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Performance evaluation of water delivery system in canal command area of PAP Basin, Tamil Nadu

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ABSTRACT : The present study examines the water delivery performance of 4(L) distributory of Pollachi canal command located in Parambikulam-Aliyar-Palar (PAP) basin of Coimbatore district, Tamilnadu. The command area is divided into two zones which receive the canal supply once in alternate years. The performance evaluation of 4(L) distributory was conducted during 2005-2010 for Zone-A and Zone-B based on the supply turn corresponding to that year. The irrigation water requirement for crops grown in the area were calculated using AquaCrop3.1 model for the years 2005-2010 based on the supply turn corresponding to that year. The sluice outlet wise water delivery performance indicators have shown poor performance of the system. Considering the irrigation season and the system as a whole, the calculated indicator's average values were found as poor for adequacy, equity and dependability. The overall efficiency in 4(L) distributory was categorized as poor. The PAP canal system acts merely as a protective irrigation system not designed to meet full cropping intensities. The water was available in the canal system when irrigation water requirements were at its minimum. Improvements for water availability during periods of crop demand need to be considered rather than supply when water was available in the canal system. So demand based supply system is a better option in these areas *i.e.*, to allow water as per the crop demand and not as per water availability. Even variable discharges based on crop demand can be helpful for effective utilization of surface water resources and reducing the groundwater draft.

KEY WORDS : Performance evaluation, Water availability, Indicators, Improvement

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Agriculture, is the centre to all strategies for planned socio-economic development of the country. Rapid growth of agriculture is essential not only to achieve self-reliance at national level but also for household food security and to bring about equity in distribution of income and wealth resulting in rapid reduction in poverty levels.The present population which is over a billion now, is projected to increase to 1333 million (higher limit) by 2025. The annual production of food grains in India has increased from around 50 million tonnes (mt) in 1950s to about 235.88 mt in the year 2010-11. Using the population projections for 2025, the total annual food grain requirement of the country has been estimated by the National Commission for Integrated Water Resources Development Plan (NCIWRDP, 1999) to be between 308 and 320 MT. The National Water Policy (Ministry of Water Resources-MoWR, 2002) envisages that the annual food grain production will have to be raised to around 350 MT by the year 2025. Much of the food production has to come from irrigated sector only even though the contribution from rainfed sector is significant. The average productivity of irrigated land is 2.2 t/ha while it is 0.5 t/ha only in rainfed agriculture. Therefore, assured irrigation is the only credible insurance against famine.

Due to the large spatial and temporal variability in the rainfall, water resources distribution in the country is highly skewed. The per capita availability of water, which was 1901 cubic meter(cu m) per year in 2001, considering the population of 1027 million and renewable water resources as 1953 billion cubic meters (b cu m),will reduce to 1518 cu m per year with the projected population by 2025. However, in several river basins, sub-basins the per capita availability of water is likely to be less than 1000 m^3/year in 2025.Under these circumstances, the ultimate irrigation potential has been assessed as 140 Mha (Million hectare) of which about 100

Mha (nearly 72 %) had been created so far. Further expansion of irrigation potential of 40 Mha will require an additional of roughly 100 b cu m to the existing total live water storage capacity of 177 b cu m. This needs huge investments and there is little room for horizontal expansion of irrigated agriculture in today's public investment context.

While there is no dearth of technological interventions for crop production, the single most impediments in the growth of agriculture production lies is, the consistent decline in the share of fresh water availability to agriculture over the years. At present, the share of fresh water use in the agriculture in various states is 70-85 per cent, but it is bound to reduce in future due to the competition from domestic and industrial sectors leading to the shrinking in net irrigated area year after year due to scarcity of irrigation water.

In states like Tamil Nadu, there is a little scope for the augmentation of water supply to agriculture as the utilization of surface and groundwater levels have already crossed 95 per cent and 78 per cent, respectively. The net irrigated area in the state is around 25 lakh hectares during 1960-2010. But the share of irrigation by surface water resources (canals and tanks) reduced from 18.12 lakh ha to 12.19 lakh ha in 2010. But the share of groundwater irrigated area increased from 6.45 lakh ha in 1960 to 14.18 lakh ha in 2010 (Seasons and Crop report, Tamil Nadu, 2010). The decline in canals and tanks was more or less compensated by the significant growth in the groundwater irrigated area. It leaped forward from about 26 per cent in 1960 to about 60.5 per cent in 2010. Because of this over exploitation, of the total 385 blocks of Tamil Nadu, only 97 blocks (25 %) are safe for extraction of groundwater now (Nandakumaran, 2005). This situation became possible mainly due to groundwater's near universal availability, dependability and low capital cost. Therefore, there is an urgent need / intervention for improving the efficiency of existing irrigation projects which will ensure its sustainability with the possibility of bringing in additional areas under its command.

