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تحلیل سیستمی بازده پروژه آبیاری تک کشتی برنج

علیرضا سپاسخواه [۱*] و روزبه پروین [۲]

چکیده

مقدار دقیق بازده پروژه‌های آبیاری در دست نیست. بنابراین برنامه‌ریزی و طراحی شبکه‌های آبیاری بر اساس مقادیر غیر دقیق انجام می‌شود که منجر به نتایج مأیوس کننده می‌گردد. هدف این پژوهش تحلیل داده‌های ارزیابی پروژه شبکه آبیاری پاشاکلا در مازندران می‌باشد که دارای سطح ایستابی کم عمق است. در این پژوهش از روشهای سیستمی و غیرسیستمی استفاده شده است. در روش سیستمی نفوذ عمقی و رواناب سطحی بعنوان اتلاف آب منظور نشده است. اما در روش غیر سیستمی این موارد جزء تلفات آب به حساب آمده است. بازده پروژه آبیاری به روش سیستمی و غیر سیستمی که در آن تلفات نفوذ عمقی و رواناب جزء تلفات محسوب شده است بترتیب ۰/۸۷ و ۰/۵۱ می باشد. اما بازده پروژه آبیاری به روش غیر سیستمی که در آن نفوذ عمقی و رواناب جزء تلفات محسوب نشده اند ۰/۸۵ محاسبه شد که با مقدار آن به روش سیستمی مطابقت دارد. بطور کلی بازده پروژه آبیاری برای شرایط تک کشتی برنج با سطح ایستابی کم عمق بالاتر از پروژه‌های چند کشتی با سطح ایستابی عمیق است. هم چنین در پروژه‌های آبیاری تک کشتی با سطح ایستابی کم عمق، نفوذ عمقی جزء تلفات آب محسوب نمی‌شود زیرا سریعاً به آب زیرزمینی پیوسته و بوسیله پمپاژ دوباره مصرف می‌شود. در این شرایط بازده یکسانی برای پروژه آبیاری به روش سیستمی و روش غیر سیستمی بدست آمد. بطور کلی پیشنهاد می‌شود که در ارزیابی پروژه‌های آبیاری از روش سیستمی که معتبرترند استفاده شود. هم چنین بنظر می‌رسد که در روش غیر سیستمی نفوذ عمقی را نمی‌توان جزء اتلاف آب به حساب آورد.

کلمات کلیدی: بازده آبیاری، بازده انتقال، بازده آبیاری برنج

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۱- استاد بخش آبیاری، دانشگاه شیراز، شیراز، جمهوری اسلامی ایران
۲- کارشناس مهندسی مشاور مهاب قدس
*- نویسنده مسئول

System Analysis for Rice Irrigation Project Efficiency

A. R. Sepaskhah [1] and R. Parvin [2]*

Abstract

The value of irrigation efficiency cannot be precisely known. Therefore, water resources planning and irrigation network design are normally based on uncertain values of irrigation efficiency which ends up with disappointing results in practice. This research used “system” and “non system” approaches to analyze the data obtained from Pasha-Kola irrigation network in Mazandaran Province in northern Iran. This network is cultivated with rice and has a shallow water table condition. Furthermore, reported data for multiple cropping projects were obtained for Dez project in the Khuzestan province and Doroodzan project in the Fars province from other investigators and used to determine the "system" efficiency. In the "system" approach the deep percolation and surface runoff were not considered as water loss. However, these were considered as water losses in the "non system" approach. The project efficiency for “system” and “non system” approaches considering the deep percolation as water loss were obtained as 0.87 and 0.51, respectively. However, the project efficiency for the “non system” approach in which deep percolation was ignored was 0.85 which is similar to that obtained by the “system” approach. It may be concluded that, for irrigation projects with single crop (rice) and shallow water table, the project efficiency (either “system” or “non system”) is generally higher than that of no shallow water multiple cropping networks. Furthermore, for rice irrigation projects, deep percolation of water may not be considered as loss due to its potential of being reused as groundwater supply and the “system” irrigation project efficiency is similar to the “non system” project efficiency. In general, it is more reliable that the “system” approach be used for evaluation of irrigation projects. Furthermore, in a “non system” approach the deep percolation may not be considered as water loss.

