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Research Paper

Evaluation of the Efficiency of Water Discharge using the Performance Indicator, in the Canals of the Nashik Irrigation Network

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ABSTRACT

In western India, the water for irrigation is supplied by the open inundation channels of the reservoir having its predominant distribution there. The Irrigation management faces issues of less capacitated water distribution systems than its apex requirement, has irregular supply rate, low inundation efficiency, and consistency. It is important to measure the delivered water supply with required water delivery in proportion to its demand. The auto water elevated gauges which are fixed at the back and front segments of each inundation canal at the left bank channel of the Godavari river assess the discharge of supplied water during the irrigation period. In the current research, the computation would be conducted for the water delivery performance indicators such as competency, productivity, prominence, and rectitude, which are fundamental for the assessment of the irrigation and drainage system management. According to the water supply performance indicator, the inundation ability is calculated with an automatic water gauge. It is measured from the structural and transient channeling of water discharge to examine the inefficiency of water supply management. The cumulative results of the performance indicator demonstrate the enhanced methods to develop water management policies that will facilitate the irrigation planners with improved temporal consistency and reasonable water distribution.

Keywords: Irrigation canals, performance indicator, water distribution, irrigation network.

INTRODUCTION

The majority of the agricultural lands in the entire world have been experiencing inefficient inundation facilities. Thus, with finite aquatic resources, the competent functioning of the inundation and drainage system is fundamental. Assessment of inundation performance can facilitate the managerial work to find technological and supervisory problems in the operation of systems. Effective operation and supervising of an inundation system plays a vital role to maintain the level of inundated farms (Mishra et al., 2001; Kumar and Singh, 2003). The major objective is to provide an apex quantity of water to the canal and get the excess of it removed via way of drainage system (Khepar et al., 2001). Also, to determine the Irrigation Network's performance by planning improved water delivery performance indicator (Shahrokhnia and Olyan-Ghiasi, 2019). Irrigation management faces the issues with the less capacitated water distribution system than during their peak demand, concerning the delivery rate, poor inundation competency, and consistency. The primary reason for the poor performance of the irrigation distribution system is because of the inefficient supervision of the water delivery irrigation system (Lozano and Mateos, 2008; Mateos et al., 2010). The efficiency of water supply in irrigation channels is monitored using performance measures that are important to irrigation nature and general irrigation improvements (Nam et al., 2016). The irrigation system has deteriorated substantially, and transportation losses have lowered the quantity of water supplied to the area. To avoid major water use, precise monitoring and supervision are required (McCready et al., 2009; Mishra et al., 2013). The irregular water measurement and the poor quality of water recording data and monitoring of irrigation efficiency are difficult. Hence, we have to focus on major purposes such as farming, water delivery, and its extent at the primary canal level. It is essential to analyze the predicted irrigation demand with real-time water delivery for taking decisions to maintain an even flow of water demand and its supply.

Inadequate water supply and inefficient administering of irrigation systems are the key causes of low productivity, and there is a need to achieve proper water distribution to a given region (Mateos, 2008; Yercan et al., 2009). The water supply performance indicators proposed by (Molden and Gates, 1990) are beneficial in determining water supply issues in extensive irrigation schemes (Dejen et al*.,* 2015). The delivery performance indicators have measured the discharges in the head regulators of the canal command area (Mirajat et al., 2017). The influence of administrative decisions to supply water from the source of water and its physical system would be represented by the irrigation system performance indicator (Irmak et al., 2011). The fundamental elements for irrigation supervisors are the irrigation performance norms of consistency and rectitude (Kharrou et al., 2013).

