ON FARM RESERVOIR AND ITS EFFICIENT OPERATION FOR CROPS OF 3 TO 7 NUMBER OF IRRIGATIONS

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Abstract - *Water is indispensible for the existence of animal and plant eco systems and is an essential element in the development of economic activities of any nation. It is the most vital resource for the existence of life on the earth. No other natural resource is having such an overwhelming influence. According to Mahatma Gandhi, the father of the nation, "Nothing can be more important than the provision of irrigation facilities in all the villages of the country, because this constitutes the basis for agricultural growth. In the absence of irrigation facilities, agriculture is nothing more than a gamble". Though, irrigation facilities is one of the most significant factors contributing to the agricultural development, a significant amount of water get wasted due to use of less efficient techniques of irrigation. The present study deals with improvement in water irrigation efficiency of crops requiring three to seven numbers of irrigations with the use and efficient operation of on-farm reservoir (OFR).*

Key Words: On-farm reservoir, Irrigation efficiency, Operation of OFR and Efficient path.

1. INTRODUCTION

Freshwater is available as rainfall, surface water, ground water and atmospheric moisture. All these sources vary over place and time both seasonally and from year to year to year. Presently, many Indian cities do not have sources of water and in future, it would have to be transported over large distances as the water is found more away from the cities. It has been observed that irrigation alone accounted around 86 present of the total water use. Also, the demand of water for domestic, industrial and thermal power generation is expected to increase sharply in the near future. A major portion of valuable irrigation water is lost to the atmosphere through evaporation and to the ground through seepage loss during its conveyance from source to the field. This leads to poor irrigation efficiency (Danny et al., 1997). It has therefore absolute necessity that efficient techniques be devised, which lead to higher water irrigation efficiency. Though certain amount of water loss can be saved by means of adopting better irrigation methods and reducing the conveyance distance, however, due to prohibitive initial cost and practical constrains in developing countries like India, their use is restricted and may not be feasible. It is, therefore, important that water efficiency should be improved. To achieve the desired goals, farmers cooperation is must in the process of water management and special emphasis must be given on the micro irrigation to increase the water use efficiency at his farm.

1.1 On farm reservoir (OFR)

On-farm reservoir is nothing but a Farm reservoir which captures rainfall and irrigation return flow from field and stores it within the cultivated area into some type of reservoir. This stored water of OFR is used as supplemental irrigation. Here, supplemental irrigation (SI) is defined as the application of a limited amount of water to the crop when rainfall fails to provide sufficient water for plant growth to increase and stabilize yields (Oweis et.al, 1999). This additional amount of water alone is inadequate for crop production. Hence, the essential characteristic of SI is the supplemental nature of rainfall and irrigation. It is assumed that the water productivity (WP) (i.e., the ratio of economic yield of a crop and the total amount of water consumed) by this method is unaffected.

The sustainability of the various types of OFR is found to depend largely upon the timing and the amount of water to be stored, crop type, cropping pattern, soil type and depth, land topography, climatic conditions and local socioeconomic factors, these systems tend to be very site-specific.

Before designing on-farm reservoir, proper estimation of water yield from the cropped field and the water requirement of the crop in the field should be assessed and for an optimum design the demand should match with the availability as reported by Panigrahi and Panda (2003).

2. RESEARCH METHODOLOGY

If the capacity of OFR is assumed to be two times the excess runoff, then there can be possibility of filling of remaining capacity of OFR through direct withdrawal of water. Thus, in addition to agricultural needs during each irrigation, if the farmer aspires to conserve water in OFR by direct withdrawal of water in OFR as shown in Fig. 1, the network of supplemental use of OFR water with different rotations of irrigations of crop becomes complex.

