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Can Efficiency Offset Reliability in Irrigation Systems?

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Abstract: One of the biggest challenges which the irrigation agencies often face is the dual objective of efficiency and reliability in the irrigation system management. Is higher physical efficiency of irrigation enough to guarantee the success of the system? An attempt to answer this question led us to evaluate the performance of the irrigation water delivery on the independent branch of Wushantou reservoir in Taiwan Chianan Irrigation Association of which the lateral serves four tertiary canals. Adequacy, efficiency, equity and reliability of irrigation water delivery to the farmers under the supervision of Madao Irrigation Station Control were assessed for four rice crop growing seasons in 2005 and 2006. The results showed a very high irrigation efficiency of about 94.5% over the 2 years while the values of adequacy indicators were 0.83 and 0.77 resulting to a fair and poor performance in 2005 and 2006, respectively. The drop of adequacy performance of about 7.2% in 2006 was mainly due to the uneven rainfall distribution and poor estimation of crop water requirement. The values of reliability index of 0.22 and 0.24 were regarded as a very poor performance over the two years. With such reliability, it would be difficult for farmers to make necessary adjustments of their cultures since they are not ensured of receiving adequate water at right time in spite of high efficiency. Although optimal irrigation efficiency can lead to substantial water conservation and increased crop yields, higher reliability can provide the inducement for farmers to invest more. Therefore, increasing dependability rate is greatly required in this irrigation branch. Improving water delivery system requires upgrading farmers' confidence to operate the system in addition to the good physical efficiency and accurate crop water requirement estimation.

Key words: Irrigation water delivery . performance indicators . Chianan

INTRODUCTION

It has been observed since the mid 1960 that most irrigation systems operate below their potential [1]. This is due to uncertainties on the availability of the water resources that generally lead to failure in reaching the level of performance expected by irrigation system [2]. Under these conditions, most irrigation project managers face challenges of ensuring how well their system performs. Very often, they were confronted with the dual objective between the efficiency and the reliability performance of the irrigation management. To address this problem, performance assessment has been prioritized as the most critical element to improve irrigation management [3]. The evaluation of the water delivery performance in irrigation systems is needed to either bring some improvement in the physical network or to reconsider the existing management rules. Small and Svendsen [4] remarked that the assessment of irrigation performance is evidently important to managers of irrigation projects, but it has been seriously neglected by those who allocate public funds for irrigation and by researchers. Performance studies are being used with increasing frequency to promote the objective of sustainability, thereby helping to improve the system operation, assess the general health of a system, evaluate impacts of intervention, diagnose constraints, better understand determinants of performance and compare the performance of a system with other systems or within the same system over the time [5]. It is not an easy task to do since irrigation performance is significantly affected by interactions between application system characteristics and water supply characteristics.

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Several indicators were developed by researchers [6-13] to measure irrigation system performance. These indicators are predictability, water use efficiency, reliability, equity, timeliness and adequacy. These indicators can be related to financial, economical, management, water delivery objectives etc. In the current study, four indicators namely adequacy, efficiency, equity and dependability were used to assess the performance of water delivery to farmers under Madao Irrigation Working Station of Chianan Irrigation Association (CIA) in the south-western part of Taiwan. For more than a decade this Irrigation Association was subjected to major modification in its management system and the vagaries of the climate. Farmers were not required to pay charges related to the use of water provided by the Wushantou reservoir any more. In addition, the region experienced frequent drought spells due to uneven distribution of rainfall that affects considerably water delivery system to the farmers. Also, due to the urbanization breakthrough and the high economic growth, agricultural activities began to decrease and the irrigation water is shared with municipalities and industrial sector. In these conditions evaluation of the performance of he water delivery system becomes essential to ensure good functioning of irrigation water distribution. The objective of this study as to assess the water delivery system of six tertiary canals that belong to the independent system of CIA as to identify its weaknesses in order to improve both irrigation network efficiency and reservoir management

MATERIALS AND METHODS

Study area: The study area is a portion of Chianan Irrigation Association. This Irrigation Association is located at 23°13'N, 120°11'E in the south-western part of Taiwan (Fig. 1) and is one of the 17 Irrigation Associations present in Taiwan. Covering a total irrigated area of 64066 ha in 2007, Chianan IA is the largest Irrigation Association. Wushantou* reservoir has an effective capacity of 59,550,000 m3 and presently remains the main water source to supply domestic, industrial and agricultural demands in the area. The area has a subtropical climate. The maximum and minimum temperatures are 33°C and 13°C, respectively with a daily evaporation of 3.5 mm.