The performance indicator is included in this study is required to evolve the delivery schedule for the NLBC irrigation project. The analysis of the canal flow data would help to examine the supply schedule of the inundation projects. The supply schedule is evolved for a better performing system during the *Rabbi* and *hot* weather season. IRCTM seemed to have the ability to improve the overall operation of an irrigated area that was crucial to farmers' rotational crop production in canal command areas. They advised that rather than using the previous distribution schedule, they should implement the alternative delivery schedule that is not only good for increasing output but also dry spells and critical growing seasons (Bhadra et al., 2010). A properly designed water distribution system will make irrigation easy and efficient. Good irrigation structure is an essential part of an irrigation layout. Conveyance of irrigation water from the headwork at a reservoir to the farmer is essentially through a system of open channels and allied structures. Returns flow to drain due to faulty canal regulation, inappropriate irrigation provisions at night, and underutilized flow during periods when there is very less need for irrigation are all examples of operational losses. Most canal systems could help minimize operational waste by diverting excess canal flow to neighboring irrigation tanks and temporary storage in system storage along the canal's course, from which water could be withdrawn to find local demands (Micheal, 2009). We should analyze the water supply performance of open irrigation channels, which are important to identify the improved water administering techniques. We calculate the water supply performance of Nasik irrigation LBC during irrigation period 2020 with regards to the internal indicator of consistency, efficiency, calculability, and rectitude. When the irrigation efficiency is analyzed with the water supply performance, the structural and transient distributions of crop water needs were calculated and water supply using automatic water gauges at inundation canals was also measured.

MATERIALS AND METHODS

Study area

The water for irrigation for inundating the areas of Nasik majorly comes from the left bank canal of Godavari River. The originates in the Western Ghats of the Godavari of central India near Nasik in Maharashtra at the latitude19° 55′ 48″N and the longitude of 19° 55′ 48″E. and is at an elevation of 920 m. The average annual precipitation and temperature is 614.2 mm and 25 °C, respectively. The inundation system of the Godavari River includes the left bank canal, which is attached to the branch canals are built substantially. The total length of the primary canal is roughly 51.54 km having a discharge of 8.49 cusec and covers the study area as shown in Fig.1.The left bank canal of Nasik district is divided into four branch canal such as Nasik, Pimpri, Kherwadi, and Sukena which cover the area 4193ha. The developments in the irrigation systems on the Godavari River have been a paramount attempt in the Nasik area to enforce more efficient irrigation technologies by developing the existing supply systems. These developments have been carried out to establish accurate water dissemination. The major objective behind improving the water supply systems is to ensure an equal distribution of water amongst all the branched canals, decrease the channeling losses from the irrigation system, and develop managerial supervision over the water usage.