The irrigation performance studies have to be carried out with the objective of improving the system operation, to assess the general health of the system, to assess the impact of intervention, to diagnose the constraints and to compare the performance of the system with other systems or with same system over time. Water delivery system design has traditionally focused on specifying the carrying and regulating capacity of the delivery structures and on increasing water conveyance efficiency.

■ METHODOLOGY

Study area:

The study was carried out in the canal command area of Parambikulam-Aliyar-Palar (PAP) Irrigation project which spreads in Coimbatore, Tiruppur and Erode districts of TamilNadu. The PAP basin spreads in 2388.72 sq.kms spread over in Coimbatore District of which, one third of the area 822.73 sq.kms is covered with hills and dense forest cover. The basin is surrounded by Cauvery basin on the North and East, Kerala State on the south and West. The water is diverted from west flowing rivers to east by constructing weirs, reservoirs, tunnels, open channels and contour canal etc. to irrigate the drought prone areas of Coimbatore, Erode and Tiruppur districts. The basin is having eight west flowing rivers, six in Anamalai Hills and two in plains. There are 7 canal systems and 3 tanks with total command area of 4.32

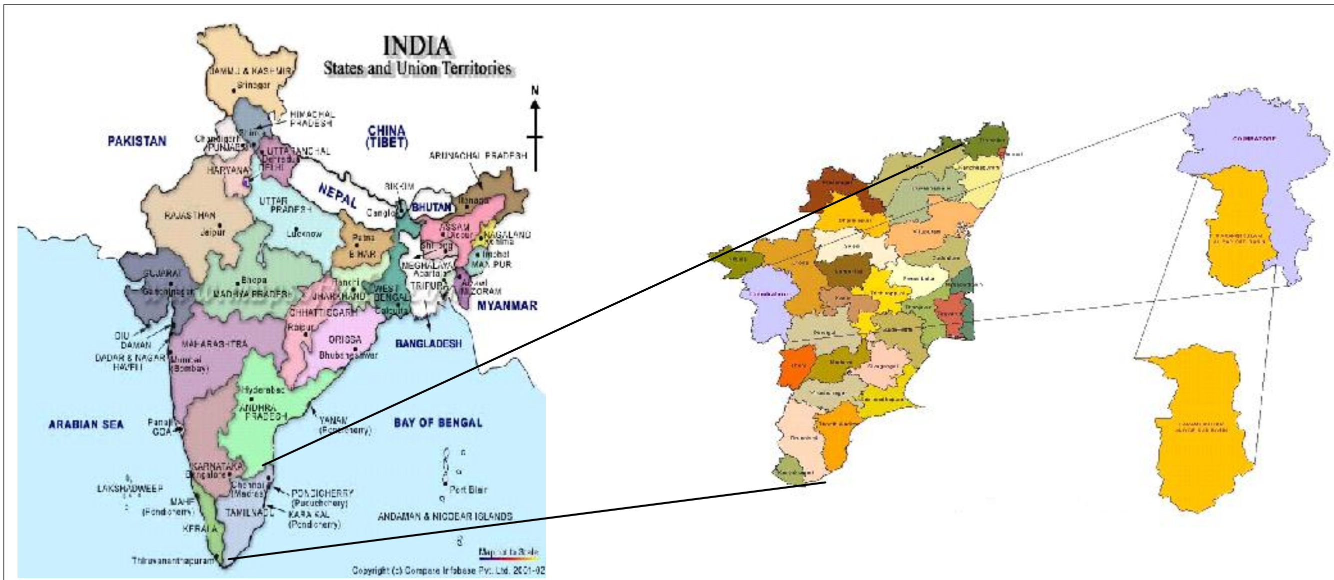

Fig. A : Location map of PAP basin

lakh ha. The basin is bounded by $10^0$10’00” to $10^0$57’20” N latitude and $76^0$43’00” to $77^0$12’30” E longitude. The basin has an undulating topography with maximum contour elevation in the plain is 300m and the maximum spot height in the plain is 385m above MSL. The location map of PAP basin is shown in Fig. A. (CE,SG and SWRDC report,2006)

For conducting performance assessment study in PAP basin, 4(L) distributory of Pollachi canal coming from Aliyar reservoir was selected. The total length of the Pollachi canal is 48 kms. The total command area under Pollachi canal is 9588.83 ha with 30 distributories. The canal command is divided into two zones which receive water every alternate year. The 4(L) distributory of Pollachi canal is located at an off take point of 5.22 kms from the main canal. Performance assessment has been carried out for Zone-A and Zone-B during the period 2005-2010 based on supply turn. The zone wise distribution map of 4(L) distributory is shown in Fig. B. The flow chart for 4(L) distributory is shown in Fig. C.