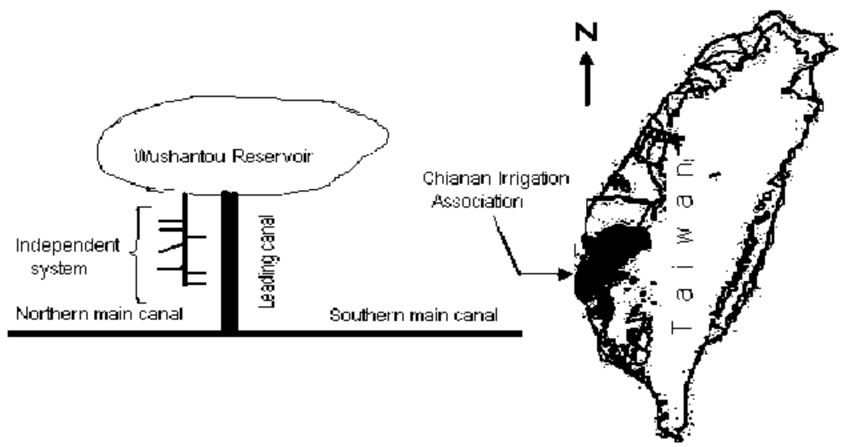


Fig. 1: Location of Chianan Irrigation Area and schematic diagram of the independent system of Wushantou reservoir

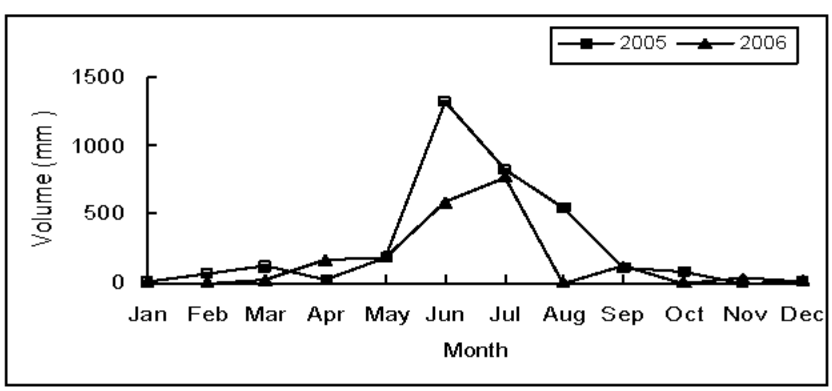


Fig. 2: Monthly variability of rainfall over years 2005 and 2006

The soil composition based on the textural triangle classification is loam with 34.94% sand, 47.95% silt and 17.11% clay. Chianan Irrigation Association witnesses an average annual rainfall of 2500 mm of which 80% is concentrated in the wet season from May to October. Figure 2 displays the variability of rainfall during the two years 2005 and 2006 where the annual averages were 277 mm and 160 mm, respectively. Globally rains were more abundant in 2005 than 2006 but were poorly distributed through the growing season. For example in June 2005 the region received more than 1300 mm of rains in one week. This surplus of volume represents about 40% of the total annual rainfall of the year 2005 and 70% of the total amount of rainfall for the year 2006.

This explains the fact that there is not only a large variability of rainfall from one season to another but also a significant variation from one month to month within the same year.

Seventy-two Irrigation Working Stations located downstream the reservoir are in charge of water distribution in the main and lateral canals, investigation of conveyance losses, record of rainfall and discharge and inspection of irrigation facilities.

Determination of crop water requirement: The tertiary canals selected are located downstream to the independent lateral canal of Chianan Irrigation land (Fig. 1). Data on actual irrigated crop areas within the selected tertiary canals were obtained for the irrigation seasons 2005 and 2006. Data related to crops planting dates were obtained from Irrigation working stations. Climatic data were provided by the Regional Weather Services located in Tainan city. Reference evapotranspiration ETo was estimated basing on four methods namely Blaney-Criddle, Penman Monteith [14], Radiation and A-Pan methods to determine net crop irrigation requirements expressed herein on a monthly basis. Figure 3 shows the variation of the reference evapotranspiration computed using these different methods. Results show that Blaney-Criddle method overestimates the reference evapotranspiration while A-Pan underestimates ETo. Values obtained by Radiation and Penman Monteith are closer over the 12 months. Crop water requirements used in the present study are those computed by the Penman Monteith method as it is in practice in this irrigation area. Using REF-ET model and FAO 56 Penman-Monteith method, Kuo *et al.* [15] estimated that the annual reference evapotranspiration was 1268 mm in Chianan Irrigation Association. In the paddy fields, the irrigation water requirements and deep percolation are 962 and 295 mm, respectively, for the first rice crop and 1114 and 296 mm for the second rice crop

Net crop irrigation requirements for each tertiary were determined according to cropping pattern. Total irrigation requirement for each tertiary (Q_R) was calculated using net crop irrigation requirements for each tertiary, tertiary irrigated area, conveyance efficiency (Ec) and water application efficiency (*E*a).