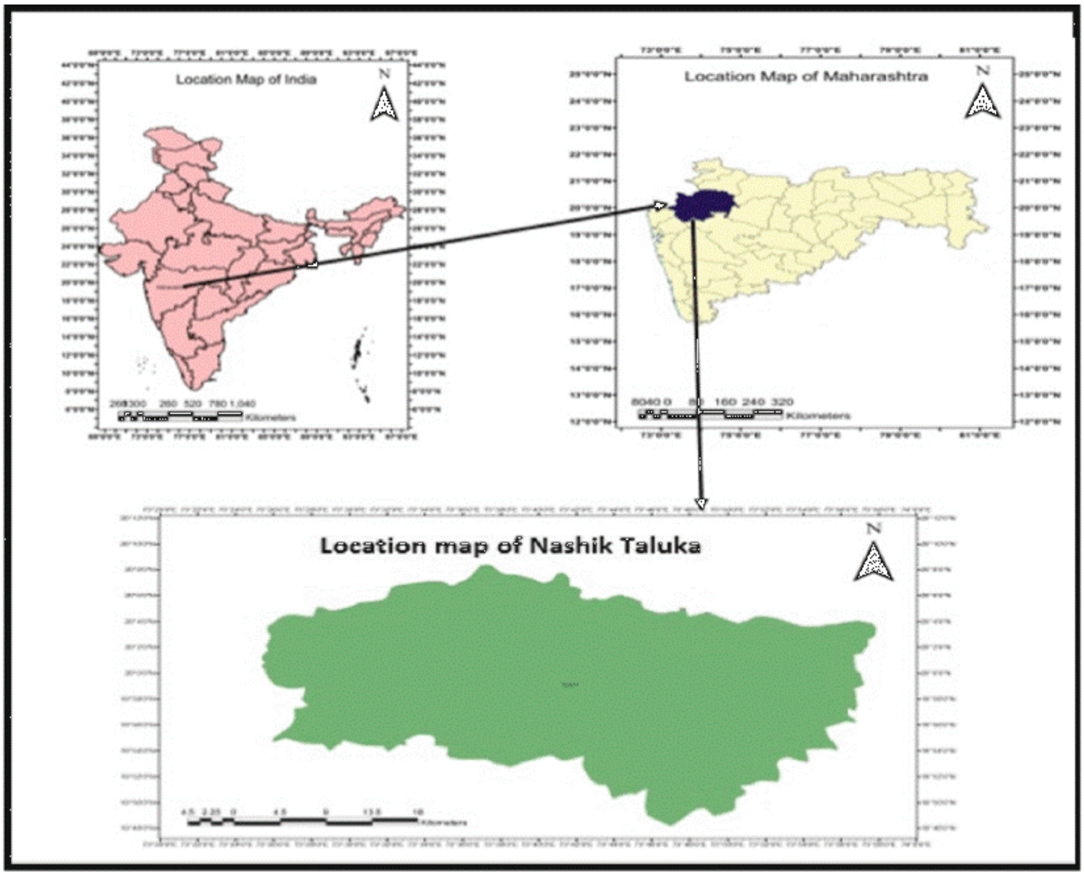

Fig. 1 Location map of the study area (Irrigation Department, Nashik)

Measurement of delivery and required irrigation water

The quantity of water delivered from the canal is recorded by grading devices. It is officially sent to Water User's Association and kept with the Section Officer, Canal Inspector, gauge karkoon of the Water Resources Department. The gauge and parole measurement would be examined at least twice a day (preferably at 12 hr. intervals) under the supervision of personnel from the Water Resources Dept and Water Use Association. (Source: Nasik irrigation division). In the case where an automatic performance gauging device is used, the results sheets which both the agencies signals long as flow meters in pressure pipelines are affected, the analysis could be monitored once a day and signed by both the agencies. The required water estimation was made using the FAO-Penman– Monteith (Allen et al., 1998) evapotranspiration model at the starting of selected canals which used the meteorological data of 2020. The water was distributed by the irrigation department in one of the following ways, as stated in Table.1.

Table 1 Period of rotation of NLBC division Nasik (Nasik Irrigation Division)

Sr.no.	*Period of Rotation*	*Season*
1	16/01/2020 to 5/02/2020	Rabbi
2	17/02/2020 to 5/03/2020	Rabbi
3	23/03/2020 to 8/04/2020	Hot weather
4	23/04/2020 to 4/05/2020	Hot weather
5	28/05/2020to 12/06/2020	Hot weather

Determination of Performance indicator

The ratio of irrigated area water supply and irrigation canal water supply indicators is the water discharge performance indicator. The ratio of the amount of water distributed for irrigated land to the amount of water delivered to the small creeks as a percentage was used to calculate water supply efficiency for canals. The water supply efficiency values were calculated using Eq. (1):

$$WS = Wu / Wt \qquad \text{.............. (1)}$$

where, Ws denotes the irrigated area's water supply efficiency (in percent), Wu denotes the volume of water used and is determined by the difference between the convexity and the aperture canals, and Wt denotes the total volume of water supplied to the protubering canal. Molden and Gates (1990) defined consistency, efficiency, durability, and equity as four performance indicators for water delivered. As mentioned in Table 2, these are used in the investigation. The measurement of consistent water channeling within a region RE is served by the system over a time period T which is called adequacy (P_A). in Eq.(2):

$$P_A = \frac{1}{T}\sum T\left[\frac{1}{RE}\sum_{RE} PA\right] \qquad \text{.............. (2)}$$

where, $P_A = Q_D/Q_R$ if $Q_D>Q_R$ and = 1 if $Q_D>Q_R$, with Q_D representing the actual volume of water provided by the system and Q_R indicating the volume of water needed at the supply point. The efficiency (E_F) is given by Eq.3

$$E_F = \frac{1}{T}\sum T\left[\frac{1}{RE}\sum{}_{RE} PF\right] \qquad \text{.........(3)}$$