Keywords: Application efficiency, Conveyance efficiency, Rice irrigation efficiency

1 – Professor , Irrigation Department, Shiraz University, Shiraz, I.R. Iran
2 - Staff , Mahab-Ghodss Consultant Engineering, Tehran, I.R. Iran
*- Corresponding Author

1-Introduction

Most parts of Iran are located in arid and semi-arid regions with limited water resources. To supply agricultural water needs, huge investments are used in dam construction. The irrigation water is however used with low efficiency. Exact value of irrigation efficiency is not known. Therefore, water resources planning and irrigation network design are based on uncertain values of irrigation efficiency which ends up in disappointing results. The accurate value of irrigation efficiency is vital for irrigation projects. Among different crops, rice uses flood irrigation and its irrigation efficiency may be lower than other crops due to greater deep percolation.

Irrigation efficiency of a project is defined as follows (Bos and Nugteren, 1982; Boss, 1979):

$$E_p=E_a\times E_d\times E_c \quad (1)$$

where E_p is the irrigation project efficiency, E_a is the irrigation application efficiency, E_d is the field distribution efficiency, and E_c is the conveyance efficiency.

The irrigation conveyance efficiency is defined as:

$$E_c=V_f/V_s \quad (2)$$

where V_f is the volume of water delivered to the farm and V_s is the volume of water obtained from the water sources.

The field distribution efficiency is defined as:

$$E_d=V_a/V_f \quad (3)$$

where V_a is the volume of water applied to the irrigation plots.

The irrigation application efficiency is defined as:

$$E_a=V_{ET}/V_a \quad (4)$$

where V_{ET} is the volume of water used by plant as evapotranspiration. Eq (1) may be considered as a “non system” approach to determine the irrigation project efficiency since deep percolation and surface runoff are considered as water loss.

The efficiency of water use in irrigation are lower than one, due to the loss of water as evaporation from water surface in canals, deep percolation, seepage from canals and fields, and surface runoff from irrigation plots. Because of the flood irrigation in rice fields, the loss of water as deep percolation is higher compared to other crop patterns. Soils with low hydraulic conductivity, like silty clay soils, are more appropriate for rice plantation.

Irrigation application efficiency for rice in India in sandy loam and clay soil is reported to be 41.6% (Rout et al., 1989). Irrigation project efficiency including conveyance, distribution, and application efficiencies for rice in the Khuzestan province (south of I.R. Iran) is reported as 45% (Fatemi et al., 1994). Irrigation application efficiencies for rice with and without surface runoff in the Fars province (south of I.R. Iran) were determined as 30.8 and 49.6%, respectively (Pirmoradian et al., 2004/2005).

In rice fields in northern parts of Iran, both surface water and pumped groundwater from shallow water table are used for irrigation in any field. Furthermore, surface runoff is often stored in ponds and pumped back to the irrigation network. Therefore, it is questionable, whether deep percolation and field runoff should be considered as water losses. Deep percolation for rice fields were reported to be 4-6, 3-4 and 1-3 mm d^{-1} for sandy loam, loam, and clay loam soils, respectively (Fukuda and Tsutsui, 1979). For compacted heavy texture soils, deep percolation in the rice field is 1.0 mm d^{-1} and it may be as high as 20 mm d^{-1} for light soils (Kung et al., 1965; Talsma and Lelij, 1976; Wickhamand and Singh, 1978). Deep percolation in rice fields in the Guilan region (north of Iran) was reported as 1.9-4.2 mm d^{-1} and for Sefid-Rood plain as 9.0 mm d^{-1} (Plusquellec, 1996). Pirmoradian et al. (2004/2005) determined deep percolation of the rice field in silty clay soil in Fars province (south of Iran) as 2.3-4.6 mm d^{-1}.