After each rotation of irrigation, the runoff of excess irrigation in the farm will make OFR either partially filled or full, depending on the storage capacity of OFR. The size of OFR depends on the type of crop(s), supplemental irrigation needs, topography and climate of the area (Palmer et al., 1981, Palmer et al., 1982 and Panigrahi and Panda, 2003). Assuming that capacity of OFR is twice the runoff, after 1^{st} rotation of irrigation the OFR will be half filled. However, in addition to agricultural needs during each watering, if the farmer aspires to conserve water in OFR through direct withdrawal of additional water through supply channel to OFR as shown in Fig.1, the network of supplemental use of OFR water with different number of irrigations of crop becomes complex. At the onset of the 2^{nd} rotation of irrigation, the farmer has various options of using stored water of OFR depending on the filled status of OFR. Any amount of water can be withdrawn from OFR depending on the ambition of the farmer. Assuming that a farmer has only three options of withdrawal of water, so that the OFR remains either full/ nearly full, half full/ nearly half full or empty/ nearly empty. After the 2^{nd} rotation of irrigation, the OFR will have different filled status depending upon the adapted withdrawal manner of water by the farmer from OFR. Similar procedure is to be adopted during the next rotation of irrigation, which may be half filled or completely filled or empty status of OFR. However, on the onset of the last irrigation, farmer would have to, in any case, empty OFR, otherwise stored water would be wasted, without any utility. Thus a network can be drawn considering these possibilities similar to the one as shown in Fig. 2 for a crop of 4 irrigations. In Fig. 2, columns 'i', 'k' and 'l' together and 'n' and 'o' together as well as 'p' represent status of OFR after 1^{st}, 2^{nd}, 3^{rd} and 4^{th} rotations of irrigation, respectively. Here, columns 'l' and 'o' correspond to direct filling of OFR through supply channel. Columns 'j', 'm' and 'p' indicate options of withdrawal of water. The numbers of possible paths in case of crops of 3, 4, 5, 6 and 7 irrigations respectively are 7, 26, 97, 362 and 1351. Once the network of various strategies is drawn, the problem is, thus, to identify the most efficient strategy or path of operation, which would lead to maximum saving of water. The most efficient strategy of operation is identified and explained with the help of an illustrative example.