If $Q_R>Q_D$, $P_F = Q_R/Q_D$, and if $Q_R>Q_D$, $P_F = 1$. On the other side, dependability (P_D), which is considered as the transitory consistency of the proportion of supplied to required water and quantified as follows Eq. (4):

$$P_D = \frac{1}{RE}\sum{}_{RE} CVT\left(\frac{QD}{QR}\right) \qquad \text{.........(4)}$$

where, $CV_T(Q_D/Q_R)$ denotes the ratio QD/temporal QR's coefficient of variation (proportion of standard deviation to mean) across time period T. Finally, the equity (P_E), which is regarded as the dimensional uniformity of the supplied-to-required ratio, is given by Eq. (5):

$$P_E = \frac{1}{T}\sum{}_{T} CV\ RE\left(\frac{QD}{QR}\right) \qquad \text{.........(5)}$$

where, $CV_{RE}(Q_D/Q_R)$ is the structural coefficient of variation of the Q_D/Q_R ratio over the R_E area.

Table 2 Evaluation standard for water delivery indicator (Molden and Gate, 1990)

Measure	Performance Classes		
	Good	Fair	Poor
Adequacy (P_A)	0.90-1.00	0.80-0.89	<0.80
Efficiency (E_F)	0.85-1.00	0.70-0.84	<0.70
Dependability (P_D)	0.00-0.10	0.11-0.25	>0.25
Equity (P_E)	0.00-0.10	0.11-0.20	>0.20

These performance metrics encourage efficient irrigation system operation and management in order to ensure the long-term viability of inundated farmlands (Mishra et al., 2001). The difference between the water delivery to the bulging canal and that to the outflow canal is used to compute the irrigation water during the irrigation period, as described in Table 3. The aggregated water used was divided by the total inundated area to determine the water usage capacity. In relation to another canal, the water consumption values in the SUK canal were higher and the water use values in the NSK canal were lower. Table 4 denotes the water usage scope per unit of the inundated area and the water discharge capability of four canals. Its scope per unit area was as curtained by the utilization of the total value of the water usage during the inundation, which would be regarded as the difference between the quantity of the protruded canal and the quantity of the aperture canal, divided by the inundated area. The average values of the water usage capacity per unit area at four canals in 2020 are 2699 m^3/day/ha. The highest water use capacities per unit area of PMR are 2968.4 m^3/day/ha and the lowest water use capacity in SUK is 2362.9 m^3/day/ha. Fig 2 shows the comparison of the inundated area and the water discharge capability. The average water delivery capability of four canals is 0.48%. Thus, in context to these values, the delivery adequacy can be denoted by the functional and managerial condition of each irrigation canal.

Table 3 Water use capacity of irrigation canals

Canal name	Seasons	Inlet water supply (m^3/day)	Outlet water supply (m^3/day)	Water use (m^3/day)	Area (ha)
NSK	2020	2126072	1193927	932145	347
PMR	2020	5081535	2945675	2135860	719
KHR	2020	6043039	2989713	3053326	1028
SUK	2020	9436439	4222787	5213652	2207

Table 4 Water use capacity per unit area and Water supply efficiency of irrigation canals

Canal name	Seasons	Water use capacity per unit area (m^3/day/ha)	Water supply Efficiency (%)
NSK	2020	2686.2	0.438
PMR	2020	2968.4	0.420
KHR	2020	2783.6	0.505
SUK	2020	2362.9	0.552