Prevention of field runoff in rice fields may enhance the irrigation application efficiency. Irrigation application efficiency was increased 61.0% by prevention of field runoff (Pirmoradian et al., 2000).

Storing rice field runoff in local ponds and pumping water from these ponds and shallow water table back to the irrigation network may alter the irrigation project efficiency. Therefore, the “system” efficiency of the project (sometimes called "drainage ratio") should be determined based on the total amount of water used for irrigation and final outflow from the entire project as follows:

$$E_{ps}=(V_s-V_{out})/V_s \quad (5)$$

where E_{ps} is the irrigation project efficiency determined by the “system” approach and V_{out} is the volume of outflow water from the irrigation project. Therefore, the irrigation project efficiencies obtained by Eqs (1) and (5) may not be identical.

The objective of this research was to analyze the data obtained from irrigation efficiency for rice fields in Pasha-Kola irrigation network in Mazandaran province (north Iran) by "system" and "non system" approaches.

2- Materials and Methods

Study area

The study area in Pashakola irrigation network is located between latitudes of 36°, 25' and 36°, 45' N and longitudes of 25°, 40' and 25°, 50' E. It is bounded by the Talar river in the east, Babol river in the west, Caspian Sea in the north, and Babol-Ghaemshahr highway in the south. The total area of the region is 25500 ha with irrigation project area of 15843 ha consisting of 14300 ha rice plantation (90%) and 1543 ha citrus orchards (10%). The sketch of the study area is shown in Fig. 1.

3- Regional water balance ("system" project efficiency)

Regional water balance was considered according to the following equation:

$$Q_{in}+W+R+P+P_u+\Delta S=CU_r+E+D+CU_o+Q_{out} \quad (6)$$

here: Q_{in} is the diverted volume of water from rivers, W is the pumping volume of water from shallow water table, R is the volume of water from storage ponds, P is the volume of precipitation water, P_u is the volume of water pumping from rivers, ΔS is the change in volume of soil water content assumed zero for seasonal water balance, CU_r is the volume of rice consumptive use, E is the volume of evaporation from canals and storage ponds, D is the volume of deep percolation from canals, storage ponds and rice fields, CU_o is the volume of citrus orchards consumptive use, and Q_{out} is the outflow volume from the irrigation project. These parameters were either measured or estimated. The results for the growing season (May to August) are shown in Table 1.