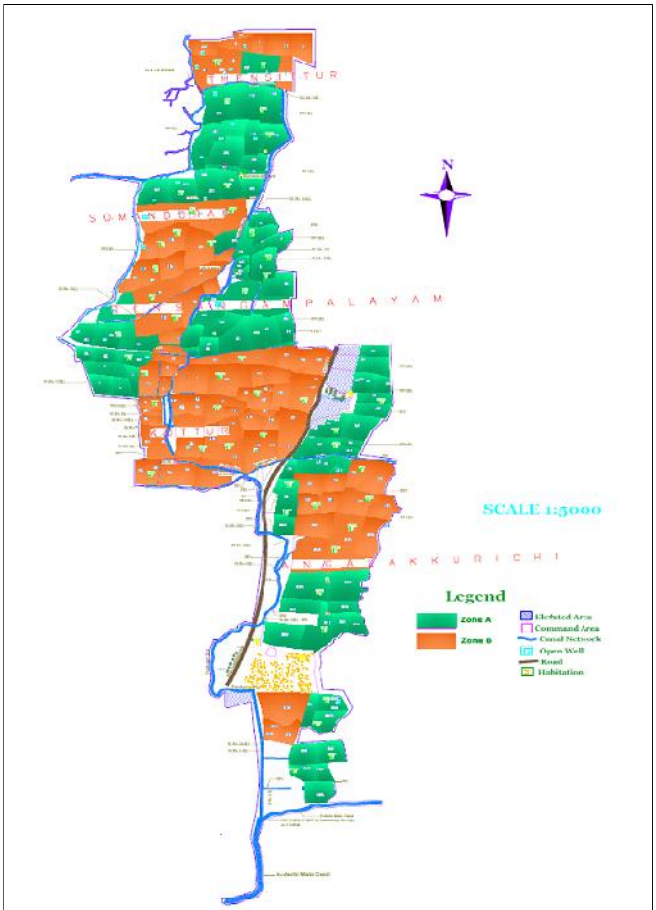

Fig. B : Zone wise distribution of the 4(L) distributory of Pollachi canal

The details of climatic data,soil data etc. were obtained from the records of the irrigation crops grown in the command, collected are used to assess the net irrigation requirement in the distributory using AquaCrop3.1 model (Raes *et al.*, 2009).

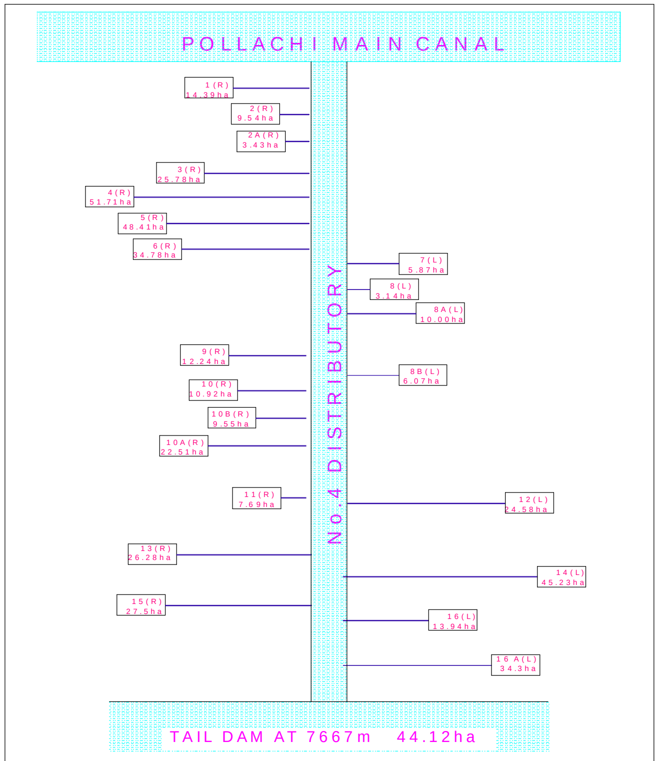

Fig. C : Flow chart of distributory 4(L) of Pollachi canal

Monthly net crop irrigation requirements were calculated using AquaCrop3.1. Reference evapotranspiration (ET0) was calculated using AquaCrop3.1 on monthly basis by Penmen-Monteith method. Crop coefficients (Ke) were developed for the main crops using FAO guidelines(Doorenbos and Pruitt,1977). Net crop irrigation requirement was computed as the difference between crop evapotranspiration (ETe) and effective precipitation (Pe). Net crop irrigation requirement for each zone (Q_R) was calculated using crop irrigation requirement, irrigated area and conveyance efficiency for each zone.

