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Evaluating Irrigation and Drainage Sub-Network Management (Case Study: Khodaafarin Network)

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Abstract

The purpose of this study was to determine the quantitative effect of management of public institutions in promoting optimal water consumption and reducing operating and maintenance costs. For this purpose, two farms with of 48 and 49 (ha) area, which cultivated with an approved cultivation pattern (40% autumn + 60% spring) were selected in two separate canals. The selected farms are irrigated by a rotating sprinkler irrigation system (center pivot). The water requirement of the mentioned systems was estimated using Netwat software and the operation of these machines was done in accordance to the relevant instructions and network design principles. The legal organization (Rural Production Cooperative) in charge of the farm #1 (48 ha) complied with the management and technical rules in relation to the second organization (in charge of the farm #2 with 49 ha) with a regular structure. Necessary calculations of irrigation efficiency were carried out according to the values recorded in the input meters of both devices and the cost of operation, maintenance, repairs and protection. Finally, the irrigation efficiency of the first and second farms were obtained 75% and 55%, respectively. Operating and maintenance costs were also reduced by 30%. The results indicated that the human and structural management have an important role in the irrigation and drainage sub-network planning.

Keywords: Irrigation Efficiency; Optimal Water Management; Netwat Software; Water Productivity.

INTRODUCTION

Food security depends on increasing agricultural production versus increasing food demand due to population growth. On the other hand, increasing agricultural production through the development of agricultural lands faces serious limitations in water supply. Lack of the renewable water resources, high cost and complexity of new water supply projects, the emergence of new competitors in the terms of water consumption and reducing the share of water in the agricultural sector due to increased drinking, industry, more attention to environmental needs and reduced water resources in agriculture due to declining quality. The only way to respond to the growing demand for food is to make better use of the resources extracted for agriculture and produce more in exchange for less water. Of course, the control of losses in the process of production and consumption of agricultural products should not be overlooked improving water consumption management of surface and groundwater resources is an important and effective step in optimal water consumption and increasing efficiency in irrigation and agricultural production. Improving management in the

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use of surface resources in terms of poor condition of operation and maintenance of irrigation and drainage networks will have a deeper impact on increasing agricultural efficiency and performance (Pourzand, 2002).

In recent decades, governments around the world have focused on the physical development of irrigation networks, and the issue of operation management and maintenance of networks, especially operation planning, has received less attention. In principle, the significant development of irrigation networks has not been in line with the slow process of development and financing, operation management and maintenance of networks. The result is a reduction in irrigation efficiency of 25 to 30 percent in developing countries. In general, increasing productivity and increasing efficiency in irrigation and drainage networks in the future in which competition for water consumption is increasing, is possible by carrying out optimal planning to use the unit of water volume from supply to consumption, and from this perspective, management Optimal operation of irrigation and drainage network is important (Pouriamanesh and Kanuni, 2015).

Drought and water scarcity in Iran is a climatic reality and due to the increasing need for water in different sectors, it will become more acute in the coming years. According to the International Water management Institute (IWMI), Iran must be able to add 112 percent to its recoverable water resources by 2025 to maintain its current status. Given the growing potential and needs of agriculture, drinking, industry and the protection of other biological resources, this is very difficult and even impossible to achieve. In this situation, one of the effective and practical solutions is the optimal use and saving of water consumption. managing water consumption in the agricultural sector, which includes a major part of water consumption in Iran and the world, can be very effective and instructive. It is very clear that in order to achieve this important issue, identifying the main indicators of water consumption management and determining these indicators in appropriate ways is an inevitable necessity. Irrigation efficiencies are one of the most important key indicators in macro planning of water supply, allocation and basic consumption in various sectors, including agriculture (Abbasi et al., 2016). Irrigation efficiency as one of the criteria for evaluating the performance of irrigation networks, explains the relationship between product yield and water input, and its high does not necessarily mean that it is effective. Water transfer, distribution and use efficiencies are other forms of this criterion that do not show the effect of factors other than water on the quantitative performance of networks (Ajdari and Hedayat, 2016).