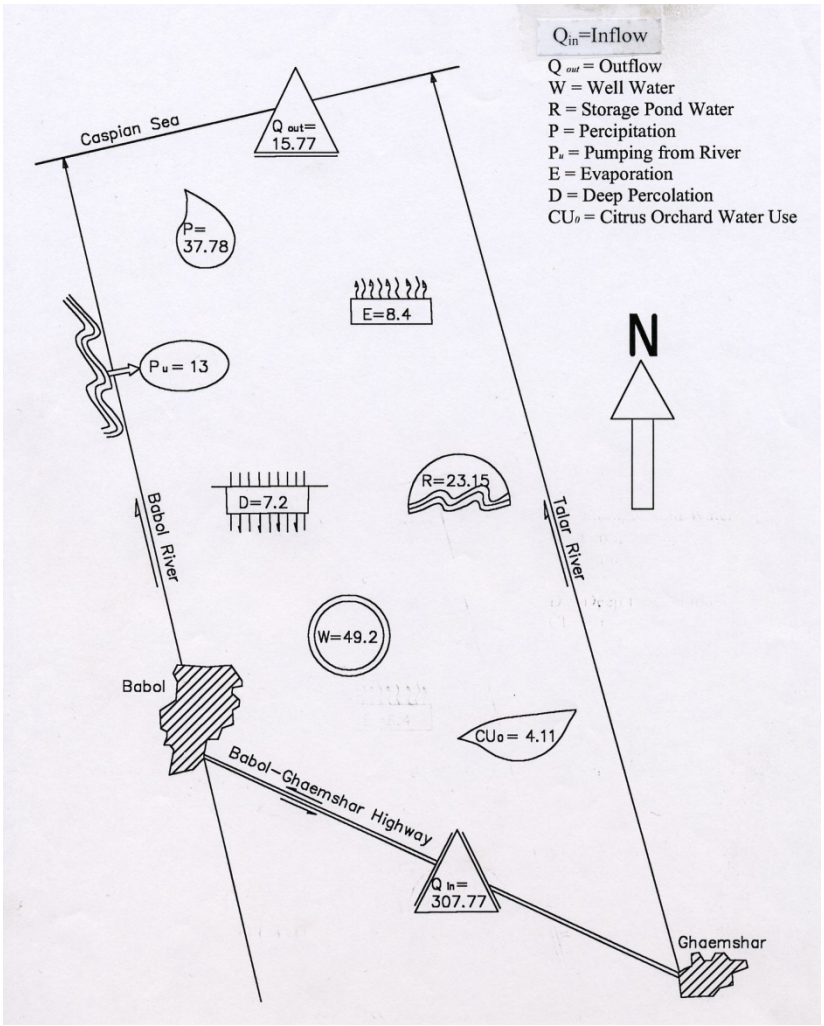

Figure 1- The Schematic representation of the study area

Table 1- The parameters in seasonal water balance for the irrigation project (106 m3).

Q_{in}	Q_{out}	P	P_u	W	R	E	D
37.769	15.778	37.78	13.000	49.200	23.150	8.400	7.200

Table 2- The Mean values of field water balance components (m^3 ha^{-1}).

Q_{in} (1)	P (2)	D (3)	Q_{out} (4)	Q_{in}+P (5)	Infiltrated water 6=(5-4)	Consumptive use (7)
11624	730	4576	216	12354	12138	7562

The consumptive use of the citrus orchards (CU_o) was estimated as $4.11x10^6$ m^3. The main water requirement for orchards was supplied by rainfall. Supplementary irrigation water supply for orchards was the pumping from the shallow water table. The deficit supplementary irrigation was applied with hose to hand basins under citrus trees (high irrigation application efficiency). Therefore, the water loss for orchards was considered negligible. The "system" project efficiency was calculated according to Eq (5).

4- Application, distribution, and conveyance efficiencies

Rice field consumptive use was determined in 10 fields with various sizes of 0.2 to 12.0 ha. Among these fields, three fields were irrigated by surface water supply and seven by pumped water from shallow water table. The growing season for these fields varied between 75 to 104 days. Q_{in}, Q_{out}, and P were measured and the value of D was estimated using water balance in fields. Their mean values are shown in Table 2. These data were then used in Eq (4) to determine irrigation application efficiency (E_a).

Evaporation from storage ponds and irrigation canals estimated from pan evaporation records in Babol climatological station. The evaporation estimates for the growing season was $8.4x10^6$ m^3 (Table 1).

Deep percolation in storage ponds was estimated by measuring inflow and outflow and the water depth variation using the stage-storage curves. Deep percolation in irrigation canals was determined measuring inflow and outflow in canals. The values of deep percolation in storage ponds and irrigation canals were $3.5x10^6$ and $3.7x10^6$ m^3, respectively (a total of $7.2x10^6$ m^3, Table 1).

The overall conveyance and distribution efficiencies were estimated as follows:

$$(E_c)(E_d)=[(Q_{in}+P_u+W+R-CU_o)-(D+E)]/(Q_{in}+P_u+W+R-CU_o) \quad (7)$$

The "non system" project efficiency was calculated by multiplying the results of Eqs (4) and (7).