The fundamental objective of any irrigation system is to control water in such a way that it increases agricultural production. The adequate, reliable, and equitable delivery of water in irrigation canals plays an important role in the achievement of this objective. Quantification of the water actually delivered at a specific time and location, and any deviation from the intended amount, determine the performance levels of the parameters mentioned above.

Molden and Gates (1990) developed the performance measures for analysis of irrigation water delivery systems in terms of adequacy (PI_A), efficiency (PI_{EF}), dependability(PI_D) and equity (PI_E) of water delivery. They opined that these performance measures can be incorporated in regular monitoring programme which can provide the frame work for assessing the system improvement alternatives.

The performance indicators expressed in terms of measurable quantities are called state variables. The major state variables that determine the water delivery system performance refer to volume rate, frequency or duration of water delivery.

$Q_D(x,t)$: Actual amount of water delivered to the system at a point 'x' in time ' t'.

Q_R (exit) : Actual amount of water required for consumptive and other uses downstream of the delivery point x.

CV_T: Temporal coefficient of variation over the standard time period T.

CV_R : Spatial coefficient of variation over the region R.

These state variables are combined in various forms to develop indicators of performance *viz.* PI_A, PI_D, PI_E and $PI_{EF.}$

Adequacy (PI_A):

Adequacy is defined as the ability of irrigation system to meet the required amount of water (Molden and Gates, 1990). PI_A is nothing but the total water delivered (Q_D) to irrigation water requirement (QR) over time period 't'.

Point performance function relative to adequacy (PI_A) is given by

$$\mathbf{PI_A} = \frac{\mathbf{1}}{\mathbf{T}}\left[\sum_{\mathbf{T}}\frac{\mathbf{1}}{\mathbf{R}}\sum_{\mathbf{R}}\mathbf{PA}\right] \quad \text{.... (1)}$$

where $P_A = Q_D/Q_R$, P_A = Point performance function relative to adequacy

Dependability (PI_D):

Dependability (PI_D) is a measure of both reliability and timeliness of water supply in a canal system. Dependability in the present analysis is taken as ratio of amount of water delivered temporally among the different sluice outlets in the command area.

Performance function relative to dependability (PI_D) is given by,

$$\mathbf{PI_D} = \frac{\mathbf{1}}{\mathbf{R}}\sum_{\mathbf{R}}\mathbf{CV_T}\left[\mathbf{Q_D}/\mathbf{Q_R}\right] \quad \text{.... (2)}$$

Equity (PI_E):

In rotational water distribution system, equity is one of the major objectives of the irrigation project. The measure of equity is the average relative spatial variability of the ratio of the amount of water delivered to the amount of water required over the time period (Molden and Gates, 1990).

Performance measure relative to equity is given by,

$$\mathbf{P_E} = \frac{\mathbf{1}}{\mathbf{T}}\sum_{\mathbf{T}}\mathbf{CV_R}\left[\mathbf{Q_D}/\mathbf{Q_R}\right] \quad \text{..... (3)}$$

Efficiency (PI_{EF}):

Water use efficiency is an important agronomic indicator for areas with limited water resources. The efficiency is expressed in terms of the volume of water required for a specific purpose and the volume of water delivered for this purpose. It is the volume of water stored in the soil for evapotranspiration compared to the volume of water delivered for this purpose.

The measure of water use efficiency is given as the spatial and temporal average of the ratio of Q_R and Q_D (Molden and Gates, 1990). Performance measure relative to efficiency PI_{EF} is given as

$$\mathbf{PI_{EF}} = \frac{\mathbf{1}}{\mathbf{T}}\left[\sum_{\mathbf{T}}\frac{\mathbf{1}}{\mathbf{R}}\sum_{\mathbf{R}}\mathbf{P_{EF}}\right] \quad \text{..... (4)}$$

where $PI_{EF} = Q_R/Q_D$,

if $Q_R = Q_D$, $P_F = 1$

The standards for these indicators are furnished in Table A.

