SENSITIVITY ANALYSIS OF IRRRGATION CANAL CAPACITY WITH RESPECT TO FARMERS' DEGREE OF FREEDOM

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ABSTRACT

One of the reasons for poor performance of irrigation networks is the problem of water distribution and delivery methods. Among different delivery methods, on request system has higher flexibility than rotational delivery, and doesn't need high cost automatic systems of on-demand methods. On request system could be applied on existing manually operated irrigation networks with minor changes. Implementation of this method in existing networks increases the flexibility. Some effective factor in canal capacity are: Farmers' Degree Of Freedom (E), the operating time of the network (t), cumulative probability (Pq) of simultaneous operation of intakes. The main objective of this paper is sensitivity analysis of canal capacity with respect to farmer's degree of freedom to be used for on request system. For this purpose, the First Clement's model was used. For the present study, the East Aghili canal was evaluated. The First Clements' model was implemented for the wide range of variation of effective factors. For degree of freedom, the range of 1 to 8, and for duration of irrigation, the range of 2 to 24 hours was examined. According to the results the degree of freedom could be divided to 4 intervals, which have sharp different impacts on canal capacity. As the degree of freedom is increased, the irrigation could be completed in a shorte time. For higher degree of freedom (6-8) irrigation duration could be completed in 4 hours, while for low degree of freedom (1-2) the minimum irrigation time is 16 hours. The sensitivity of canal capacity for longer irrigation time is, higher.According to these results, the most suitable degree of freedom for Aghili canal is 1 to 2.

Keywords: Sensitivity Analysis, Farmers' Degree of Freedom, Irrigation canal capacity, on request method, First Clements' Model

1. INTRODUCTION

Limited available water for agriculture, and high costs of irrigation networks, require planning, managing, and operating of irrigation networks in a way that water productivity is maximized. Studies on a large number of irrigation networks worldwide, especially in developing countries, indicate that water use and distribution performance is not desirable. Unsuitable distribution of water delivered to users, is one of the reasons for poor performance of irrigation networks (Monem and Namdarian, 2005). Water distribution and delivery scheduling is a process by which the irrigated area, the water receivers, and the quantity and time of water delivery are specified. Flow factors such as discharge, irrigation time, irrigation period, and policies such as farmers' degree of freedom, range of management constraints, and the interval between request and delivery must be determined in planning water distribution. Decision on of flow adjustment, are made at different decision-making levels between network manager and farmers which results to diverse operation methods with various flexibility levels. The rotational, on demand, and on request (consensual) methods are among the most important ones proposed by researchers for water distribution and delivery (Savari and Monem, 2017).

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In the rotational method of water distribution and delivery, three factors (discharge, irrigation time, and irrigation period) are usually constant and predetermined by network officials (Mathur et al., 2009). Low cost of the network and high covered area, beside low flexibility and high water losses are the main charachteristics of this method. In on demand method, flow factors vary within a broad range and farmers are in charge, therefore this method enjoys the highest flexibility.High network cost due to high canal capcities, storage reserviors, and automation are among limitations of this method. on request method falls somewhere between the rotational and on demand methods. It is more flexible than the rotational method but the farmers are not in full control.Farmers request the water, network manager modifies requests considering available water, the number of farmers requesting water, and the capacity of the canal and structures, and reaches an agreement with farmers. Network managemnt adjusts the structures in a way to implement the agreement in the best possible way (Burt, 2011). Water delivery through this method improves flexibility compared to the rotational method, does not require automatic systems or water reservoirs, and entails lower costs. Moreover, this method can be implemented in existing irrigation networks with upstream control systems and manual operation with management improvement.

Most irrigation networks worldwide employ the rotational method and are operated manually. The best solution for increasing flexibility and productivity at low cost is to change the rotational method to the on request one. It should be noted that the increase in flexibility and decision making on water delivery factors should be done in such a way that the required flow does not exceed the canals’ capacity and could be implemented using existing structures.

One of the models that have been used in determining irrigation canals’ capacity for on demand systems isa model called the Clément’s first formula introduced by Clément in 1966. It is based on a probabilistic method according to which the number of farmers that simultaneously demand water follows a binomial distribution (Monserrat, J. et al., 2004).

