Increasing Water Use Efficiency by Canal Lining: A Case Study on the Birinchiguri Flow Irrigation Project, Assam, India

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Abstract: ***Water is the most essential commodity for human beings to be alive and so it is very necessary to make proper use of water without wasting it. Irrigation sector is the biggest consumer of water as more than 80% of available water resources in India is being presently utilized for irrigation purposes. However, the average water use efficiency of irrigation projects in the country is assessed to be only of the order of 30 to 35%. In the north eastern region also, performance of the existing irrigation schemes suffer from low water use efficiency due to distribution losses and poor operational maintenance and management and results in non - availability of water in the tail ends. Again, water demand for various purposes namely irrigation, drinking, domestic, power, industrial and other uses is increasing day by day leading to severe seasonal stress on water resources in the region. Its scarcity is more pronounced with increasing population and needs. In the present study, the water use efficiency of the Birinchiguri Flow Irrigation Project is determined as per methodology given in the guidelines for computing the Water Use Efficiency of the Irrigation Projects, Central Water Commission (CWC), February, 2014. It has also been attempted to analyze the scope of improvement of water use efficiency of the same.***

Keywords: Water use efficiency

1. Introduction

Irrigation is the essential input for agricultural development in any country. But, the irrigation sector has not produced the intended benefits and has created certain difficulties such as techno - economic, social and environmental character that must be addressed on a priority basis if the project is to be implemented on a solid foundation. As a result, there is a significant disparity between irrigation potential created and utilised. This serious issue has drawn the attention of water managers, directing them towards the basic goal of improving water use efficiency through various intervention techniques such as modernization and rehabilitation, irrigation network operation and maintenance, and conjunctive irrigation.

Again, due to constant use, irrigation systems suffer from wear and tear, resulting in a number of irrigation projects in the country operating far below their potential and the performance of existing irrigation systems suffering from distribution losses, poor operation and maintenance and non - availability of water in the tail ends. As a result, it becomes vital to examine the project's efficiency on a regular basis so that appropriate changes may be done to optimize the system's performance for maximum output from the command area.

The main objective of the study is determination of water use efficiency of the selected canals of the Birinchiguri Flow Irrigation Project which is located in the village Birinchiguri, under Chirang district of Assam, India.

2. Literature Review

A lot of researchers have contributed to the study of Water Use Efficiency in the past years. P. B. Jadhav, *et al., (*2014) in their paper, "Conveyance Efficiency Improvement through Canal Lining and Yield Increment by Adopting Drip Irrigation in Command Area" worked out the conveyance losses from lined and unlined sections of canal irrigation network under existing situation and the scenario for different management strategy to utilize saved water for irrigation in Panchnadi Minor Irrigation Project. They found the overall efficiency of lined, unlined sections of the canal and unlined field channel to be respectively 75%, 52% and 35% and the losses from them were found to be respectively 0.184 $Mm^{3,}$ 0.61 Mm^3 and 0.183 Mm^3. They also found that management interventions of converting the unlined canal network sections into lined sections can improve efficiency up to 75% and 0.376 Mm^3 of water can be saved from which about 43 Ha additional area can be irrigated.

K. S. Sujitha, *et al., (*2020), in their paper "water use efficiency in different crops cultivation: a study of borewell owning farmers from south India" made an attempt to estimate the water use efficiency of three water - intensive crops namely curry banana, sugarcane and paddy which are cultivated using groundwater irrigation. The study was carried out using field survey data collected from Sivagangai district of Tamil Nadu, India. The study found that irrigation water productivity and water use efficiency were higher for sugarcane crop. But, in terms of profitability and economic water productivity, curry banana crop cultivation seems to be more efficient. Sugarcane seems to be an efficient crop in terms of water productivity, but curry banana appears to be an efficient in terms of economic water productivity.

Maduri Mallareddy, *et al.*, (2023) in their paper "Maximizing Water Use Efficiency in Rice Farming: A Comprehensive Review of Innovative Irrigation Management Technologies" have made an attempt to show the suitability of different water - saving rice production methods. For example, drip - irrigated rice and IoT - based automated irrigation are not feasible for poor farmers due to the high production costs associated with specialized machinery and tools. Similarly, aerobic rice, drip - irrigated rice, and the SRI are labor - intensive, making them unsuitable for areas with a shortage of labor. On the other hand, DSR is suitable for labor - scarce areas, provided herbicides are used to control weeds. In their paper, the suitability of different water - saving rice production methods is reviewed based on factors such as climate, soil type, labor, energy, and greenhouse gas emissions, and their prospects and challenges are evaluated. Additionally, the article examines how cultural practices, such as seed treatment, weed control, and nutrition management, contribute to enhancing water use efficiency in rice production.