Table A : Performance standards for irrigation systems

Measure	Good	Fair	Poor
PI_A	0.90 - 1.0	0.80 - 0.89	< 0.80
PI_{EF}	0.85 - 1.0	0.70 - 0.84	< 0.70
PI_E	0 - 0.10	0.11 - 0.25	> 0.25
PI_D	0 - 0.10	0.11 - 0.20	> 0.20

There is a reciprocal relationship between the adequacy and efficiency indices. If efficiency is >1.0, water delivery is efficient but inadequate. If efficiency <1.0, water delivery is adequate but not efficient. Under ideal conditions of adequacy (PI_A=1.0), it is also ideal with respect to efficiency.

RESULTS AND DISCUSSION

The results of the present study as well as relevant discussion have been summarized under following heads:

Performance assessment for Zone-A of 4(L) distributory of Pollachi canal:

Adequacy:

The canal operation days were 127, 82 and 122 days in the years 2006, 2008 and 2010, respectively in Zone-A. This variation was mainly due to supply position in the reservoir. The adequacy was almost equal to 1 during the months of November and December whereas other months possessed values from 0 to 0.5. In 2006 and 2008, February showed a value of 0.03 and 0.3 which indicated a very poor adequacy. The average values of PI_A in Zone-A were 0.47, 0.63 and 1.0 during the years 2006, 2008 and 2010, respectively. The low values of PI_A were mainly due to uneven distribution of rainfall in the season and also poor supply from the canal system. During the year 2010, the PI_A value was equal to 1.0 indicating a 'good' performance as far as the adequacy was concerned.

The adequacy index values for Zone-A during the years 2006, 2008 and 2010 are presented in Fig. 1 to 3.