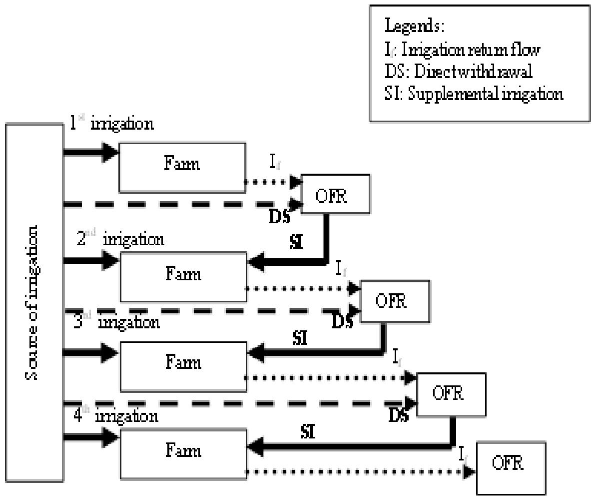

Fig. 1: Flow diagram showing the source of water to OFR and its utilizations

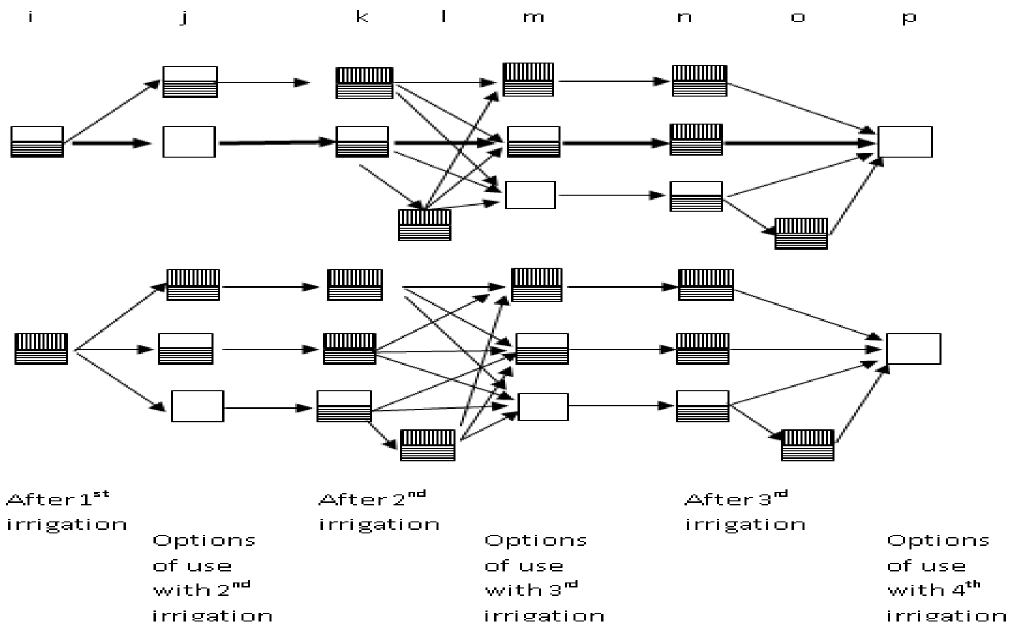

Fig. 2 Network for a crop of four numbers of irrigation

3. ILLUSTRATIVE EXAMPLE

Consider a farm having a lined OFR at the end corner of the field as shown in Fig. 3(a) and 3(b). The OFR can be filled by agricultural runoff collection from the field and directly through the supply channel. Let the total area of the field be 1 hectare excluding the surface area of OFR. It is assumed that the crops grown require 40 cm of water in 4 numbers of irrigation. It is given that water application efficiencies through field and supply channel are 75% and 90 %, respectively. The respective coefficients due to evaporation, deep percolation and runoff are assumed as 0.25, 0.25 and 0.50. It is also assumed that during entire crop period, there is no rainfall and application efficiency of OFR is 100%.

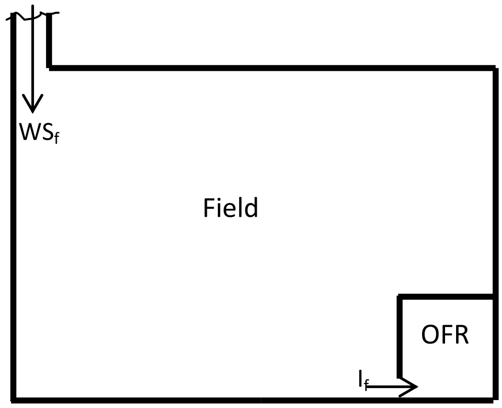

Fig. 3.a Plan of field and lined OFR

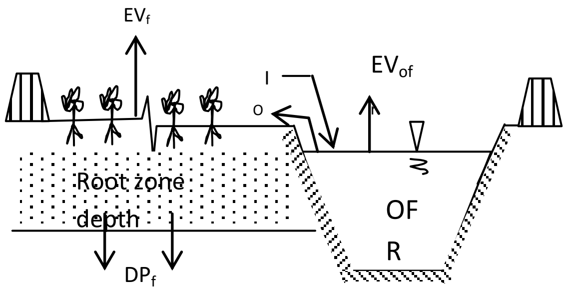

Fig. 3.b Cross-section of lined OFR with flow details

LIST OF NOTATIONS

Let us use the following notations and equations for the convenience, as shown in Fig. 3.(b).