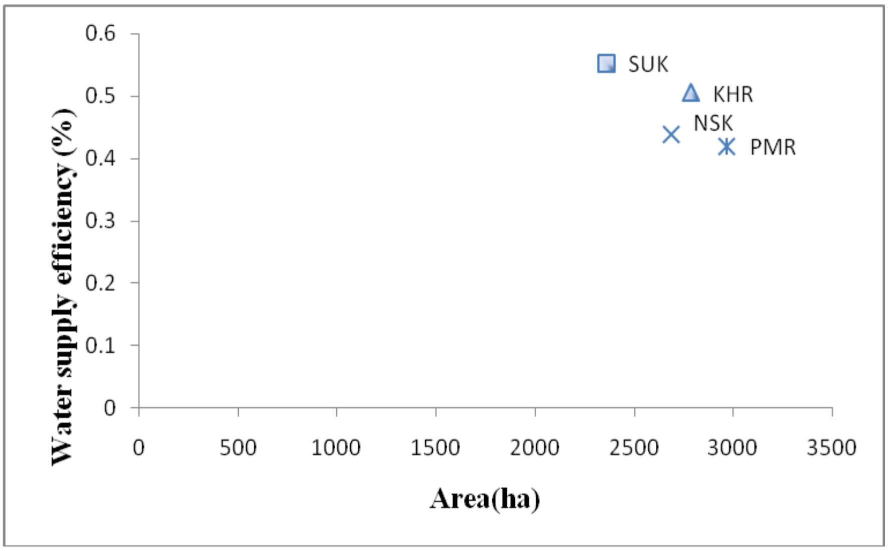

Fig. 2 Comparison of irrigation area and water supply efficiency

RESULTS AND DISCUSSION

Analysis of the irrigational water supply pattern

Table 5 presents the Q_D and Q_R for each of the irrigation canals. In 2020, entire Q_D values for KHER canal are more than the total Q_R from January to May, whereas Q_R values in SUK canal are higher than others. More irrigation water has also been supplied to the canals KHER and PMR. However, the majority of the inundated water is wasted by the exit canal due to this poor schedule, and the rotation plan has also not been efficiently accomplished. Also, because of the drought in 2020, there wouldn't be enough irrigation water to supply the canal from January to May. Out of the four canals, the NSK and SUK canals have the lowest Q_D values.

Table 5 QD and QR at irrigation canals in the irrigation season 2020.

Canal Name	Season	Variables (m^3/day)	Irrigation periods					Total (m^3/day)
			Jan	Feb	March	Apr	May	
NSK	2020	QD	611643	518674	440383	371879	183493	2126072
		QR	612200	612200	518600	502600	241000	2486600
PMR	2020	QD	1653885	763331	880767	1541342	242210	5081535
		QR	1306920	1286400	1111400	385540	392790	4483050
KHR	2020	QD	1717496	1834931	831835	738865	915019	6038146
		QR	966660	950660	328320	722070	721710	3689420
SUK	2020	QD	2030657	1962153	2055123	2446575	941931	9436439
		QR	3203200	3371200	3141000	5598000	2070000	17383400

Structural performance indicators values

Fig. 3 illustrates the structural average performance indication values such as sufficiency, competency, and reasonability for the four canals in 2020. Table 6 uses the mean and SD to demonstrate the basic statistical data of sufficiency and competency-based on irrigation time. Monthly consistency and efficiency are computed as the average of all canal values, although equity is calculated as the sum of all four canal values. PA was less than 0.80 in February and May, and more than 0.80 in January, March, and April. According to these figures, the sufficiency index is strong in January, fair in March and April 2020, and low for the rest of the year. The premise that consistency is inefficient when the demand for water for irrigation is high suggests that there is water scarcity in the system. Despite the reality that comparatively very less amount of water is delivered to the system during the months when sufficiency is favorable enough because the demand for water for irrigation is low in those months, adequacy is good or fair for practically all four canals throughout the growing season.

In May, the spatial average values of PF are 0.94, greater than 0.8 in January, February, March, and April. When the water is discharged from the reservoir, the efficiency is fair since water is generally provided to the canal more than is required. These studies reveal that when the demand for inundated water is large, farmers use irrigation water more efficiently.PE spatial average values in each irrigation season reached 0.20 in February, April, and May. In January and March, the equity PE was 0.183 and 0.144, respectively. Apart from these periods, though, they are all considered to be poor. Because water is only discharged from the reservoir for a fraction of the irrigation season, the equity received a low rating. Additionally, when those supplies were distributed, many canals received more than they need, while others obtained much less than their requirements.

Hence, the irrigation system's structural performance indicators are effective in maintaining enough water delivery while having a negligible impact on efficiency. A massive surplus is used to achieve excellent adequacy, and water losses are caused by heavy water discharge in the alternate canals compared to its demand, as well as excessive application to the field.