Measurement of the water discharges and crop data collection: The portion of the irrigation area under consideration in the study consists of six tertiary canals supplied by a lateral canal that forms an independent sub-system because it is supplied with water directly derived from the reservoir. These tertiary canals convey water to two irrigation zones namely Zhong Xie and Wujia. The deliveries were measured at the outlet of the tertiary canals over 4 irrigation seasons (two seasons in 2005 and two seasons in 2006). Investigations were conducted before each irrigation season by the Irrigation Working Station to verify the functioning conditions of the network and to determine farmers' water needs for the growing season. Flow depths were recorded at regular intervals at farm ditch level by the irrigation groups under the supervision of Working Stations during the irrigation season.

Determination of performance indicators: The simplest and yet probably the most important hydraulic performance indicator is water delivery performance

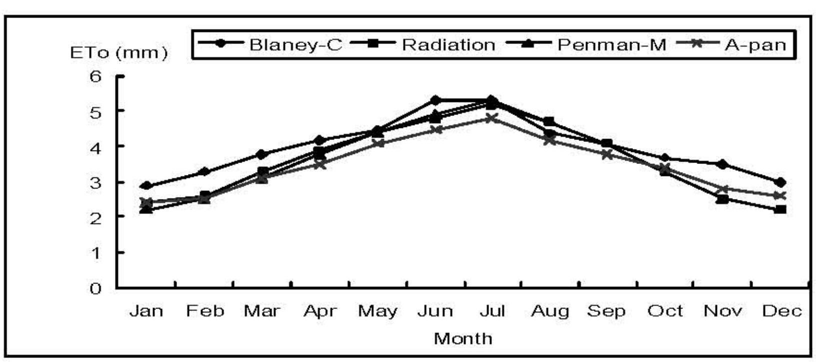


Fig. 3: Reference Evapotranspiration ETO computed from four different methods in Chianan irrigation area

[16, 17]. Molden and Gates [11] used the structural characteristics and management components of the irrigation system to determine the state of the water delivery system. They set up a performance standard grill and classified the water delivery systems as "poor"," fair" and "good". Analysis of the relative irrigation supply dynamics throughout the cycle of rice crop could provide deep insight into irrigation performance of Chianan Irrigation Association where farmers recently were freely granted irrigation water and no other charge related to the use of irrigation network facilities were imposed on them.

Adequacy: The common indicator of water delivery performance is whether adequate water is reaching the farmers at the end of the canal system. Adequacy is defined as the ability of irrigation to meet the required amount of water. It relates to the desire to deliver targeted amounts of water needed for crop irrigation to delivery points in the system [11]. It can be expressed as:

$$PI_A = \frac{1}{T}\sum_T \left(\frac{1}{S}\sum_S pA \right)$$

With $pA = Q_D/Q_R$ if $Q_D \leq Q_R$, otherwise $pA = 1$

Where PI_A is the adequacy performance indicator, T represents time and S represents site where canals are located, Q_D the actual amount delivered by the system and Q_R the amount of water required for consumptive use. When $Q_D \geq Q_R$ the delivery is considered adequate and despite the magnitude of excess, the ratio is taken as one. Ideally, if this ratio is close to one, it infers good adequacy. A value of PI_A less than 0.80 indicates poor performance while PI_A ranging between 0.80 and 0.89 shows that the system exhibits a fair performance.

Efficiency: Water use efficiency is an important agronomic indicator for areas with limited water resources [18,19]. The efficiency is defined as the ratio of the volume of water required for a specific purpose to the volume of water delivered for this purpose. It is commonly interpreted as the volume of water stored in the soil for evapotranspiration compared to the volume of water delivered for this purpose. Its expression is given by:

$$PI_{Ef} = \frac{1}{T}\sum_T \left(\frac{1}{S}\sum_S pEf \right)$$

where PI_{Ef} is the spatial and temporal average of the ratio Q_R/Q_D and equals 1 if $Q_R = Q_D$, otherwise. The more the value of PI_{Ef} goes closer to unit, the more the system becomes efficient. A delivery system for which PI_{Ef} values range between 0.7 and 0.84 is considered as fairly efficient.

Dependability: Dependability is the performance indicator related to the degree of temporal variation CV_T in the ratio Q_R/Q_D that occurs over the given region. This variability is measured using the expression:

$$PI_D = \frac{1}{S}\sum_S CV_T \left(\frac{Q_D}{Q_R} \right)$$

where, CV_T is the coefficient of variation of the ratio Q_D/Q_R during the period of the time T, at the site S. When the standard deviations get smaller and that the values of PD approach zero, the relative water delivery becomes more dependable over the time. The boundaries values of fair performance range between 0.11 and 0.20, thus beyond 0.2 the performance becomes poor according to the standard classification grill.