DP_f = Deep percolation loss from field in m^3
EV_f = Evaporation loss from field in m^3
EV_{ofr} = Evaporation loss from surface of the OFR in m^3
I_f = Inflow to the OFR from field as irrigation return flow in m^3
O_f = Outflow or withdrawal from the OFR into field to supplement irrigation needs in m^3
WS_f = Water supply in the field in any particular irrigation in m^3
C = Storage capacity of OFR in m^3
C_p = Percolation coefficient
d = Total depth of crop water requirement in m
f = No. of irrigations of the crop
K_f = Coefficient of water loss from field
K_{ofr} = Coefficient of water loss from OFR through evaporation
NS = Net storage in OFR in m^3
R_c = irrigation return flow coefficient
TWR = Total water required for the particular crop in m^3
WR = Water required by the crop in any particular irrigation in m^3
η_f = Water application efficiency of the system. In terms of these notations, the following relationships hold good.

$$WR = \frac{TWR}{f} \quad (1)$$

$$WS_f = \frac{TWR}{\eta_f . f} = \frac{WR}{\eta_f} \quad (2)$$

$$DP_f = C_p.(WS_f - WR) \quad (3)$$

$$EV_f = K_f.(WS_f - WR) \quad (4)$$

$$I_f = R_c.(WS_f - WR) \quad (5)$$

Water balance model of the OFR was run by considering all the inflow and outflow components of the OFR. The inflow is irrigation return flow from the field coming to the OFR and the outflows are evaporation, seepage and percolation and supplemental irrigation supplied to crops in the field. The various components of the OFR water balance model are:

$$S_i - S_{i-1} = NS_i = I_{fi} + P_i - EV_{ofri} - SI_i - DP_{ofri} \quad (6)$$

Where:
S_i is the OFR water storage at stage i, m^3
I_{fi} the volume of irrigation return flow from the field to the OFR, m^3
P_i the volume of direct rainfall in the OFR, m^3
EV_{ofri} the volume of water lost as evaporation from the OFR, m^3
SI_i the volume of water used as supplemental irrigation in the cropped field, m^3
DP_{ofri} the volume of water lost as seepage and percolation from the OFR storage, m^3
i is the time index taken as the time interval between two consecutive irrigations.

If A_{field} is the field area given as:
$A_{field} = FA - A_{ofr}$

Where: FA is the farm area

A_{ofr} is the area of the OFR, the value of total water required (TWR) for any crop is estimated by multiplying depth of water required (d) by the crop with $A_{field.}$

With $C_p = 0.25$, $K_f = 0.25$, $R_c = 0.50$, and $K_{ofr} = 0.1$, and using the data given in the illustrative example and invoking Eqs.(1) to (6), we get various quantities during first irrigation event at node "i" as :

WR = 1000.00 m^3
WS_f = 1333.33 m^3
EV_{ofr} = 33.33 m^3
I_f = 166.67 m^3
I_c = 166.67 m^3
WS_c = 185.19 m^3
O_f = 0
$C = 2 \times I_f$ = 333.33 m^3 (Assuming that the maximum storage capacity if OFR = 2 I_f = C i.e after two irrigation events OFR is full provided there is no evaporation loss).

Using the same equations, procedure and the network drawn for a crop requiring four number of irrigations as shown in Fig. 2, the saving in water using OFR, strategy of operation against the crops requiring number of irrigations is as shown in Tables 1.

Table -1: Saving of water

Strategy No.	Crop of no. of Irrigations	Strategy of operation	WS with OFR (m^3)	WS ithout OFR (m^3)	Net Saving (m^3)	Saving(%)
1	3	i1j1k1m1	3730.00	4000.00	270.00	6.75
5	4	i1j2k2m2n2p1	5002.67	5333.33	330.67	6.20
20	5	i1j2k2m3n3p2q2s1	6238.93	6666.7	427.73	6.42
76	6	i1j2k2m3n3p3q3s2t2v1	7477.76	7999.98	522.22	6.53
284	7	i1j2k2m3n3p3q3s3t3v2w2y1	8715.56	9333.33	617.77	6.62

The strategies of operation of OFR for a crops of 3 to 7 numbers of irrigations for maximum water saving is given in Table No. 2 to 6

Table 2: Strategy of operation of OFR for a crop of three numbers of irrigations

Stage of irrigation	Operation required
After 1st irrigation	Conserve excess irrigation return flow in OFR
With 2nd irrigation	Do not use OFR water
After 2nd irrigation	Conserve excess irrigation return flow in OFR along with the previous storage
With 3rd irrigation	Use entire OFR water as supplemental irrigation