Nehtani et al. (2013) investigated the role of transferring the management of irrigation networks to consumers in order to optimally manage irrigation networks. The results showed that poor maintenance of irrigation networks is not just a financial problem. This problem is rooted in management issues. Management of irrigation networks is the most important factor in their optimal use. Exploitation of the network and providing services to farmers, continuous maintenance of the network based on the criteria of optimal operation and management practices at the lowest possible cost are the goals of network management.

Abbasi et al. (2016) in a study to prepare a database of irrigation efficiencies in the country, summarized the results of studies related to irrigation efficiencies. The results of field studies in different irrigation systems and networks (traditional and downstream dams) in the country during the years 1370-1394 were collected and analysed. The results of the analysis showed that the efficiency of irrigation water application in the country varies from 22 to 80% and its average is 56%. The mean of this efficiency in Cretaceous, strip and brood systems were 55.3%, 52.9% and 52.5%, respectively. Among the sprinkler methods, the roller method (rolling geyser) and the classical fixed method had the highest (66.9%) and lowest (52.1) efficiency, respectively, and in drip irrigation this quantity was 71.1%. The average efficiency of irrigation application in pressurized and surface irrigation systems was 66.6% and 53.6%, respectively since the 1970s, total irrigation efficiency has grown by about one percent each year. Al-Ghobari (2006) evaluated six contribute sprinkler irrigation systems in Saudi Arabia and provided solutions to improve the condition of the systems. The results showed that proper maintenance of the studied systems improves the uniformity coefficients and ultimately increases their performance. Chirico et al., (2013) conducted research on the relationship between hydraulic criteria for irrigation and drainage and management of Italian irrigation and drainage networks and simulated the characteristics of plant water requirements, soil hydrology, soil solubility transfer and plant water reuse. irrigation efficiency could be increased by simulating flow, standardizing valves, and designing support systems for irrigation management. According to the researches, it can be concluded that the main innovation of this research is to study the effects of human management through legal organizations of irrigation networks on the improvement of irrigation management indicators and network economy.

MATERIALS AND METHOD

This study was carried out in two farms with an area of 48 hectares related to lands under the management of Noor Mohammad Kennedy Rural Production Cooperative with Center Pivot Irrigation System (Z15-CP1) and 49 hectares of lands under the management of Khanlar Rural Production Cooperative with CenterPout Irrigation System (Z19-CP3), was performed. The lands of both cooperatives belong to the first development unit (east of Horud), one of the four development areas of Khodaafarin irrigation and drainage network in Ardabil province (the other part of Khodaafarin irrigation network with reservoir dam and diversion dam is located in East Azarbaijan province) in Aslanduz city. Noor Mohammad Kennedy Rural Production Cooperative Company of Dasht-e Moghan has been established in the first development zone (east of Darrood) and in Aslandooz city. This cooperative is in Noor Mohammad Kennedy village, which is about 55 km away from Parsabad city and about 8 km away from Aslandooz city. The study is located at 39° 28′ 13″N; 47° 30′ 19 E. The mentioned cooperative was finally registered on 20.10.2019 in the registration office of companies and non-commercial institutions of Parsabad city, whose registration number is 2658 and it has a national ID number 14008708786. Table 1 shows the amount of land covered by different modern irrigation systems within the management of the said rural production cooperative, which have been implemented in various ways according to the topography of the region and soil condition.

This research has been accomplished in two farms, with an area of 48 hectares of Noor Mohammad Kandi Rural production cooperative lands with center pivot irrigation system (z15- cp1 specifications) and 49 hectares of Khanlar Rural production cooperative lands with center pivot irrigation system (z19-cp3, specifications). First civil unit(sharq darreh rood) one of the quadruplet civil units of KhodAfarin irrigation and drainage network in Ardebil province, (another part of the Khodafarin irrigation network, including the storage dam and diversion dam is located in East Azerbaijan province, Aslanduz county).

