrey DJ, Johnson HG, Snellen WB. 1994. Methodologies for assessing performance of irrigation and drainage management. Irrigation and Drainage Systems **7,** 231-261.

Chambers R. 1988. Managing Canal Irrigation: Practical Analysis from South Asia. Cambridge University Press, Cambridge, UK.

Clemmens AJ, Bos MG. 1990. Statistical methods for irrigation system water delivery performance evaluation. Irrigation and Drainage Systems **4(4),** 345-365.

Clemmens AJ, Dedrick AR. 1994. Irrigation techniques and evaluations (pp.64–103). Advanced Series in Agricultural Sciences, Vol. 22. Berlin: Springer.

Cowell FA. 2011. *Measuring inequality* (3rd ed.). New York, NY: Oxford University Press.

El-awad OM, Gowing JW, Mawdsley JA. 1991. An approach to multi-criterion evaluation of irrigation system performance. Irrigation and Drainage Systems **5(1),** 61-75.

GoKP. 2011. Provincial Irrigation Department, Khyber Pakhtunkhwa, Peshawar.

GoKP. 2012. Unpublished data collected from Outlet-wise register (*Mogawar*) Irrigation Division-II, District Swabi.

GoNWFP. 1987. General Operation and Maintenance Procedures of Canal Management, Vol. 1. Irrigation and Power Department, Peshawar, Pakistan.

GoP. 2000. District Census Report of Swabi, Population Census Organization of Pakistan, Islamabad.

Gorantiwar SD. 1995. A model for planning and operation of heterogeneous irrigation schemes in semi-arid regions under rotational water supply. Ph. D. Thesis, Loughborough University of Technology, Loughborough, Leicestershire, UK.

Gorantiwar SD, Smout IK. 2005. Performance assessment of irrigation water management of heterogeneous irrigation schemes: 1. A framework for evaluation. Irrigation and Drainage Systems **19(1),** 1-36.

Gorantiwar SD, Smout IK. 2006. Model for performance based land and water allocation within irrigation schemes. Irrigation and Drainage Systems **20,** 345-360.

Hussain I, Hussain Z, Sial M, Akram W, Farhan MF. 2011. Water balance, supply and demand and irrigation efficiency of Indus Basin. Pakistan Economic and Social Review **49(1),** 13-38.

Kalu IL, Paudyal GN, Gupta AD. 1995. Equity and efficiency issues in irrigation water distribution. Agricultural Water Management **28(1995),** 335-348.

Khepar SD, Gulati HS, Yadav AK, Brar TPS. 2000. A model for equitable distribution for canal water. Irrigation Science **19,** 191-197.

Latif M, Sarwar S. 1994. Proposal for equitable water allocation for rotational irrigation in Pakistan. Irrigation and Drainage Systems **8,** 35-48.

Malhotra SP. 1982. The Warbandi System and its Infrastructure. Central Board of Irrigation and Power 15(7).

Malhotra SP, Raheja SK. 1984. A Methodology for Monitoring the Performance of Large Scale Irrigation System: A Case Study of Warbandi System of North India. Agricultural Administration **17,** 231-259.

Maskey RK, Weber KE, Loof R. 1994. Equity aspects of irrigation development: Evidencefrom two systems in the hills of Nepal. International Journal of Water Resources Development **10,** 431-443.

Molden DJ, Gates TK. 1990. Performance measures for evaluation of irrigation-water delivery systems. Journal of Irrigation and Drainage Engineering **116(6),** 804-823.

Oad R, Sampath RK. 1995. Performance measure for improving irrigation management. Irrigation and Drainage Systems **9(4),** 357-370.

Punjab Irrigation and Drainage Authority. 2008. Performance Monitoring and Evaluation of Farmers Organizations. PIDA H/Qs, Irrigation Secretariat Premises: Old Anarkali, Lahore, Pakistan.

Qureshi SK, Hussain Z, Nisa Z. 1994. An Assessment of Warabandi (Irrigation Rotation) in Pakistan: A Preliminary Analysis. The Pakistan Development Review **33, 4(II),** 845-855.

Renault D, Vehmeyer PW. 1999. On reliability in irrigation service preliminary concepts and application. Irrigation and Drainage Systems **13(1),** 77-105.

Sam-Amoah LK, Gowing JW. 2001. Assessing the performance of irrigation schemes with minimum data on water deliveries. Irrig Drain **50(1),** 31-39.

Sampath RK. 1988. Equity Measures for Irrigation System Performance Evaluation. Water International **13,** 25-32.

Seckler D, Sampath RK, Raheja SK. 1988. An index for measuring the performance of irrigation management systems with an application. Water Resources Bulletin **24(4),** 855-860.

Shah MMA, Anwar AA, Bell AR, Haq Z. 2016. Equity in a tertiary canal of the Indus Basin Irrigation System (IBIS). Agricultural Water Management **178,** 201-214.

Sharma D, Oad R. 1990. Variable-time model for equitable irrigation water distribution. Agricultural water management **17(4),** 367-377.

Ul Haq A. 2010. Performance of farmers' organizations in Punjab, Pakistan: The challenges and way forward. Irrigation and Drainage **59,** 23-30.

Wegerich K. 2007. A critical review of the concept of equity to support water allocation at various scales in the Amu Darya basin. Irrigation and Drainage system **21,** 185-195.

World Bank. 2002. Pakistan poverty assessment. Poverty in Pakistan: Vulnerabilities, social gaps, and rural dynamics. Washington, DC: World Bank.

Young HP. 1994. Equity: In theory and practice. Princeton, NJ: Princeton University Press.

Zardari NUH, Cordery I. 2010. Estimating the effectiveness of a rotational irrigation delivery system: A case study from Pakistan. Irrigation and Drainage **59,** 277-290.