3. Study Area

For the present study, the Birinchiguri Flow Irrigation Project was selected which is located at village Birinchiguri in the Chirang district of Assam, India. The Birinchiguri village is about 30 km away from Bongaigaon town towards West direction under Sidli Development Block. It has its headwork over Birinchi River. The project has been supplying irrigation water to around 3 villages. This project was first operational in the year 2011 - 12. The project comprises of one main canal, M_1 and three branch canals viz., B_1, B_2 and B_3. The location of the project is shown below in the fig 1.

Figure 1: Location of headwork

4. Irrigation Potential Created and Utilised

The project started to supply water to the agriculture field in the year 2012 - 13. In 2012 - 13, irrigation potential created was 249 ha and out of this 195 ha was utilised. Since then, the scheme has been supplying water to the agriculture field and the potential created is also decreasing every year. In 2022 - 23, potential created was 70 ha and out of this 65 ha was utilised. Hence, there is an urgent need to increase the water use efficiency so as to increase the irrigation potential created and also to reduce the difference between the irrigation potential created and that utilised.

5. Methodology

The study was conducted as per the methodology given in the "Guideline for computing Water Use Efficiency for Irrigation Projects" of Central Water Commission - 2014. The overall Water Use Efficiency was fragmented into two components, (i) Conveyance Efficiency, (ii) On Farm Application Efficiency. Both the efficiencies was worked out separately and multiplied to get the overall water use efficiency.

5.1 Conveyance Efficiency (W_C)

The conveyance efficiency mainly depends on the length of the canals, the soil type or permeability of the canal banks and the condition of the canals. During flowing through the canals, losses like, evaporation, deep percolation, seepage, bund breaks, overtopping of the bunds, runoff in the drain, rat holes in the canal bunds etc. eventually happen. So it is necessary to assess the losses to determine the quantity of water actually delivered to the field in the project area.

So, the Conveyance Efficiency (W_C) =

$$\frac{\text{Water delivery at the inlet to the block of fields}}{\text{Water released at the project headwork}}$$

"Indian standard code of practice for measurement of seepage losses from canal, part II Inflow –outflow method" (IS: 9452 Part II 1980) was used to determine the conveyance efficiency of canals.

5.2 On Farm Application Efficiency (W_F)

The on farm application efficiency has two components:

a) W_{F1} known as water courses/field channels efficiency which accounts for the transit losses.
b) W_{F2} known as on field water application efficiency which accounts for the water loss from the field in deep percolation, leaching etc.

Thus, on farm application efficiency, $W_F = W_{F1} \times W_{F2}$

W_{F1} was determined by the inflow - outflow method. For determining W_{F2}, first, CLIMWAT 2.0 for CROPWAT software was downloaded. By opening the CLIMWAT, the nearby ET station from the study area, Dhubri was selected and the climatic data of Dhubri was exported. The various parameters like reference evapotranspiration, effective rainfall, percolation losses in the fields, crop water requirement and net Irrigation requirement were calculated for Sali paddy by using CROPWAT 8.0 software.

6. Results and Discussion

6.1 Determination of Conveyance Efficiency, W_C

"Indian standard code of practice for measurement of seepage losses from canal, part II Inflow –outflow method" (IS: 9452 Part II 1980) was used to determine the conveyance efficiency of canals. First the outlets of the canals were blocked. Then, each canal was divided into some reaches of 50.00 m (approximately). Head works cross regulator gates were closed and the head regulator gate was opened and water was allowed to flow through the canals. Then, the parameters like cross wetted perimeters, time required to travel a certain distance were measured and thus the conveyance efficiency was determined.