NoorMohammad kandi Rural production cooperative Company, Moghan plain; has been established in Aslanduz county area. This cooperative is in NoorMohammad Kandi village, 55 kilometers distance from ParsAbad city and 8 kilometers distance from Aslanduz city. The mentioned cooperative has been registered with registration code of 2658 and National ID of 14008708786 on 21 October 2019 at ParsAbad Company Registration Office. Table 2 illustrates the amount of land that according to the soil state and topography of the area is under cover of various new irrigation systems (NoorMohammad Kandi Rural Cooperative Company management scope/range)

Table 1. Summary of farms and specification of study area

Name	Area (hectares)	Location coordination	Type or method of irrigations	Owners
Noor Mohammad Kennedy Rural Production Cooperative (NRC)	48	s38 region at 39 degrees, 28 minutes and 14 seconds north latitude and 47 degrees, 30 minutes and 19 seconds east longitude	CenterPout Irrigation System (Z19-CP3) irrigation and drainage by	First development unit (east of Horud
NoorMohammad Kandi Rural Production Cooperative Company (NRCC)				

Table 2. Cooperative specifications and status of irrigation systems implemented

Number of operators	Fixed classic (ha)	Center pivot (ha)	Drip irrigation (ha)	Cooperative area (ha)
33	27	117	288	432

Fig. 1. view of center pivot system of Noor Mohammad Kandi area (Anonymous, 1994)

Kosar Sabz Rural production Cooperative Company, Aslanduz plain, (Khanlar) has been established in Aslanduz area. This cooperative is located in Khanlar village (Mahbub Kandi) with 45 kilometers distance from ParsAbad and 10 kilometers from Aslanduz cities (39° 28′ 26″N; 47° 30′ 33 E). The mentioned cooperative has been registered with registration code of 2661 and National ID of 14008719627 at ParsAbad Company Registration Office on 13 November 2019. Table 2 illustrates the 48 hectares of land that according to the soil state and topography of the area is under cover of various new/modern irrigation systems (Kosar Sabz Rural Production cooperative Company management scope/range).

Tables 3 and 4 illustrate the specs of the center pivot machines. Center pivot system consist of the pivot legs, viser pipe, pivot swivel, control panel, j pipe and collector rings.

Fig. 2. view of Khanlar area, center pivot system (Anonymous, 2020)

Table 3. Cooperative specifications and status of irrigation systems implemented

Number of operators	Fixed classic (ha)	Center pivot (ha)	Drip irrigation (ha)	Cooperative area (ha)
149	_	490	108	598

Table 4. Specs of center pivot machines (Anonymous, 2020)

Device name	Number of spans	Length of overhung (12)	Length of the device (m)	Area (ha)	Flow rate (L/S)	Sprinkler distance (m)	Type
z15_cp1	8	12	390	48	74	3	R_3000
z19_cp3	8	12	396	49	76	3	R_3000

Table 5 illustrates the cultivation pattern of Khodafarin networks first civil/construction area/region. The networks main consultant (local consultant company) has designed the present cultivation pattern according the water resources capacity, susceptibility of soil, crop rotation, marketing, sovereignty policy storage capacity and inventory, environmental considerations and etc. which the most cultivated area is for wheat strategic product and the least cultivated area is for soy and corn fodder and 20 percent is for second cultivation (spring soy and fodder corn) that cultivates after cereal harvesting.

Irrigation network optimal management is not possible without estimating the pure and impure water requirement of cultivation pattern products. In case of inattention network water is wasted or failure in supplying the water because of water deficit stress can damage the crops so the NETWAT model was used. The mentioned model is famous as the National Water Document and at the end the result and output of this project/scheme is “Iran’s pure water requirement of crops and garden products” which it has it has been done by Iranian Ministry of Agriculture (IMA) and Iranian Meteorological Organization (IMO).

Fast and uniform assessment of volumetric distribution in the whole country with cooperation of Ministry of agriculture, Ministry of Energy and Meteorological Organization was prepared and after approval was implemented, for preparation, statistics of the years from 1995 up to 1970 was used (Erfanian et al. 2010). In a research the plants/crops water requirement was calculated with the use of recent years and all years meteorological statistics for Khorasan Razavi province and compared with the results in National Document and reported the 47 to 48 percent increase in potential evapotranspiration of reference crop which shows the National Water Document needs an update. The NETWAT model has been prepared in all parts of the country for various crops and used in many irrigation schemes (Alizadeh and Kamali, 2007). Fig. 3 shows the pure water requirement of the Khodafarin irrigation networks first civil areas cultivation pattern products.