Table 3: Strategy of operation of OFR for a crop of four numbers of irrigations

Stage of irrigation	Operation required
After 1st irrigation	Conserve excess irrigation return flow in OFR
With 2nd irrigation	Use entire OFR water as supplemental irrigation
After 2nd irrigation	Conserve excess irrigation return flow in OFR
With 3rd irrigation	Do not use OFR water
After 3rd irrigation	Conserve excess irrigation return flow in OFR along with the previous storage
With 4th irrigation	Use entire OFR water as supplemental irrigation

Table 4: Strategy of operation of OFR for a crop of five numbers of irrigations

Stage of watering	Operation required
After 1st irrigation	Conserve excess irrigation return flow in OFR
With 2nd irrigation	Use entire OFR water as supplemental irrigation
After 2nd irrigation	Conserve excess irrigation return flow in OFR
With 3rd irrigation	Do not use OFR water
After 3rd irrigation	Conserve excess irrigation return flow in OFR along with the previous storage
With 4th irrigation	Use entire OFR water as supplemental irrigation

After 4th irrigation	Conserve excess runoff in OFR along with the previous storage
With 5th irrigation	Use entire OFR water as supplemental irrigation

Table 5: Strategy of operation of OFR for for a crop of six numbers of irrigations

Stage of irrigation	**Operation required**
After 1st irrigation	Conserve excess irrigation return flow in OFR
With 2nd irrigation	Use entire OFR water as supplemental irrigation
After 2nd irrigation	Conserve excess irrigation return flow in OFR
With 3rd irrigation	Use entire OFR water as supplemental irrigation
After 3rd irrigation	Conserve excess irrigation return flow in OFR
With 4th irrigation	Use entire OFR water as supplemental irrigation
After 4th irrigation	Conserve excess irrigation return flow in OFR
With 5th irrigation	Do not use OFR water
After 5th irrigation	Conserve excess irrigation return flow in OFR along with the previous storage
With 6th irrigation	Use entire OFR water as supplemental irrigation

Table 6: Strategy of operation of OFR for a crop of seven numbers of irrigations

Stage of irrigation	**Operation required**
After 1st irrigation	Conserve excess irrigation return flow in OFR
With 2nd irrigation	Use entire OFR water as supplemental irrigation
After 2nd irrigation	Conserve excess irrigation return flow in OFR
With 3rd irrigation	Use entire OFR water as supplemental irrigation
After 3rd irrigation	Conserve excess irrigation return flow in OFR
With 4th irrigation	Use entire OFR water as supplemental irrigation
After 4th irrigation	Conserve excess irrigation return flow in OFR
With 5th irrigation	Use entire OFR water as supplemental irrigation
After 5th irrigation	Conserve excess irrigation return flow in OFR
With 6th irrigation	Do not use OFR water
After 6th irrigation	Conserve excess irrigation return flow in OFR along with the previous storage
With 7th irrigation	Use entire OFR water as supplemental irrigation

4. DISCUSSION :

If the farmer aspires to conserve water in OFR through direct withdrawal of water to OFR in addition to agricultural needs during each irrigation, operation sequence of OFR is investigated for supplemental irrigation use in case of single crops of various numbers of irrigations. Based upon the experiments results, use of OFR water as supplemental irrigation leads to improved irrigation efficiency for most of the times. The efficiency of water use increases with increase in the numbers of irrigations.

5. CONCLUSIONS

It has been found that use of OFR water as supplemental irrigation leads to improved irrigation efficiency for all the numbers of irrigations (3 to 7) of a single crop. The water application efficiency is also observed to increase with increase in the numbers of irrigations of the crop. Operation strategy of OFR for the single crop consists of conserving excess irrigation return flow from each irrigation in it and using entire OFR water as supplemental irrigation with subsequent irrigations, except last but one irrigation. With last but one irrigation, one should not use OFR water. Entire water of OFR should be used as supplemental irrigation with the last irrigation.

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