Equity: In rotational water distribution system equity is one of the major objectives of the irrigation project. Equity is defined as the spatial uniformity of the ratio of the delivered amounts of water to the targeted amounts. The mathematical expression of equity performance indicator is:

$$PI_{Eq} = \frac{1}{T}\sum_T CV_S \left(\frac{Q_D}{Q_R} \right)$$

Where PI_{Eq} is the performance indicator for equity, T represents time, CV_S the spatial coefficient of variation over the site S for the ratio (Q_D/Q_R), Q_D the actual amount of water delivered by the system and Q_R the amount of water required for consumptive use. PI_{Eq} describes the variation of the relative delivery from location to another. According to the standard, the closer the value of PI_{Eq} is to unit the greater the degree of impartiality in the delivery water. A good performance in terms of equity is expressed by PI_{Eq} value comprised between 0 and 0.1 while value greater than 0.25 shows poor performance.

RESULTS AND DISCUSSION

Rice cropped areas under the selected lateral canal did not vary too much during the two years 2005 and 2006. The total land under rice cultivation was about 193.5 ha under the selected tertiary canals representing about 51% of the area supplied by the lateral canal. The

Table 1: Required and delivered discharges to farm and related areas for year 2005

Farm	Zhong Xie 1 21.17 (ha)		Zhong Xie 2 44.93 (ha)		Zhong Xie 3 35.2 (ha)		Wujia 1 25.03 (ha)		Wujia 2 27.07 (ha)		Wujia 3 40.05 (ha)	
Month	Qreq	Qdel	Qreq	Qdel	Qreq	Qdel	Qreq	Qdel	Qreq	Qdel	Qreq	Qdel
Jan	0.330	0.352	0.704	0.704	0.572	0.572	0.396	0.374	0.440	0.440	0.649	0.649
Feb	0.692	0.550	1.486	1.175	1.172	0.925	0.828	0.650	0.904	0.700	1.338	1.050
Mar	0.622	0.306	1.182	0.564	0.954	0.451	0.736	0.354	0.798	0.386	1.058	0.499
Apr	0.700	0.470	1.330	0.890	1.080	0.720	0.830	0.550	0.900	0.600	1.200	0.800
May	0.335	0.377	0.560	0.719	0.440	0.582	0.370	0.445	0.390	0.479	0.475	0.651
Jul	0.519	0.355	1.112	0.763	0.880	0.586	0.625	0.429	0.668	0.447	0.996	0.679
Aug	0.568	0.536	1.208	1.153	0.950	0.885	0.671	0.641	0.733	0.668	1.084	1.016
Sep	0.540	0.476	1.260	1.071	0.990	0.857	0.690	0.597	0.790	0.669	1.190	1.027
Oct	0.460	0.527	1.000	1.185	0.770	0.948	0.560	0.658	0.630	0.737	0.950	1.132

Discharge (cms)

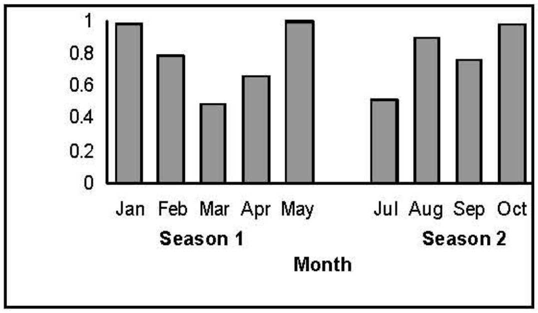
Table 2: Required and delivered discharges to farm and related areas for year 2006

Farm	Zhong Xie 1 21.17 (ha)		Zhong Xie 2 44.93 (ha)		Zhong Xie 3 34.8 (ha)		Wujia 1 25.03 (ha)		Wujia 2 27.07 (ha)		Wujia 3 40.05 (ha)	
Month	Qreq	Qdel	Qreq	Qdel	Qreq	Qdel	Qreq	Qdel	Qreq	Qdel	Qreq	Qdel
Jan	0.542	0.461	1.158	0.981	0.934	0.793	0.656	0.559	0.726	0.616	1.059	0.889
Feb	0.552	0.446	1.172	0.952	0.918	0.750	0.656	0.529	0.712	0.570	1.050	0.854
Mar	0.643	0.436	1.390	0.934	1.089	0.727	0.757	0.520	0.809	0.540	1.245	0.831
Apr	0.640	0.324	1.380	0.694	1.070	0.540	0.760	0.385	0.800	0.401	1.220	0.617
May	0.215	0.358	0.385	0.767	0.305	0.597	0.235	0.419	0.245	0.436	0.335	0.670
Jul	0.614	0.326	1.321	0.696	1.037	0.500	0.738	0.382	0.805	0.405	1.202	0.608
Aug	0.569	0.513	1.200	1.093	0.931	0.786	0.673	0.606	0.724	0.642	1.076	0.962
Sep	0.630	0.473	1.360	1.009	1.020	0.725	0.780	0.559	0.720	0.592	1.120	0.888
Oct	0.553	0.532	1.155	1.136	0.847	0.816	0.664	0.629	0.613	0.666	0.928	0.999