Fig. 4 shows the amount of impure/gross water requirement of the Khodafarin irrigation networks first civil area cultivation pattern products that according to the efficiency of the new irrigation systems especially center pivot machines has been calculated 75 percent.

Fig. 5 shows the gross water requirement of cultivation pattern products with efficiency of 75 percent, in cultivation pattern per hectare in term of percentage. For example, the impure water requirement for cotton has been calculated 1400 cubic meters according to the 15 percent of it in cultivation pattern. If the mentioned number multiplied by every single one of the center pivots in downstream, total water requirement of the mentioned products for a year will be obtained.

Table 5. The cultivation pattern of Khodafarin networks first civil/construction area/region (1994)

Product	Whe at	Barl ey	Lucer ne	cott on	Mai ze	Spring Soy	Can ola	Fodder Corn	Summer Soy	Tre es	Tot al
Agricultural (%)	25	15	10	15	15	5	15	5	15	_	120
Garden (%)	_	_	_	_	_	_	_	_	_	100	100

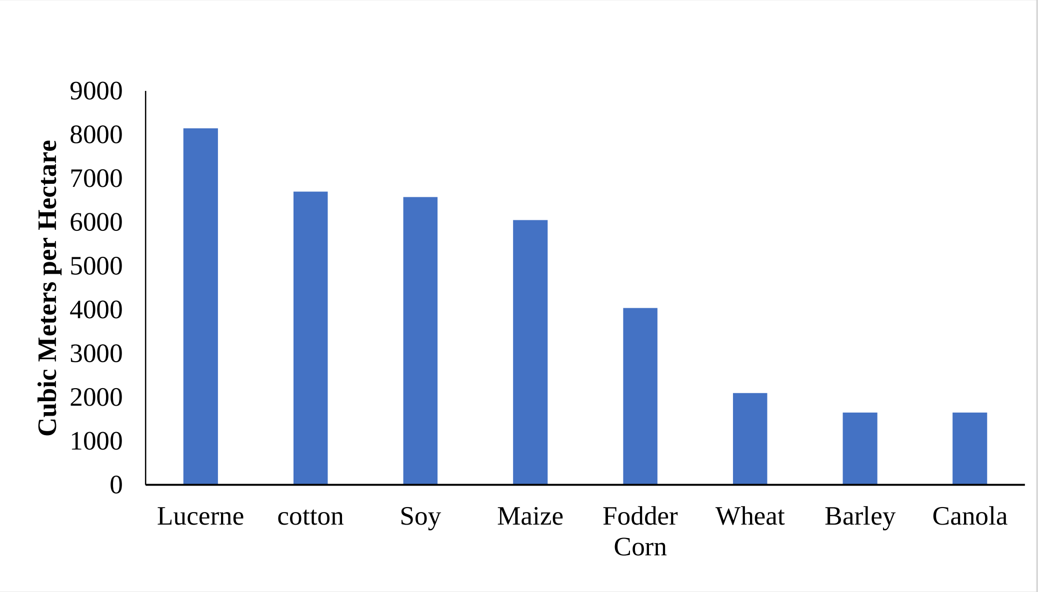

Fig. 3. The net water requirement of the Khodafarin irrigation networks in first civil areas crop pattern products based on National Water Document of Iran