Since both the on request and on demand methods aim to provide crop water requirement to achieve the highest yield, it can be said that simultaneous demands and number of requests are similar. Therefore, this model can be used to predict the requests and calculate the canal flow in on request method.For this purpose the important factors such as farmers’ degree of freedom, cumulative probability of simultaneous operation of intakes, and operating time of the intakes should be investigated. In this research sensitivity analysis farmers’ degree of freedom, irrigation time, and the probability of simultaneous operation of the intakes on the canal capacity is performed. The study is done on a sample canal and appropriate on request water delivery is suggested.

1.1 Introducing the Clément’s First Formula

In the on demand irrigation practices, the nominal discharge of intakes is considered higher than that of the peak period compared to the rotational method. This allows farmers to irrigate their lands in less than 24 hr. In this situation the probability of simultaneous operation of all intakes is low. Therefore, it is not logical to consider canals’ capacity equal to the sum of the capacities of all the intakes. In 1966, Clément introduced the first formula (equation 1) for calculating the flow for the on demand method by assuming normal distribution for simultaneous operation of the intakes (Lamaddalena et al., 2000).

$$Q_k = \sum_{i=1}^{R} P_i d_i + (U_{p_q}) \sqrt{\sum_{i=1} P_i (1 - P_i) d_i^2} \qquad (1)$$

Where Q is the canal capacity that supply R intakes located downstream in $l\,s^{-1}$; p_i is probability that an intake is open, which is defined as equation 2; q_i is probability that an intake is closed; d_i is the nominal discharge for each intake in $l\,s^{-1}$; p_q is the cumulative probability of simultaneous operation of intakes. $U(p_q)$ Is the standard normal variable corresponding to the p_q.

$$P_i = \frac{q_s A_p}{r d_i} \qquad (2)$$

Where q_s is the specific continuous discharge, 24 hours per day ($ls^{-1}A^{-1}$); $A_p$is the area of the plot irrigated by the intake (ha); r is the coefficient of utilization of the network.

Coefficient of utilization indicates to what degree farmers are free to adjust their irrigation time and can irrigate their lands in less than 24 hr. (equation 3**)**(Lamaddalena et al., 2000).

$$r = \frac{T'}{T} \qquad (3)$$

Where T is the duration of the peak period (hr.); T' is the operating time of the network (hr.) during the period T. The values selected for the parameter r normally lie between 16/24 (r=0.67) and 22/24 (r=0.93).

Farmers' degree of freedom shows that at how much higher a discharge level than the specific continuous discharge the farmers can irrigate their lands (equation 4).

$$E = \frac{d_i}{q_s A_p} \qquad (4)$$

In on demand systems, the least value for degree of freedom is about 1.5 to 2 and values of 6 to 8 are the highest degree of freedom.

Probability ofsimultaneous operation of intakes ($\boldsymbol{p_q}$), indicates the farmers' possibility for simultaneous utilization of the network. In other words, it shows the probability of simultaneous operation of N intakes in the network. For high fexible systems this value is about 0.95 to 0.99(Lamaddalena et al., 2000).

In a pilot study, Naghaee and Monem, evaluated the Clément's first formula application. Results indicated that although this model was introduced to determine irrigation networks' capacity for on demand method, it could also be employed for determining irrigation canals' capacity using the on request method provided that the suitable coefficients were applied.(Naghaee and Monem, 2018)

1.2 Introducing East Aghili canal

The Aghili Irrigation Network became operational in 1980. It consists of the main Aghili Canal and 2 first-order canals called East Aghili and West Aghili Canals. The main canal has the capacity of 12 m3/s, receives water from the Gotvand Regulating Dam, and the East and West Aghili Canals (with the capacity of 5 and 7 m3/s, respectively) are branched at kilometer 931+1 (Figure 1). The East Aghili Canal, studied in the present research, has 21 intake structures, 11 regulating structures, and 4 siphons serving 1,529 hectares of irrigable land. All intakes and regulating structures in this network are operated manually. Water distribution and delivery in the East Aghili Canal is as follows. As in the case of all Iranian irrigation networks, the Dam Operations Office announces the water share at the beginning of each irrigation season. Considering the volume of available water, each network makes the necessary plans for the next crop season. Depending on the regional weather conditions, each network usually has a specific crop pattern in which summer crops, wheat, and maize are the most important crops (shahverdi et al., 2015).This study investigated the canals' flow and the water delivery program for the first summer month of 2014, which serves 642.68 ha at maximum discharge of 3.4m3/s.