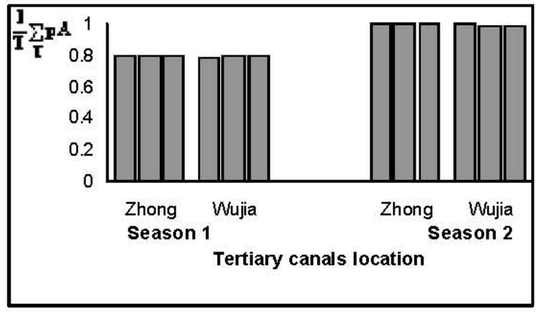
Discharge (cms)

cropping patterns in Chianan Irrigation Association were established and carried out to adapt to the local farmland production. It consists of a double-cropped cultivation, single-cropped cultivation and three year-two crops cultivation (rotational cropping). The double-cropped cultivation is characterized by two rice crop harvest every year. The single-cropped cultivation is the system where the irrigation water is provided for the first rice crop season in a year or provided for the second rice-crop season in a year. The rotational cropping consists of growing rice twice in three years.

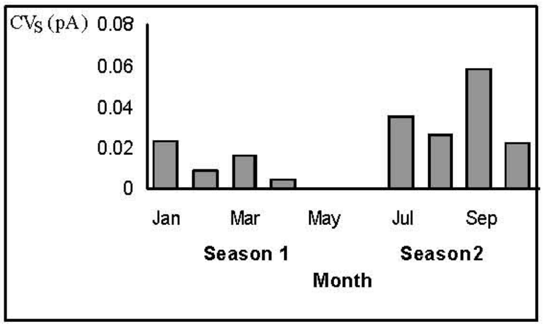
The different discharges corresponding to 4 irrigation seasons (two seasons per year) recorded by Madao Irrigation Working Station are reported in Table 1 and 2. The first irrigation season starts each year in January and ends in May while the second begins in July and ends in October. Data of June are not reported herein because this month is considered as the transition period between the two seasons. During the 2005 irrigation season, the ratio of the delivery to the required discharges (Q_D/Q_R) was higher than unit in January, May and October implying that the delivery exceeded the requirements for most of the areas except Wujia 1 where Q_D/Q_R in January is 0.94. The ratio Q_D/Q_R equals 1.37 in May for year 2005 means that the canal received at least 37% more water discharge than the required. The reason is that the irrigation working station estimates the allocation based on the average of the crops requirement for each season and sometimes the farmers adjust their planning without informing the Irrigation Working Station on time. This results in less water use than that planned by the IWS. This anomaly was also observed during the irrigation season 2006 where the ratio $Q_D/Q_R>1$ in May for all the zones. The