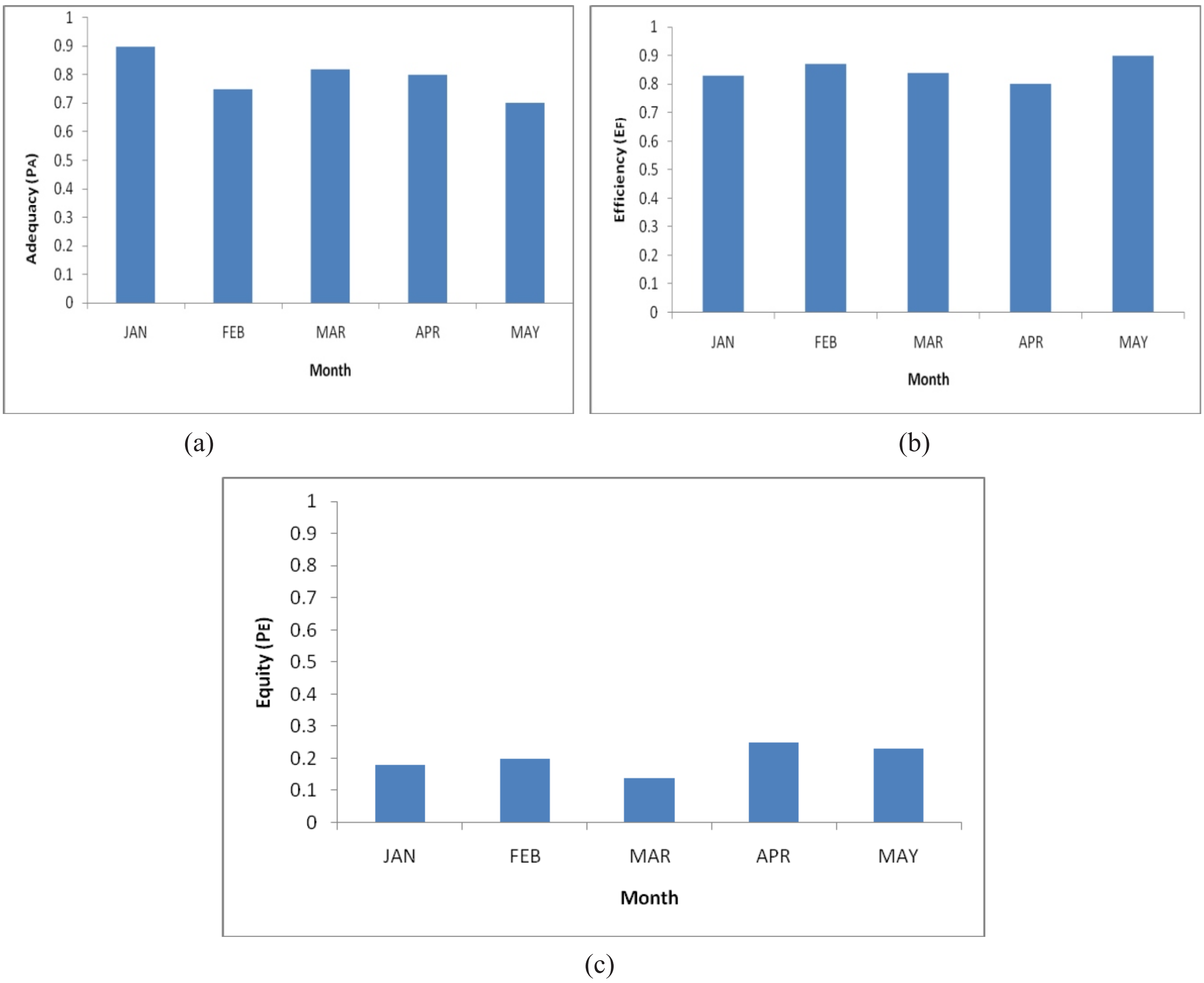

Fig. 3 Comparison of temporal values of the performance indicators; a) Adequacy; b) Efficiency; c) Equity