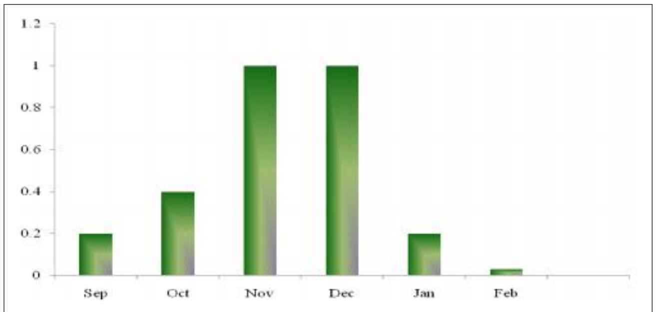

Fig. 1 : Adequacy index (PIA) of 4(L) distributory for Zone-A in 2006

Fig. 2 : Adequacy index (PIA) of 4(L) distributory for Zone-A in 2008

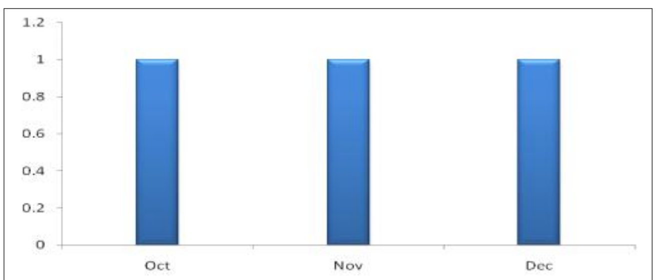

Fig. 3 : Adequacy index (PIA) of 4(L) distributory for Zone-A in 2010

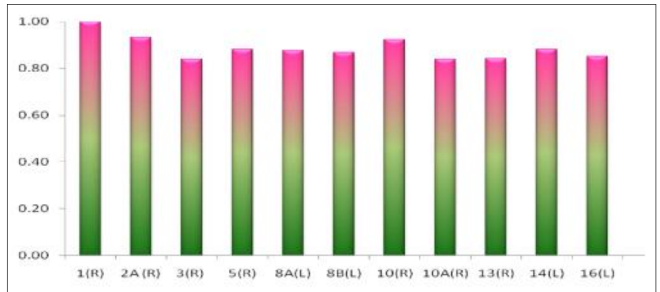

Fig. 4 : PI_D of 4(L) distributory for Zone-A in 2006

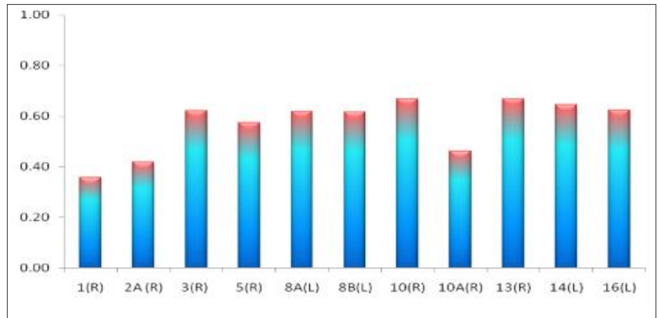

Fig. 5 : PI_D of 4(L) distributory for Zone-A in 2008

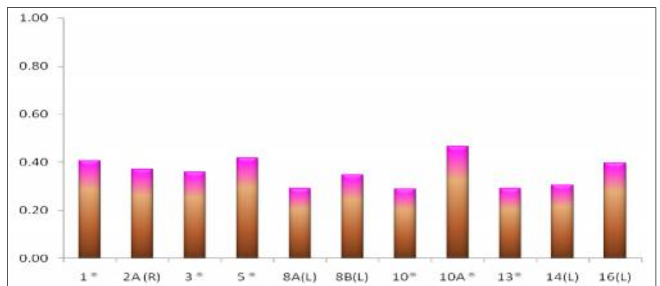

Fig. 6 : PI_D of 4(L) distributory for Zone-A in 2010

Dependability(PI_D):

The performance index relative to dependability was done based on their respective turns for years 2006, 2008 and 2010 in order to assess the dependency of the farmers on canal water over the years and also within the zone. The spatial variations in PI_D in Zone-A for the years 2006, 2008 and 2010 were worked out and are presented in Fig. 4 to 6.

During the years 2006, 2008 and 2010, the calculated values of PI_D were above 0.20, indicating a 'poor' performance in the case of dependability of the system. It indicated that the water deliveries were not uniform over time in accordance to demand, thus poor timeliness. Also, some times, closure of irrigation canal in response to high rainfall during the months of October and November might have resulted in high PI_D values.

Equity (PI_E):

The calculated monthly values of PI_E were given in Table 1.

The PI_E values were less than 0.2 for the months October and November in 2006 and 2008 indicated equitable distribution of water in the system. The PI_E values in 2006 were 'zero' indicated a 'good' equity. In 2008, equity values of < 0.2 were observed in all months of canal supply except December whereas higher values in November and December during 2010 indicated poor equity. But poor equity in the months of November and December during 2008 and 2010 was offset to some extent by low or no requirement of irrigation

Table 1 : Monthly variations in PI_E in Zone-A during 2006, 2008 and 2010

PI_E	2006	2008	2010
Sept	0.00		
Oct	0.00	0.00	0.16
Nov	0.00	0.00	0.33
Dec	0.00	0.59	0.60
Jan	0.00	0.14	
Feb	0.00	0.02	

to crops due to rainfall and less evapotranspirative demand during that period.

The equity performance during 2006 could be rated as "good". The average values of PI_E were 0.25 and 0.16 during 2008 and 2010 indicated 'poor' equitable distribution of water in the system.

Efficiency (PI_{EF}):

The PI_{EF} values of Zone-A for the years 2006, 2008 and 2010 are presented in Table 2.

Table 2 : PI_{EF} (Efficiency performance index) for Zone A for the years 2006, 2008 and 2010 of 4(L) distributory

Year	2006	2008	2010
PI_{EF}	0.53	0.62	0.45

The efficiency performance index PI_{EF} for Zone-A can be rated as 'poor' ($PI_{EF} < 0.85$) during the years of canal supply in Zone-A.

The average values of the performance evaluation for the 4(L) distributory for Zone-A during 2006, 2008 and 2010 are summarized in Table 3.

Performance indicators for Zone-B of 4(L) distributory of Pollachi canal:

The performance indices *viz*. Adequacy (PI_A), dependability (PI_D), equity (PI_E) and efficiency (PI_{EF}) were worked out for years 2005, 2007 and 2009 during which the canal supply was in Zone B. The number of canal operation days during 2005, 2007 and 2009 were 98, 149 and 131 days, respectively.

Adequacy (PI_A):

The PI_A values of 4(L) distributory in Zone-B during the years 2005, 2007 and 2009 are presented in Fig. 7- 9.