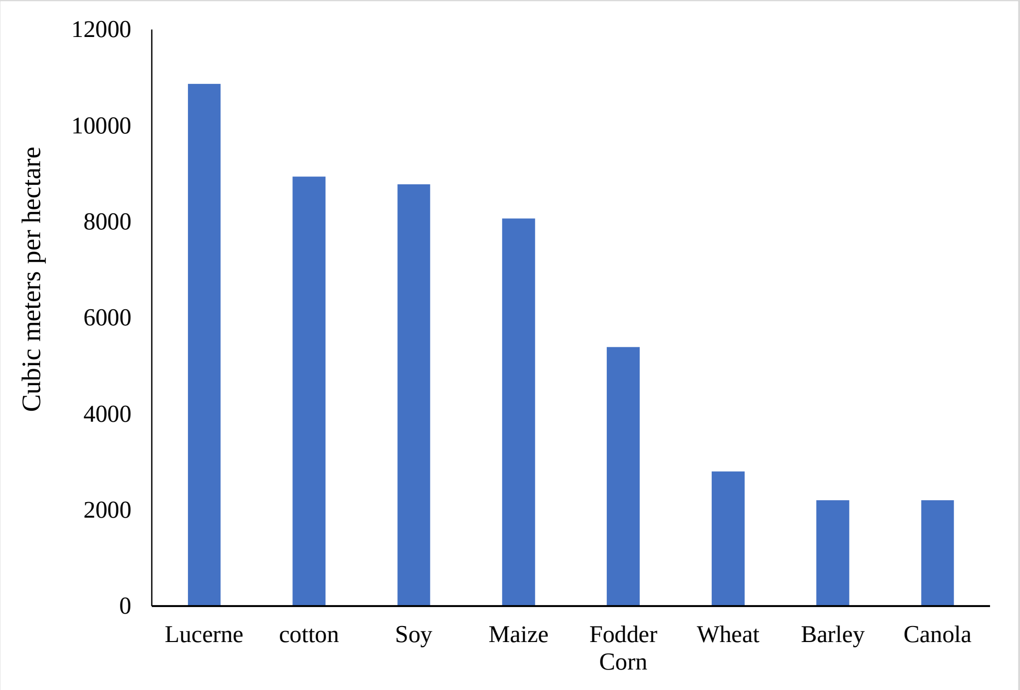

Fig. 4. The amount of gross water requirement of the Khodafarin irrigation networks in first civil area crop pattern products with efficiency of 75%

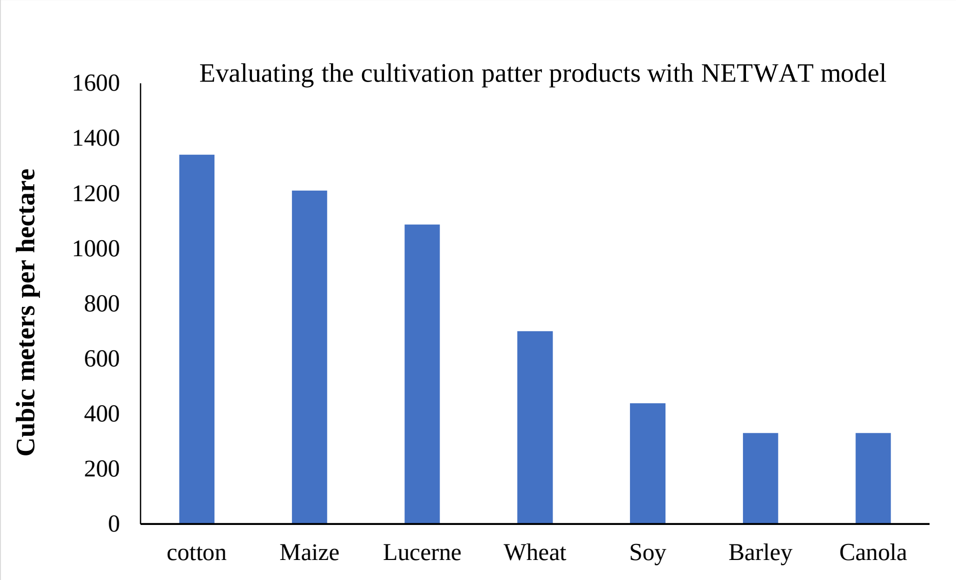

Fig. 5. The gross water requirement of crop pattern products with efficiency of 75%

The soil in the case study areas has a sandy loam texture. Fig. 6 separately shows the consuming water volume of the center pivot (z15-cp1) irrigation system for Noor Mohammad Kandi legal organization (Rural production cooperative company) and center pivot (z19-cp3) irrigation system for Khanlar legal organization (Rural production cooperative company).