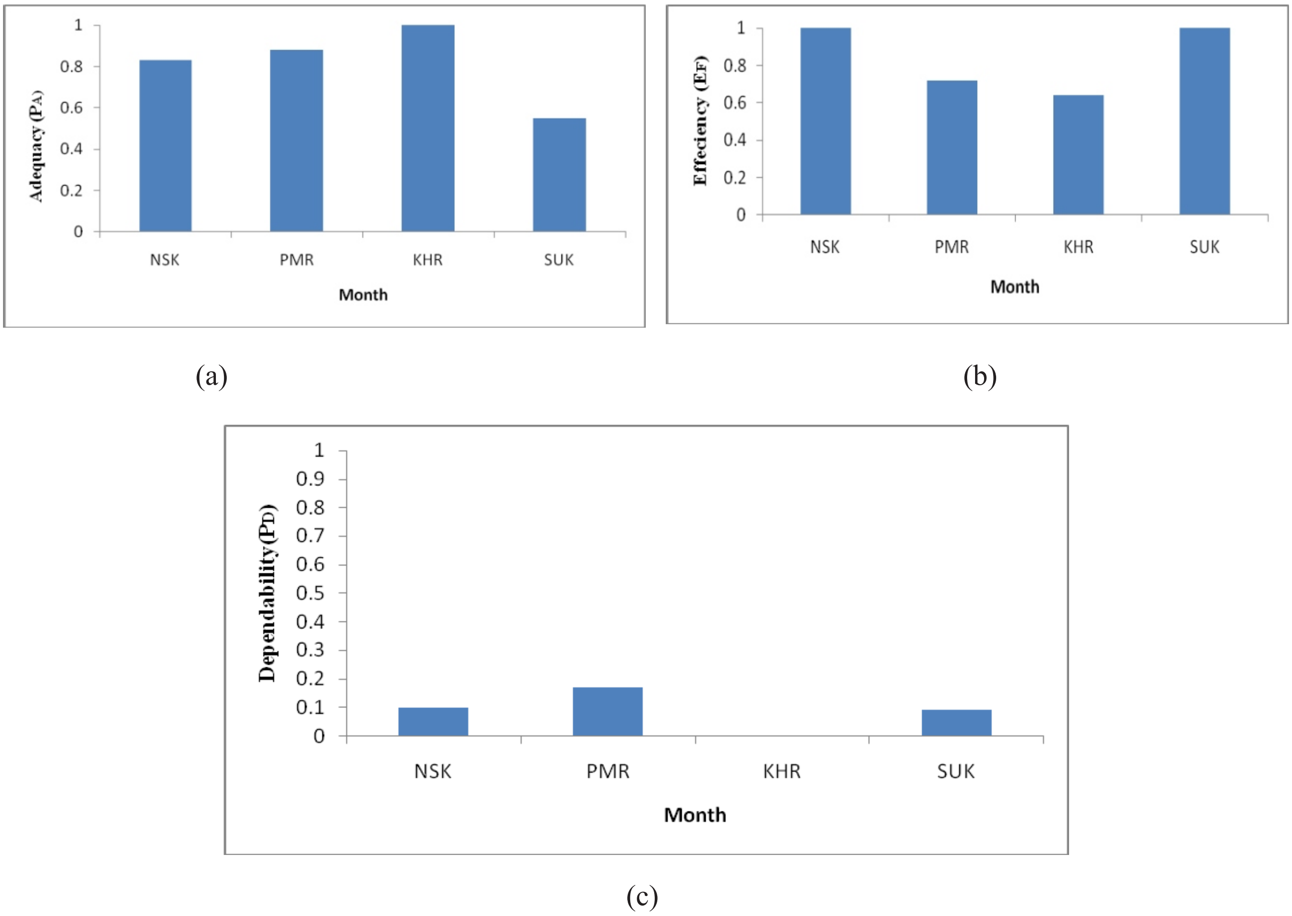

Fig. 4 Comparison of temporal values of the performance indicators; a) Adequacy; b) Efficiency; c) Dependability

Transient performance indicators values

Fig. 4 illustrates the average transient values for the irrigation canal- its consistency, efficiency, and credibility in the 2020 seasons. Table 7 utilizes the mean and SD to provide the foundational statistics of consistency and efficiency for each canal. Each canal's aforementioned indicators are calculated as average from January to May, whereas dependability is measured as a singular value from January to May. During the 2020 season, the consistent performance in NSK and PMP was fair, with the highest PA values in KHER canal and the lowest values in SUK canal. When the PA is less than 0.80, it is especially shallow for canals with constraints, such as the SUK canal. The cause for the deficient demonstration by the transient average values of the PA, and why the sufficiency is generally considered as poor in 2020, is that the delivery is not carried out considerately with regards to the demand in the different time frames throughout the irrigation season. This condition is thought to be the result of managerial problems with the functioning of the irrigation system. The PF indication is assessed as efficient for most of the canals in 2020, except for the KHER canal, according to the performance indicator study. Water is provided to these canals more than they require, resulting in poor consistency ratings for the canals in the region. The effectiveness of the KHER canal is assessed to be lower than that of the other canals.