Table 1: Computation of conveyance efficiency, WC

Canal no.	Discharge at head, (cumec)	Effective length, (m)	Conveyance loss factor, m^3/sec per m^3/sec of inflow	Total conveyance loss	Delivery at check point	Conveyance efficiency (%)	Average (%)
M_1	0.765	700	0.167	0.127	0.637	83.3	68.13
B_1	0.178	225	0.318	0.056	0.121	68.2	
B_2	0.190	200	0.38	0.072	0.118	62	
B_3	0.246	150	0.41	0.100	0.145	59	

Thus, the conveyance efficiency is found as 68.13 %

6.2 Determination of On Farm Application Efficiency (W_F):

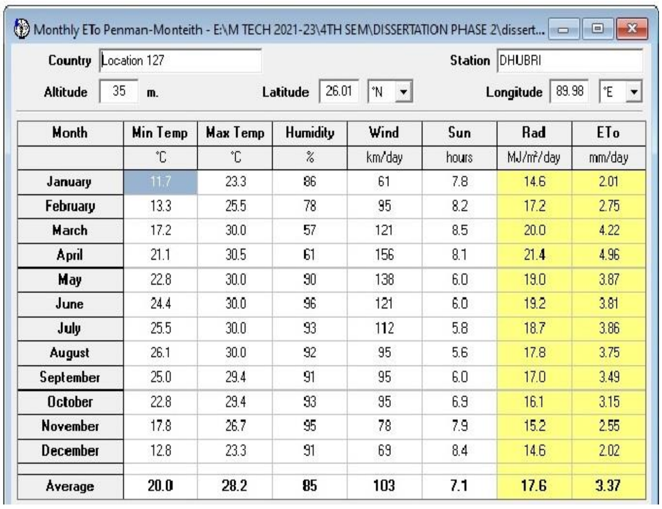
6.2.1 Determination of Water courses/field channels efficiency (W_{F1}):

To compute the water courses/field channels efficiency (W_{F1}), only the part of the canals which were not lined were considered and efficiency was computed as 62.08%.

6.2.2 Determination of on field water application efficiency (W_{F2}):

For determining W_{F2}, first, CLIMWAT 2.0 for CROPWAT software was downloaded. By opening the CLIMWAT, the nearby ET station from the study area, Dhubri was selected and climatic data of Dhubri was exported. The various parameters like reference evapotranspiration, effective rainfall, percolation losses in the fields, crop water requirement and net irrigation requirement were calculated for Sali paddy by using CROPWAT 8.0 software. (Table 2)

Table: 2 Reference evapotranspiration, ETo, in the command area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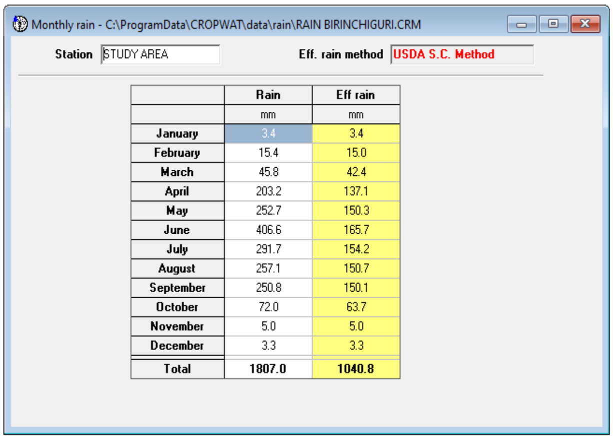
Country: Location 127 | Station: DHUBRI
Altitude: 35 m. | Latitude: 26.01 °N | Longitude: 89.98 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	11.7	23.3	86	61	7.8	14.6	2.01
February	13.3	25.5	78	95	8.2	17.2	2.75
March	17.2	30.0	57	121	8.5	20.0	4.22
April	21.1	30.5	61	156	8.1	21.4	4.96
May	22.8	30.0	90	138	6.0	19.0	3.87
June	24.4	30.0	96	121	6.0	19.2	3.81
July	25.5	30.0	93	112	5.8	18.7	3.86
August	26.1	30.0	92	95	5.6	17.8	3.75
September	25.0	29.4	91	95	6.0	17.0	3.49
October	22.8	29.4	93	95	6.9	16.1	3.15
November	17.8	26.7	95	78	7.9	15.2	2.55
December	12.8	23.3	91	69	8.4	14.6	2.02
Average	20.0	28.2	85	103	7.1	17.6	3.37

For determining the effective rainfall, the rainfall data of the command area for 19 years (2001 - 2019) were collected from the CHRS data portal. From these data, the average monthly rainfall was calculated and these values were put into the CROPWAT software. The effective rainfall was calculated using USDA Soil Conservation Service Method (Table 3).