Cultivation of the all mentioned cultivation pattern products with various water requirement, growth period and irrigation time in an irrigation network or land with a center pivot irrigation system is not possible because of inflexibility, rotating and continues motion of mentioned systems, for preventing this type issues the lands have been divided to two semicircles and to observe the cultivation pattern, each semicircles have been allocated to spring and autumn cultivation with 50 percent ratio, with that said in crop year (2019_2020) the mentioned 48 and 49 hectare lands with z15_cp1 and z19_cp3 center pivot irrigation systems were allocated to wheat and maize by 50 percent ratio. It is worth to be mentioned that because of low water requirement and long growth period, increasing the cultivated area in autumn, compared to the intended share, it does not make any issues in utilization, but it would cause problems in spring. The permissible water consumption with 60 percent irrigation efficiency according to gross water requirement of wheat and maize products in mentioned cultivation pattern (50% autumn + 50% spring) is 326000 m^3yr^{-1}. Numbers shows that the z15_cp1 irrigation system has consumed 330000 cubic meters which according to the following calculation the total irrigation efficiency is approximately 60%: 60% (Ep) = 75% (Ea) × 87% (Ed) × 92% (Ec).

And numbers show that the z19_cp3 irrigation system has consumed 453807 cubic meters which according to following calculation, the total irrigation efficiency is 44%: 44% (Ep) = 55% (Ea) × 87% (Ed) × 92% (Ec)

Average crop yield for wheat and maize in cultivated area with z15_cp1 irrigation system respectively is 7 and 7.5 ton per hectare, while this numbers are 4 and 4.2 to per hectare for cultivated areas with z19_cp3 irrigation system. In near/adjacent farms of the Khodafarin irrigation and drainage network, especially Moghan and Pars Agricultural cooperatives which are Equipped with new irrigation systems including center pivot, the crop yield has

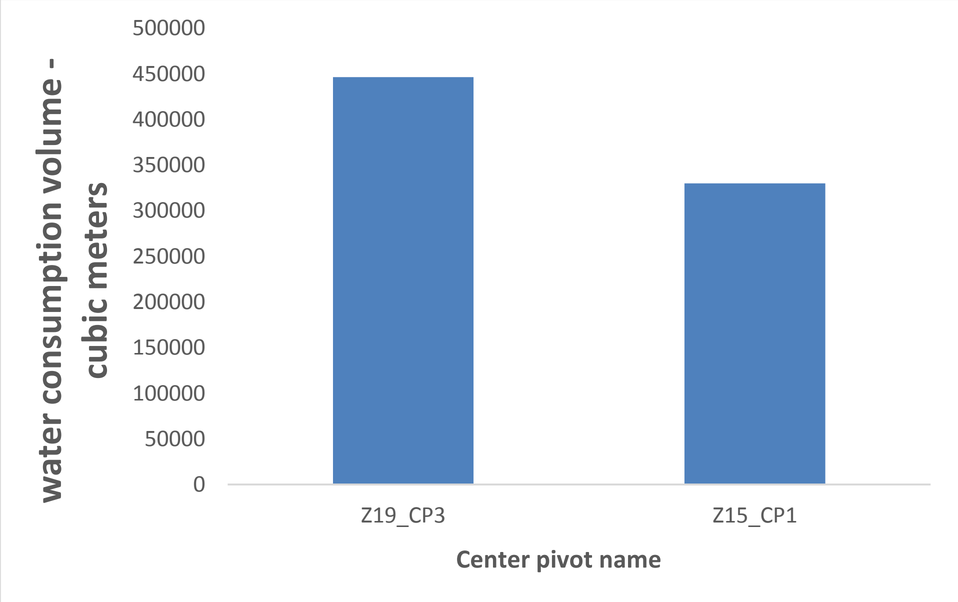

Figure 6- water consumption volume of cp1 and cp3 irrigation system

been reported 8.5 ton/ha for wheat and 10 ton/ha for maize. Utilization and maintenance cost for subnet, pump age station and Z15_cp1 irrigation system for Noor Mohammad Kandi cooperative has been reported 700000 tomans and for Khanlar cooperative with z19_cp3 irrigation system 10000000 Rials per hectare.