2. RESULT AND DISCUSSION

The Clément's first formula was studied for 1-8 degrees of freedom, 50-99% cumulative probability of simultaneous operation of intakes, and 2-24 hr. irrigation times to determine the degree of sensitivity of the canals' capacity to the mentioned factors. At the first step, for a specific probability the canals' capacityvariation is investigated for different

degree of freedom ranging from 1-8, and irrigation time of 2 to 24 hr.The results for the cumulative probability of50-70-90-99% and are presented in Figure 2.

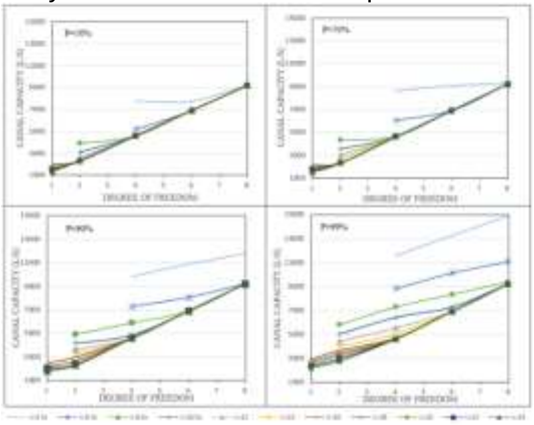

Figure 2: East Aghili canal capacity relation to the degree of freedom for$\boldsymbol{p_q} = \mathbf{50}\%,\ \mathbf{70}\%, \mathbf{90}\%\ \boldsymbol{and}\ \mathbf{99}\%$ in different irrigation times

At the second step, for a specific irrigation times, the canals' capacity variation with respect to different degree of freedom ranging from 1 to 8, and different probabilities ranging from 50% to 90% is investigated. The resuts for irrigation times 4-8-16-24 hr. are presented in Figure 3.

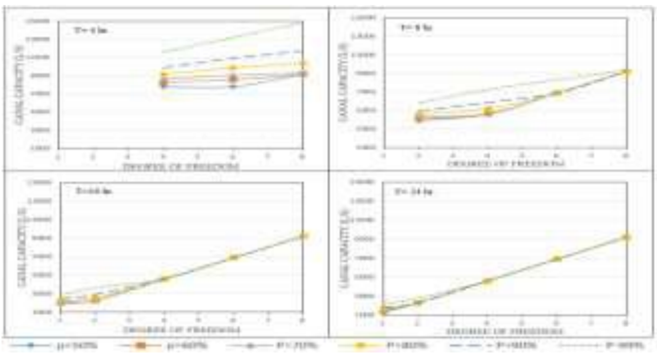

Figure 3: East Aghili canal capacity relation to the degree of freedom for$\boldsymbol{T} = \mathbf{4}, \mathbf{8}, \mathbf{16}\ \boldsymbol{and}\ \mathbf{24}\ \boldsymbol{hr}.$ In different cumulative probability

According to the results the degree of freedom could be divided to 4 intervals, which have sharp different impacts on canal capacity. As the degree of freedom is increased, the irrigation could be completed in a short time. Therefore for higher degree of freedom (6-8) irrigation duration could be completed in 4 hours, while for low degree of freedom (1-2) the minimum irrigation time is 16 hours(Table 1), (Figure 4).

Table 1: Canal capacity sensitivity with respect to Farmers' degree of freedom

Number of intervals	Farmers' Degree Of Freedom (E)	Slope of canal capacity variation (S)	Length of Irrigation time (t)
First	1-2	Mild	16-24
Second	2-4	fairly steep	8-24
Third	4-6	Steep	4-24
Fourth	6-8	very steep	4-24