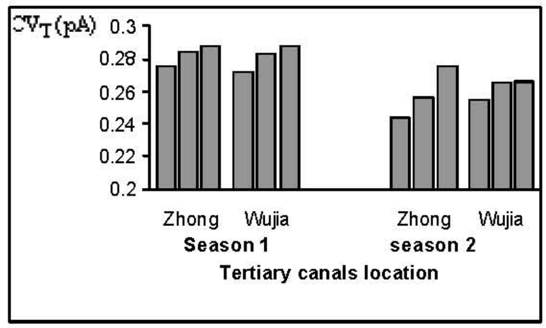
a) Spatial variation of pA



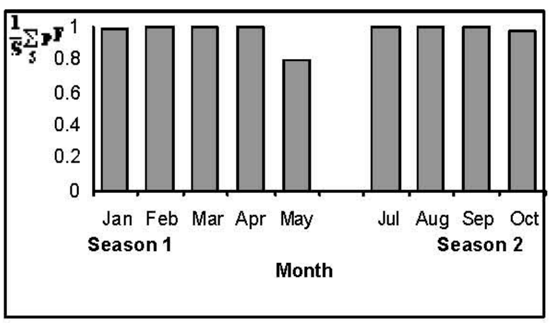
d) Temporal variation of pA



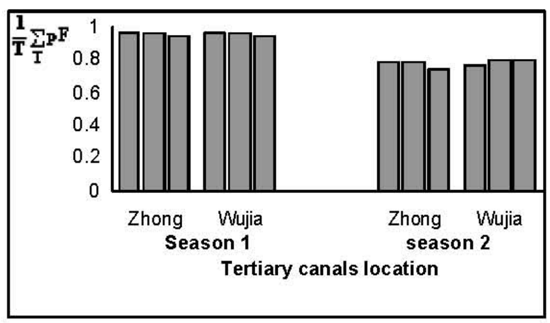
b) Spatial variation of CV



e) Temporal variation of CV



c) Spatial variation of pF



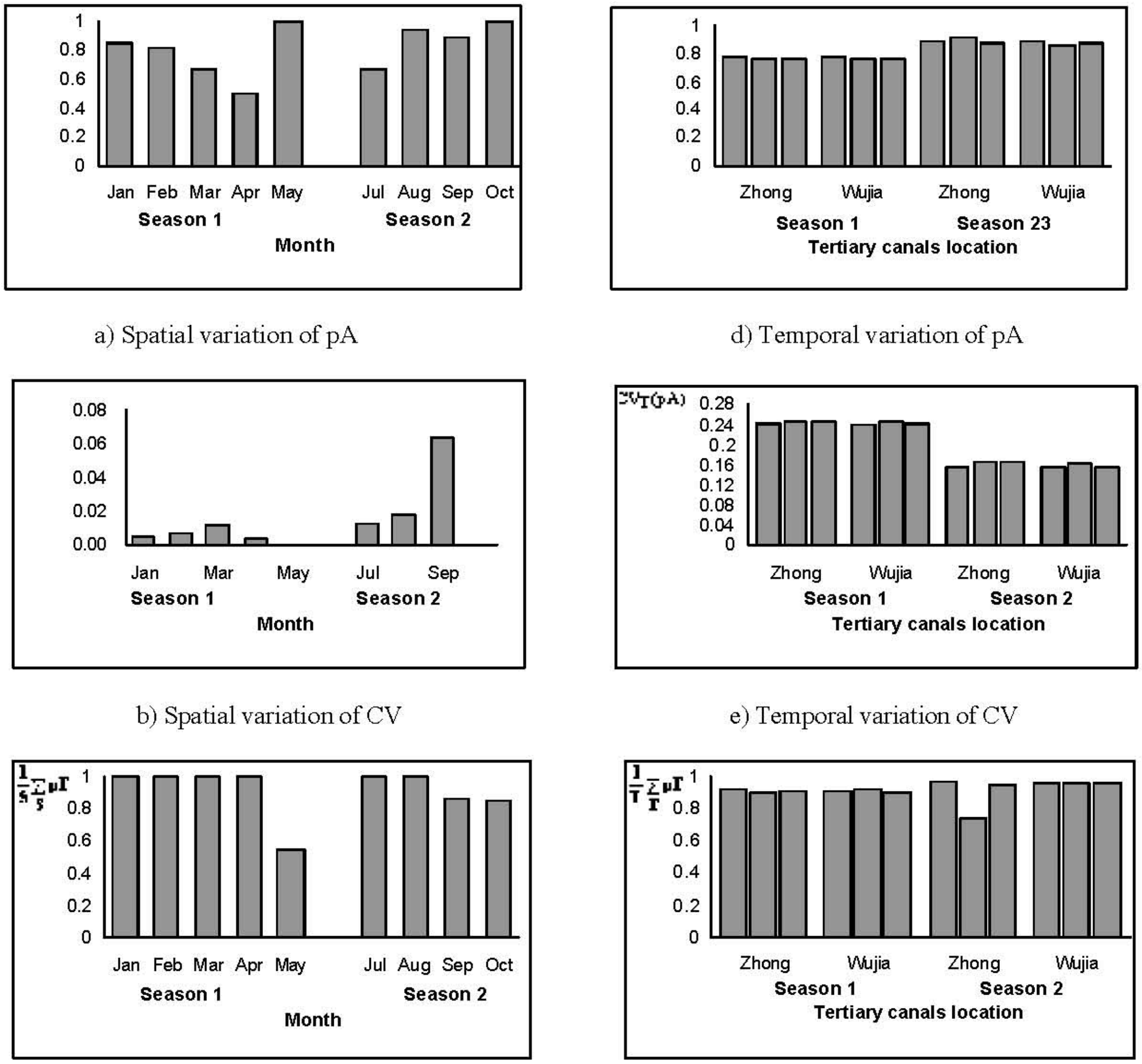
f) Temporal variation of pF

Fig. 4: Spatial and temporal variations of averages values of pA, CV, pF for the irrigation season 2005

ratio is also greater than unit in October only for Wujia 2 and Wujia 3. These results imply that an unscheduled use of water exists in the irrigation land under Madao working station and this must be corrected.

Performance assessment: Table 1 and 2 show the distribution of water discharges measured by the Madao Irrigation Working Station. These data were used to compute spatial and temporal indicators values relative to adequacy, efficiency, dependability and equity performance on the selected tertiary canals over four growing seasons of years 2005 and 2006.