RESULTS AND DISCUSSIONS

The performance comparison of two z15-cp1 and z19-cp3 center pivots respectively used in two 48 and 49 hectares farms which they are managed by legal organizations (NRC) shows that the z15-cp1 center pivot performance in terms of increasing the irrigation efficiency, reduce maintenance costs and increasing the production per unit area of the farm is more appropriate than z19-cp3 center pivot system. Unified management by managing director/executive director and nonintervention of the participant operators in the amount and time of the irrigation and movement speed of center pivot machine caused optimal water consumption and utilization based on water requirement. Machines timer was adjusted on number 50 during the irrigation, which means 30 seconds movement and 30 seconds flag stop that because of this suitable adjustment, wastewater was very low and wheels movement were convenient and also fixing possible bugs and intime maintenance has been done. The main reason for inappropriate performance of the z19_cp3 machines was weakening the management position by participant operators. In this organization (Rural Production Cooperative Company) same as (NRC), management of the irrigation plan is managing director’s responsibility but operator’s intervention in irrigation time, changing the movement direction and speed caused decreasing in water productivity and consuming water more than water requirement. lack of unified management caused an uneven growth of products also in addition to water waste, increase in operation and maintenance costs and decrease in production rate per unit area can be seen, although cohesive management of pressurized subnet and new/modern irrigation system by creating appropriate/suitable operating system, cooperation with main irrigation network management for integrated management in all parts of the net. Observing the garden and agriculture optimal cultivation pattern, observing basics of network design, attention to technical commitments, believing in fair distribution of water, attention to water and soil conservation, observing environmental considerations can promotes the utilization and maintenance condition of nets and leads to optimal water consumption, decrease in utilization and maintenance cost and gain in production rate per unit area but it's not enough. Nets optimal management is not achievable without technical and social preparations prior phases/stages like feasibility, cognition, design, studies and implementation, unfortunately due to intervention of politicians in performance of capital asset acquisition plans especially water resources development plans and not paying attention to land use planning, technical view to the schemes, business consideration of consulting engineers, lack of peoples participation in prior stages/phases of operation period peoples/public distrust of the authorities, prolongation of execution time, lack of coordination between water and soil management authorities in country, low literacy among agricultural operators, consulting engineers low level of knowledge of rural sociology. Technical and social preparations like applying operation requirements in design and perform phase of the irrigation facilities, attract participants to cooperate in mentioned phases and paying attention to social and environmental considerations before operation phase has not been done so problems and issues are transferred to operation phase. The case study (Khodafarin irrigation and drainage network first civil area) is no exception to mentioned principles. Studies of the mentioned area with other Khodafarin irrigation parts were started and ended in 1990s. executive operations started in 2004 which because of financial and credit issues continued slowly and finally stopped and in 2015 with support of the National Development Fund, started working again with other internal projects and become operational in 2019. Prolongation of execution time period, in addition to depreciation of some facilities caused discouragement and participants distrust of project that its effects are tangible in current phase (operation phase).

The lands of the area are rangelands and its transfer to the eligible nomads coincides with the exploitation period. Social based on design, etc., realized the design, which is not unaffected by the management of the operation. The technical one-dimensional view and inattention to social issues in the project in question was evident in the design and implementation phase by the contractors and consultants, and the result can be seen in the current phase. On the other hand, users' weak belief in participation, high cost of agricultural inputs, high cost of maintenance and operation of pressurized sub-network and new irrigation systems and limited water resources due to reduced water quota of Moghan and Khodaafarin irrigation networks and its allocation to upstream provinces. The concern of the increased operators and the stability of the new exploitation systems threaten.

CONCLUSIONS

The amount of permissible volume of consumable water according to the percentage of designed cultivation pattern is 320880 cubic meters for cultivated areas of Noor Mohammad Kandi cooperative with z15-cp1 center pivot irrigation system, with an area of 48 hectares which the cooperative organization consumed 330000 cubic meters in the crop year that shows the appropriate management of the cooperative and the pleasant performance of the machine/system. The amount of permissible volume of the consumable water for 49 hectares lands of Khanlar Rural production cooperative company with z19-cp3 center pivot irrigation system is 327565 cubic meters but the mentioned cooperative has used total of 446439 cubic meters in the crop year that indicates the very poor management of the cooperative in operating the machine and machines inappropriate performance. Irrigation efficiency for foresaid machine is about 55 percent which is low. The cost of utilization and maintenance for the first farm is 30 percent less than the second one and average production of 48-hectare farm is 43 percent more than 49 hectares farm, per hectare.

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