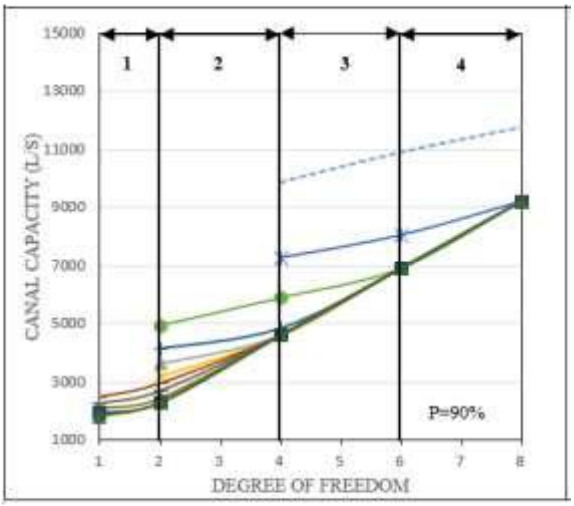

Figure 4: 4 Intervals of degree of freedom

The sensitivity of canal capacity for longer irrigation time is, higher. For instance for Pq=99%, when the degree of freedom is reduced by 50%, for t= 6 hr. canal capacity is reduced by 20%, whereas for t= 24 hr. it is reduced by 50% (Figure 5).

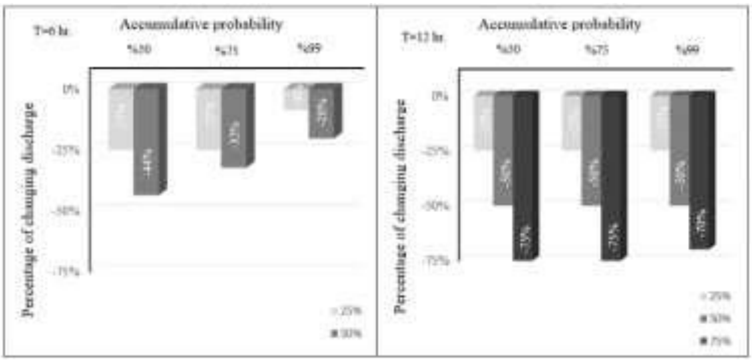

Figure 5: percentage of changing discharge with respect to percentage of reducing 25%, 50% and 75% degree of freedom

3. CONCLUSION

The East Aghili Canal can employ the on request method at E=1.5, t=16 hr. and p=99% without making considerable changes in the physical conditions of the canals. On the other hand, maintaining the present canal capacity, the degree of freedom can be increased by up to 4, and the irrigation time can be reduced down to 8 hr. (for p_q=55%), if the capacity of the intakes could be increased.

According to these results, the first interval with the degree of freedom of 1 to 2 is the most suitable for Aghili canal.

4. REFERENCES

Burt, C. M. (2011).“The Irrigation Sector Shift from Construction to Modernization: What is required for Success?” 8th N.D. Gulhati Memorial Lecture for International Cooperation in Irrigation and Drainage. pp. 7-22.

Clément, R. (1966). “Calcul des débitsdans les réseauxd'irrigationfonctionnant à la demande”. La Houille Blanche 5: 553-575.

Lamaddalena, N. and Sagardoy, J. A. (2000).”performance Analysis of On-demand pressurized Irrigation Systems”. FAO Irrigation and Drainage Paper 59.

Mathur, Y. Sharma, G. and Pawde, A. (2009). “Optimal operation scheduling of irrigation canals using genetic algorithm” 1(6): 11–15.

Monem, M. J. and Namdarian, R. (2005). “Application of simulated annealing (SA) techniques for optimal water distribution in irrigation canals.” *Irrigation and Drainage*54(4): 365-373.

Monserrat, J. Poch, R. Angeles Colomer, M. Mora, F. (2004). Analysis of clement’sfirstformula for irrigation distribution networks. Published in Journal of Irrigation and Drainage Engineering, Vol. 130, n.2, April 2004.

Naghaee, R. and Monem, M. J. (2018). “Defining the basics of the three methods, rotational, on request and on demand for Determining of Irrigation Canal Capacity Using First Clements' Model(Case Study: East Aghili Canal)”. 17th National Conference on Iranian Hydraulic Associate, Shahrekord University, Shahrekord, Iran. (In Persian).

Savari, H. and Monem, M. J. (2017). “Development the Basis of On-request Method in Irrigation Networks”. 15th National Conference on Iranian Hydraulic Associate, Emam Khomeini International University, Ghazvin, Iran. (In Persian).

Shahverdi K, and Monem, M. J. andNili, M. (2015)."Fuzzy Sarsa Learning of Operational Instruction to Schedule Water Distribution and Delivery". *Irrigation and Drainage*.