Indicators of performance in 2005: The average values of delivery performance indicators vary with tertiary outlet and irrigation season. Figure 4 displays the average values of spatial and temporal performance for the two growing seasons of the year 2005. Spatial values of pA (Fig. 4a) range between 0.48 and 1 then between 0.51 and 0.98 for the first and second irrigation season, respectively. The value of 1 means that the system is able to deliver the required amount of water while values less than 1 show that insufficient amount of water was delivered to the farmers. Figure 4b shows the average value of CV_S. The value of CV_S was zero for May but varied between 0.01 and 0.02 for the rest of the months in the first season. In the second season the values of CV_S were higher but varied between 0.02 and 0.06. The variation of CV_S over the time shows values less than 10% indicating a good equity performance in the study region during the two irrigation seasons in 2005.



a) Spatial variation of pA

d) Temporal variation of pA

b) Spatial variation of CV

e) Temporal variation of CV

c) Spatial variation of pF

f) Temporal variation of pF

Fig. 5: Spatial and temporal variations of averages values of pA, CV, pF for the irrigation season 2006

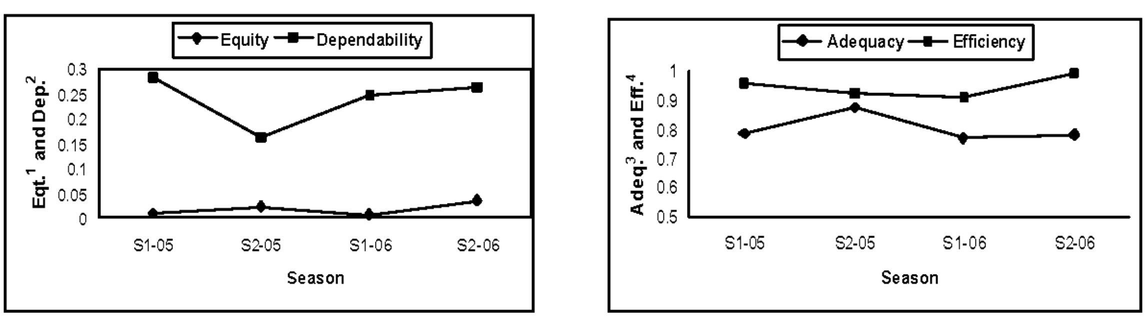
Spatial values of pF (Fig. 4c) are either one or close to one for most of the growing periods in 2005. This may imply that the efficiency was good to fair because no large water shortage occurred in 2005 at Wushantou region. Figure 4d-4f depict temporal performance indicators in the growing periods of year 2005 at the level of the six tertiary canals serving Zhong Xie and Wujia areas located at head and the tail of the lateral canal respectively. No significant variation was noticed in the average values of pA for both Zhong Xie and Wujia regions. The pA values of 0.79 were the same for the first group of tertiary canals and an average value of 0.78 for the second group. Despite the small difference, the rotation group at the head of the system exhibits an adequacy performance higher than that in the tail of the system. The values of pA in the second season varied from 0.95 to 0.99 with average of 0.98 and 0.97 for the first and the second group of tertiary canals respectively. Similar to the variation of pA, temporal variation of CV was not very significant. The values ranged from 0.27 to 0.29 and 0.24 to 0.27 for the first and second season respectively. However, temporal values of pF fluctuated between 0.98 and 1.0 in the first season and 0.75 and 0.77 in the second season. Moreover, in the second irrigation season 2005 pF is 0.77 for Zhong Xie group and 0.75 for Wujia group.

Indicators of performance in 2006: Averages spatial values of performance indicators for 2006 are reported in Figure 5a-c and temporal performance indicators are given in Figure 5d-f. Figure 5a shows average values of adequacy indicators. With an average of 0.77 pA values ranged between 0.50 and 1.0. In the first growing period, March and April are months where the indicators values of adequacy are lower with pA equals 0.67 and 0.5, respectively while the minimum and maximum values in the second growing period are 0.68 and 1.0, respectively. Over the five and four month periods corresponding to the first and second irrigation seasons pA values indicate poor performance throughout the year. The adequacy index shows that the system was able to deliver only 77% of the required amount of water to farmers for the entire year 2006. Spatial values of CVs (Fig. 5b) were zero in May and October. Other values of CV_S varied from 0.01 to 0.06 implying equity similar to that of year 2005. In the first season of 2006, except for the month of May where pF value was 0.54 (Fig. 5e), the pF value was equal to 1.0. Contrary, all the values of pF are higher than 0.85 in the second season. The overall indicator value of pF is 0.95 inferring good efficiency for year 2006. Figure 5d displays temporal variation of pA. Average values of temporal pA were relatively homogenous over the six regions but smaller in magnitude compared with those obtained in 2005. The average values are 0.77 and 0.92 in the first and second season, respectively.