Table 3: Effective rainfall (mm) computed by CROPWAT 8.0 software of FAO


Monthly rain - C:\ProgramData\CROPWAT\data\rain\RAIN BIRINCHIGURI.CRM

Station: STUDY AREA | Eff. rain method: USDA S.C. Method

	Rain	Eff rain
	mm	mm
January	3.4	3.4
February	15.4	15.0
March	45.8	42.4
April	203.2	137.1
May	252.7	150.3
June	406.6	165.7
July	291.7	154.2
August	257.1	150.7
September	250.8	150.1
October	72.0	63.7
November	5.0	5.0
December	3.3	3.3
Total	1807.0	1040.8

The four stages of crop development are as follows: -

(i) 1st stage (nursery and initial) – Germination and initial growth
(ii) 2nd stage (development stage) – From end of initial stage to attainment of effective full ground cover.
(iii) 3rd stage (mid stage) – From attainment of effective full ground cover to time of start of maturing.
(iv) 4th stage (late stage) – From end of mid - season stage until full maturity or harvest.

The values of Kc were fed into the CROPWAT software as shown in Figure 2 for Sali paddy.

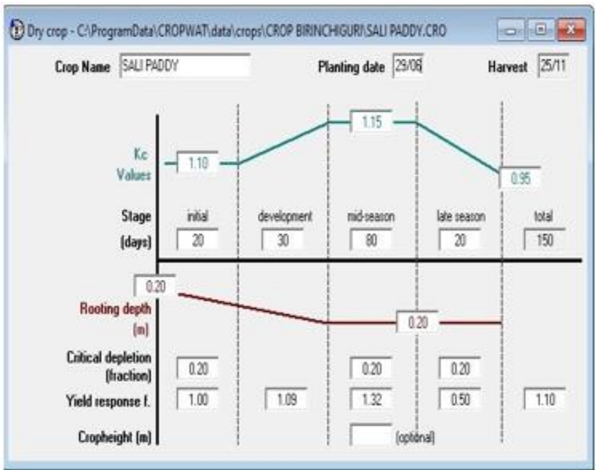


Figure 2: Window of CROPWAT for feeding the various inputs relating to the crop Sali paddy.

The type of soil was determined by using Arc GIS software and the type of soil available is found as sandy loam type.

The amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. With the help of the parameters like crop coefficient, reference evapotranspiration, crop evapotranspiration, effective rainfall and the soil data, the CROPWAT software calculated the crop water requirement as shown in table 4 for Sali paddy.

Table 4: Crop water requirement for Sali paddy.

Crop Water Requirements

ETo station: DHUBRI — Crop: SALI PADDY
Rain station: STUDY AREA — Planting date: 29/06

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	3	Init	1.10	4.21	8.4	11.0	8.4
Jul	1	Init	1.10	4.23	42.3	52.4	0.0
Jul	2	Deve	1.10	4.25	42.5	51.0	0.0
Jul	3	Deve	1.11	4.26	46.8	50.8	0.0
Aug	1	Deve	1.13	4.28	42.8	50.6	0.0
Aug	2	Mid	1.15	4.30	43.0	50.1	0.0
Aug	3	Mid	1.15	4.21	46.3	50.1	0.0
Sep	1	Mid	1.15	4.12	41.2	52.8	0.0
Sep	2	Mid	1.15	4.02	40.2	54.1	0.0
Sep	3	Mid	1.15	3.89	38.9	43.1	0.0
Oct	1	Mid	1.15	3.75	37.5	30.0	7.6
Oct	2	Mid	1.15	3.62	36.2	19.9	16.3
Oct	3	Mid	1.15	3.39	37.3	13.8	23.5
Nov	1	Late	1.13	3.12	31.2	4.8	26.4
Nov	2	Late	1.04	2.66	26.6	0.0	26.6
Nov	3	Late	0.97	2.30	11.5	0.1	11.4
					572.8	**534.7**	**120.1**

Net Irrigation Requirement is the amount of water required to bring the soil moisture level in the effective root zone to the field capacity before applying irrigation water. The net irrigation requirement (NIR) was worked out based on the "Modified Penman Method" as shown in table 5.