The adequacy during the months of October, November

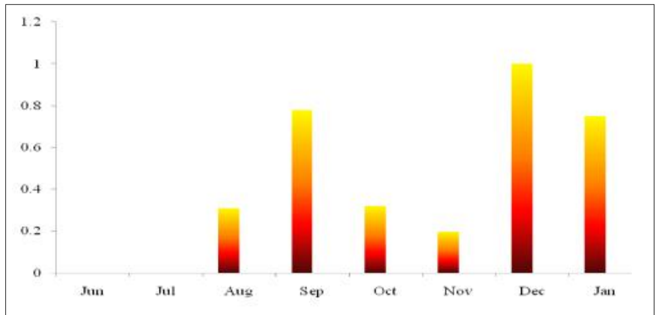

Fig. 7 : Adequacy index(PI_A) of 4(L) distributory for Zone-B in 2005

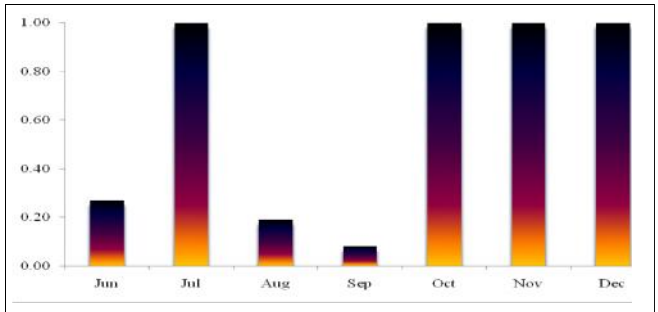

Fig. 8 : Adequacy index (PI_A) of 4(L) distributory for Zone-B in2007

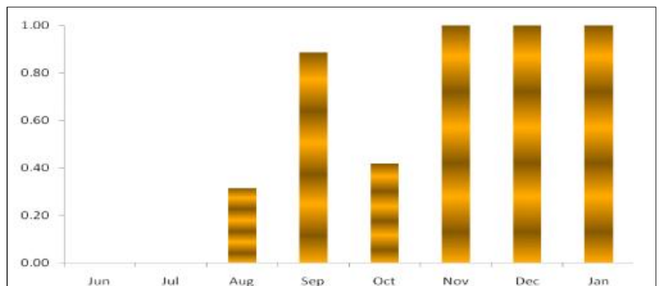

Fig. 9 : Adequacy index (PI_A) of 4(L) distributory for Zone-B in 2009

and December was greater than 0.90 during 2007 and 2009 indicating adequate canal supply except during 2005. The canal supply during the months of July, August and September during 2005, 2007 and 2009 were varying between 0.10 and 0.78 indicate inadequate canal supply to meet the requirements of crops grown in the distributory. The average values of PIA (Adequacy performance) in Zone-B during the years 2005,

Table 3 : Performance of water delivery in Zone-A of 4(L) distributory in Pollachi canal

Year	Adequacy (PIA)		Efficiency (PI_{EF})		Equity (PIE)		Dependability (PID)	
2006	0.47	Poor	0.53	Poor	0.00	Good	0.21	Poor
2008	0.63	Poor	0.62	Poor	0.25	Poor	0.22	Poor
2010	1.0	Poor	0.45	Poor	0.16	Poor	0.36	Poor

2007 and 2009 were 0.58, 0.92 and 0.72, respectively. The low values of PIA were mainly due to variation in canal supply within the months during 2005 and 2009 whereas the average PIA value of 0.92 during the year 2007 indicates adequate supply, according to performance standard indicates 'good' performance of the system

Dependability (PI_D):

The values of PI_D (Dependability performance) in the Zone-B for years 2005, 2007 and 2009 are presented in Fig.10, 11 and 12. The average values PI_D (Dependability performance) for the years 2005, 2007 and 2009 were 0.32, 0.48 and 0.38, which fall above the upper limits accounting to 'poor'performance ($PI_D > 0.20$). This indicated that the water deliveries were not in accordance with the demand over the area. Higher values of dependability in middle and tail end areas indicated that they do not receive sufficient quantity of water from canal system.