5- "System" efficiency for other projects with multiple cropping

Based on the reported data for the Dez project in the Khuzestan province, Iran, with multiple cropping pattern (Sadeghi-Attar et al., 2000) the average "system" project efficiency for a period of 1976-1991 was calculated by Eq (5). Similar data was collected from Doroodzan irrigation project in Fars province, Iran, with a multiple cropping pattern for 1994 (Fars Water District Authority, personal communications) and the "system" project efficiency was calculated based on Eq (5).

6- Results and Discussion

6-1- "System" project efficiency

Total irrigation supply in the study area was $119.01x10^6$ m^3 and the total outflow from the irrigation project was $15.78x10^6$ m^3. Therefore, the E_{ps} based on Eq (5) was obtained as 0.87. This value was quite higher than those reported for other project efficiencies in southern parts of Iran with a multiple cropping pattern (Sadeghi-Attar et al., 2000; Sanaee-Jahromi et al., 2000).

6-2- "Non system" project efficiency

Using the data in Table 2 (columns 1, 2, and 7) and Eq (4), the irrigation application efficiency (E_a) was calculated to be 0.59, when rice field deep percolation was considered as water loss. This value was in accordance to the values of E_a reported by Bos and Nugteren (1982) for a rice field in a clay soil (0.50-0.55).

Total irrigation water supply conveyed in irrigation canals was $119.01x10^6$ m^3. The total seepage and evaporation losses from the irrigation canals was $15.0x10^6$ m^3. Therefore, the overall conveyance and distribution efficiency, based on Eq (7) is 0.87. This value was in accordance with those reported by Bos and Nugteren (1982) especially for heavy soils and shallow water table conditions.

The project irrigation efficiency calculated by the "non system" approach based on Eq (1) was 0.51.

Using the data in Table 2 (columns 5, 6), the irrigation application efficiency (E_a) was calculated to be 0.98, when rice field deep percolation was not considered as water loss. The irrigation project efficiency calculated by the "non system" approach based on Eq (1) was 0.85. This is quite similar to that obtained by the "system" approach (0.87). Therefore, it may be concluded that for rice irrigation projects with shallow water table as a parallel supply of water, the deep percolation of water may not be considered a loss, since it may be pumped again as groundwater supply. In these conditions, the irrigation application efficiency and the overall efficiencies of conveyance and distribution are rather high. Therefore, the irrigation project efficiency is also very high. Furthermore, high values of irrigation project efficiency (0.64) has been reported for a similar region (Guilan province,Iran) by Plusquellec (1996).

These results indicated that certain design of the irrigation system in rice fields can improve the total irrigation efficiency by control and reuse of the surface runoff as reported by Pirmoradian et al. (2004/2005).

6-3- "System" efficiency for other projects

For Dez project in the Khuzestan province, Iran, with the multiple cropping pattern (Sadeghi-Attar et al., 2000) the average "system" project efficiency is obtained as 0.57. The "system" project efficiency for Doroodzan irrigation project in Fars province, Iran (Fars Water District Authority, personal communications) is determined as 0.44. However, "non system" irrigation project efficiency for 1993-1994 was reported as 0.31 for Dez irrigation project (Sadeghi-Attar et al., 2000) and 0.33 for Doroodzan irrigation project (Sanaee-Jahromi et al., 2000). It is clear that, similar to the Pashakola irrigation project (with a single cropping pattern (rice) and the shallow water table, project efficiency obtained by "system" approach is higher than that resulted in the "non system" approach.

7- Conclusions

For an irrigation project with a rice cropping pattern and shallow water table, the project efficiencies (either "system" or "non system") are generally higher than that for projects with multiple cropping patterns. Furthermore, for such an irrigation project deep percolation of water may not be considered as loss and the "system" irrigation project efficiency is similar to the "non system" project efficiency. In general, it is proposed that the "system" approach be used for evaluation of irrigation projects as a more reliable approach. Furthermore, in a "system" approach, deep percolation of water should not be considered as loss.

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