Table 5: Net irrigation requirement for Sali paddy

Crop irrigation schedule

ETo station: DHUBRI — Crop: SALI PADDY — Planting date: 29/06 — Yield red.: 0.3 %
Rain station: STUDY AREA — Soil: SANDY LOAM — Harvest date: 25/11

Table format: (•) Irrigation schedule ( ) Daily soil moisture balance

Timing: Irrigate at critical depletion
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
29 Jun	1	Init	0.0	0.63	63	57	22.6	0.0	0.0	32.3	3.74
1 Jul	3	Init	0.0	1.00	100	21	8.4	0.0	0.0	12.1	0.70
4 Jul	6	Init	0.0	1.00	100	21	8.5	0.0	0.0	12.1	0.47
6 Jul	8	Init	0.0	1.00	100	21	8.5	0.0	0.0	12.1	0.70
8 Jul	10	Init	0.0	1.00	100	21	8.5	0.0	0.0	12.1	0.70
10 Jul	12	Init	0.0	1.00	100	21	8.5	0.0	0.0	12.1	0.70
12 Jul	14	Init	0.0	1.00	100	21	8.5	0.0	0.0	12.2	0.70

Totals

Total gross irrigation	784.1	mm	Total rainfall	876.8	mm
Total net irrigation	548.9	mm	Effective rainfall	40.1	mm
Total irrigation losses	0.0	mm	Total rain loss	836.7	mm
Actual water use by crop	568.9	mm	Moist deficit at harvest	0.0	mm
Potential water use by crop	570.5	mm	Actual irrigation requirement	530.4	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	4.6	%
Deficiency irrigation schedule	0.3	%			

Yield reductions

Therefore, net irrigation requirement (NIR) = 548.90 mm

Field irrigation requirement (FIR) = $\frac{NIR}{WF1} = \frac{548.90}{0.6208}$

= 884.18 mm

Actual supply = Gross Irrigation Requirement (GIR) + Effective Rainfall

GIR = $\frac{FIR}{0.70} = \frac{884.18}{0.70}$ = 1263.11 mm

Actual supply = 1263.11 + 40.10

= 1303.21 mm

On field water application efficiency, $W_{F2} = \frac{FIR}{\text{Actual supply}}$

= $\frac{884.18}{1303.21}$ x 100 = 67.84 %

Hence, on farm application efficiency,

$W_F = \frac{62.08}{100} \times \frac{67.84}{100}$ x 100 = 42.11 %

Therefore, overall water use efficiency Wp= W_C x W_F

= $\frac{68.13}{100} \times \frac{42.11}{100}$ x 100 = 28.69 %

7. Improvement of Conveyance Efficiency through Canal Lining

It is found that, the conveyance efficiency of the Birinchiguri Irrigation Project is only 68.13 %. This is mainly because the canal network is not fully lined and this causes huge seepage losses. The seepage loss in the canals accounts for major portion of water conveyance loss. As per the "Guideline for computing water use efficiency (WUE) of irrigation projects" put forward by the Central Water Commission (CWC), Ministry of Water Resources, Government of India, the conveyance efficiency can be improved and can be brought up to at least 75%. If the level of maintenance is very good, this value can be further improved and can be brought up to 95%. The probable water saving and the additional area that can be irrigated by converting the canals into lined canals have been also determined. It has been found from the study that a total volume of 0.0703 Mm^3 can be saved if the whole canal system is lined. With the help of this water, an additional area of 78.144 Ha can be irrigated. Again, if the whole canal network is lined and the maintenance level is also very good then 2.18 Mm^3 of water can be saved which can irrigate an additional area of 242.54 ha. Thus, the command areas at the tail end of the project, which at present does not receive much benefit from the project, can easily be irrigated if the canals are lined.

The increase in the conveyance efficiency will also lead to an increase in the water use efficiency. By lining the whole canal network, the water use efficiency can be increased up to 37.92%. If the level of maintenance is very good, it can be further improved up to 60.23%

8. Conclusions

The irrigation sector requires more attention in order to achieve maximum water use efficiency and close the gap between irrigation potential created and irrigation potential used. This can be accomplished through a variety of intervention techniques, including modernization and rehabilitation, irrigation network operation and maintenance, conjunctive use, maintenance practices, and improved on - farm development works such as field channel construction, regulatory structures, land levelling and drainage, irrigation distribution rotational system, and periodical performance evaluation of all of these measures, among others. The Birinchiguri Irrigation Project was expected to increase the region's cropping pattern by approximately 152.36 percent. However, due to a variety of factors such as poor management and wear and tear on the channels, the cropping pattern has decreased significantly resulting in less than the expected value. The project's conveyance efficiency based on the selected four canals was found to be 68.13%, with an on - farm application efficiency of 42.11%. The overall water use efficiency is thus determined to be 28.69 percent. According to the results of the study on the four canals, lining them would increase the conveyance efficiency significantly and subsequently the overall water use efficiency and thereby 2.18 Mm^3 of water can be saved.

With the help of this water, the tail ends can be irrigated easily.

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