This is due to the reason that water is delivered to the canals in an ample amount than what is required. This is a difficulty with management and operations. One of the main causes of this issue is that the irrigation association is in charge of water supply during the times when water from the reservoir is unavailable. The NSK, PMR, KHER, and SUK canals are rated as Fair in terms of dependability, with average PD scores of 0.123. Briefly, this analysis indicates that water is not delivered to the canals during the appropriate periods due to a lack of a precise water distribution strategy.

Table 6 Adequacy and efficiency of the irrigation periods

Measure	Season	Variables	Irrigation periods				
			Jan	Feb	March	Apr	May
Adequacy	2020	Mean	0.90	0.75	0.82	0.80	0.70
		SD	0.18	0.20	0.14	0.25	0.23
Efficiency	2020	Mean	0.83	0.87	0.84	0.82	0.94
		SD	0.20	0.24	0.30	0.37	0.11

Table 7 Adequacy and efficiency of each canal

Measure	Season	Variables	NSK	PMR	KHER	SUK
Adequacy	2020	Mean	0.83	0.88	1.00	0.55
		SD	0.10	0.17	0.00	0.09
Efficiency	2020	Mean	1.00	0.72	0.64	1.00
		SD	0.00	0.31	0.23	0.00

Average values of the performance indicators

Table 8 represents the typical indicator values for the four water supply performances. The average PA for the 2020 season is above 0.80, while the PF is 0.713. The PD and PE readings are well over zero. According to the performance standard, water supply performance in 2020 will be fair in terms of adequacy, efficiency, and dependability, but it will be poor in terms of equity. The four-performance averages revealed that the level of the application system for water level is required to improve in 2020. The Nasik Irrigation Department has attempted to improve water delivery efficiency at the Godavari left bank canal. The results of this study show that precise water level measurement technology can be used to accomplish adequacy and efficiency. However, due to inadequate inundated water and poor irrigation equity because of the eminently large inundated area, the results indicated low dependability. As previously stated, the lack of water management planning that includes the outright shortage of irrigation water; the time when water is discharged from the reservoir; and other factors all contribute to the environmental delivery issues. Some canals have a small capacity in comparison to the requirement and the reservoir and irrigation donor period overlap. The performance indicators would aid in efficient water delivery supervision and the classifying of issues that are leading to the irrigation system's inefficient performance. To improve the system's water delivery performance, water conveyance losses must be reduced to develop water discharge efficiency, water channelizing plans must be prepared that include canals, and water redirected to canals must be measured and monitored.

Table 8 Water delivery performance values at the total irrigation canals in the irrigation season 2020

Seasons	Adequacy (PA)	Efficiency (PF)	Dependability (PD)	Equity (PE)
2020	0.813	0.713	0.123	0.251

CONCLUSIONS

The major objective behind this research is to analyze the water discharge and its performance of Godavari left bank canals in Nasik considering indicators such as sufficiency, consistency, cohesion, and equity, as well as the structural and transient channeling of requested and supplied water. The irrigation system is a type of irrigation system that is used to water plants. Fair adequacy, efficiency, and dependability, as well as poor equity, are the water delivery performance factors at the level of the canal in 2020. These indicators indicated that irrigation water was not being delivered on schedule. These findings for equity demonstrated that the system had a systemic water delivery problem. The estimated performance indicators are advantageous for analyzing the behavioral pattern of irrigation and its overall trends as a consequence of the water supply irrigation system's effectiveness. The elements creating this problem are obtained in part from managerial and functioning and in part from the substantial structure, according to the results of the structural and transient distribution of these indicators. By measuring the efficiency of water supply and delivery, the study of the data provided insight into irrigation management approaches that are required to increase the transient uniformity and equity in the channeling.

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