The temporal adequacy performance for the whole season was 7.2% lower than that in 2005. Conversely, averages values for CV_T in 2006 were higher than those in 2005 for all the tertiaries and ranged between 0.23 and 0.24. This means that the dependability was poor in the two groups of the system. In Figure 5f average values for pF were given. The first planting period exhibits an average of 0.91 while in the second season pF average value is about 0.92 for all tertiary canals.

Evaluation of the performance indicators: Figure 6 reveals the variation of the average values of performance indicators through the four irrigation seasons. As shown in Fig. 6b the delivery system presents a poor performance relative to adequacy in the first, third and fourth irrigation seasons and fair performance in the second one. However, the values of efficiency varied from 0.91 to 0.99 implying that the allocation of water fully meets farmers' requirement. According to the standard grill the delivery systems demonstrates a good performance as regards to efficiency. This may be due to the good functioning of the irrigation canal network of which almost all the channels are lined resulting in less loss of water on one hand and regular channel monitoring by the agents of distribution at the tertiary canals on the other hand.

The equity in the delivery of water was considered competitive since the average of PI_{Eq} was around 0.02 for the whole study period and that no value exceeded the limit of 0.1. The water flowing in this 2181 meter long canal was equitably distributed to the farmers during the four 4 seasons. It was noticed during field visits that the discipline of the farmers themselves and the vigorous impartiality in the water distribution at the farm ditches level contributed to attainment of this good performance. Figure 6a shows the variation in temporal uniformity of the ratio Q_D/Q_R. The value of PI_D is an indicator that measures the performance of the system reliability and the closer the value of this indicator comes to zero the more reliable the delivery system is over the considered period. The maximum and minimum values of PI_D were 0.28 and 0.16 respectively implying that the distribution of this ratio was not consistent. In this case the farmers cannot plan well because they are not assured of adequate supply at the time of need. Poor reliability can cause production failure especially for plants very sensitive to water stress. Dependability performance was very poor during the successive four growing seasons. As the physical irrigation network is regularly monitored, the reasons for the poor performance related to dependability may be a management problem. In addition, the desire to grant the volume of water requested by the farmers



a. [1]Equity and [2]Dependability

b. [3]Adequacy and [4]Efficiency

Fig. 6: Variation of indicators performance relative to adequacy, efficiency, equity and dependability through the four irrigation seasons of year 2005 and 2006

Table 3: Wushantou irrigation system performance of water delivery at the tertiary canals for year 2005 and 2006

Year	Adequacy (PI_A)	Efficiency (PIE_f)	Equity (PIEq)	Dependability (PI_D)
2005	0.83	0.94	0.02	0.22
2006	0.77	0.95	0.02	0.24

quickly becomes blurred with the poor distribution of rainfall of year 2006. It is well known that in the condition of limited irrigation water, optimal irrigation efficiency can lead to substantial water conservation and increased crop yields; however the reliability can provide the inducement for farmers to invest more. Therefore, increase dependability rate is highly required in this irrigation branch. By upgrading the system, irrigation farmers will be able to count on a more reliable delivery of water during the irrigation season and greater water availability. In order to improve reliability, the agency in charge of the irrigation must pay attention so that the time of transport of water from the source and the period when water is awaited at farmer's level coincides completely.

The results of the performance evaluation for the whole system during the two years are summarized in Table 3. The PI_D value of 2005 is less than of 0.02 that of year 2006, implying that water delivery system is more reliable.

The system exhibited good equity in 2005 and 2006; however, with regard to adequacy performance a large gap of 7.2% occurred between the two years. As the total land under rice cultivation during the two years has not varied the large difference in the adequacy performance was mainly due to operation insufficiencies. Equity and efficiency performance are considered good. According to the established performance standard, adequacy is fair in 2005 and poor in 2006 while both years demonstrate poor dependability through the four seasons.

CONCLUSIONS

Although the study area is an independent system in terms of water supply, it exhibited a decrease in the global performance even though some indicators gave good figures over short period. Water delivery system in Zhong Xie and Wujia rotational block was good in terms of equity and efficiency. Adequacy that had fair performance in 2005 witnessed a harsh decrease of 7.2% leading to very poor performance in 2006. The dependability of the distribution system which establishes confidence between the farmers and the Irrigation Working Station was assessed as very poor according to the performance standard. One investigation at the beginning of each campaign by the Irrigation Working Station proved to be insufficient with regard to changes intervened in management system. Improvement of the water delivery involves good estimation of water crop requirement; constant monitoring of the channel network and reinforcement of cooperation between farmers and the Irrigation Working Station. Irrigation managers and reservoir management staff have been informed about the results of this evaluation that hopefully can help to improve the quality of water delivery within the system.

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