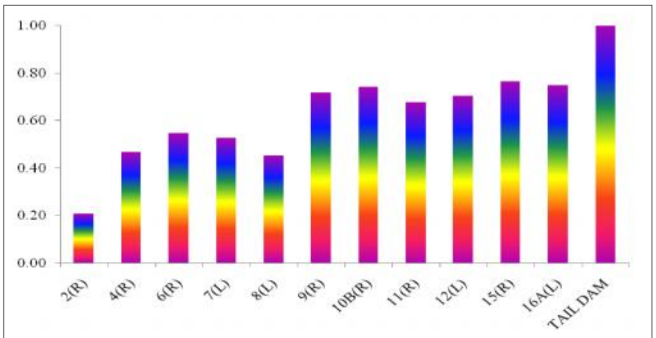

Fig. 10 : PI_D of 4(L) distributory for Zone-B in 2005

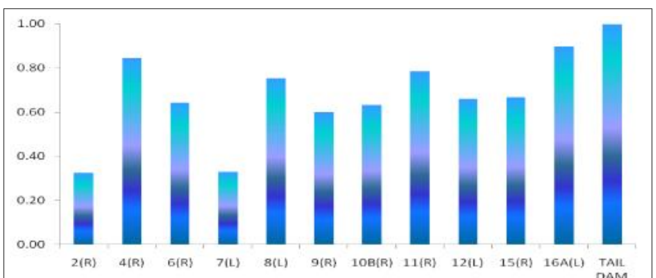

Fig. 11 : PI_D of 4(L) distributory for Zone-B in 2007

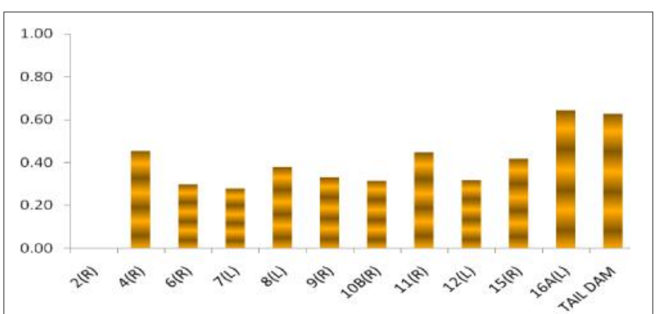

Fig. 12 : PI_D of 4(L) distributory for Zone -B in 2009

Equity (PI_E):

The average values PI_E (Equity performance) in Zone-B for the years 2005, 2007 and 2009 were 0.32, 0.62 and 0.30, respectively which fall above the upper limits was accounting to "poor"performance ($PI_E > 0.20$). The PI_E values were less than 0.15 for the month August in all years indicate equitable distribution of canal water in the distributory whereas higher values in other months indicated inequitable distribution. During months of October, November and December, farmers do not depend much on canal water due to NE monsoon. The PI_E (Equity performance) values over the months of canal

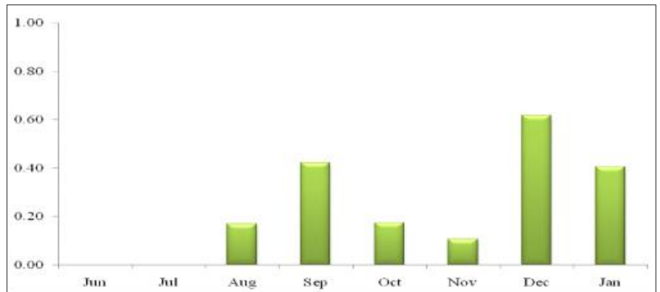

Fig. 13 : PI_E (Equity performance) of 4(L) distributory for Zone-B in 2005

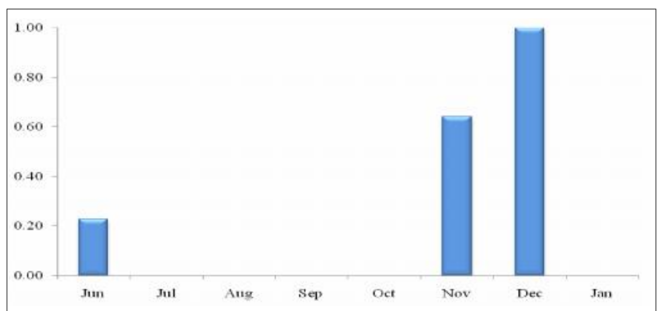

Fig. 14 : PI_E(Equity performance) of 4(L) distributory for Zone-B in 2007

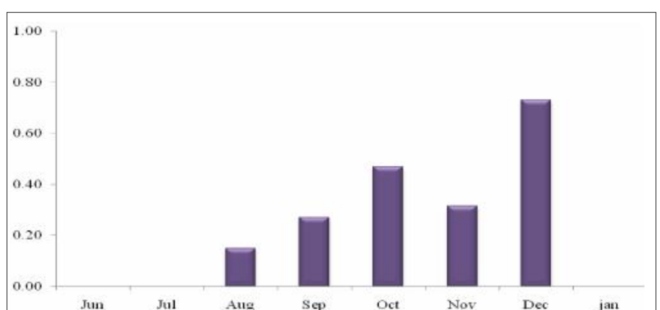

Fig. 15 : PI_E(Equity performance index) of 4(L) distributory for Zone-B in 2009

Table 4 : PI_{EF} (Efficiency Performance Index) for zone B of 4(L) distributory for the years 2005, 2007 and 2009

Year	PI_{EF}
2005	0.50
2007	0.52
2009	0.21

Table 5 : Performance of water delivery in Zone-B of 4(L) distributory of Pollachi canal

Year	Adequacy (PI_A)		Efficiency (PI_{EF})		Equity (PI_E)		Dependability (PI_D)	
2005	0.58	Poor	0.50	Poor	0.30	Poor	0.32	Poor
2007	0.92	Good	0.52	Poor	0.62	Poor	0.48	Poor
2009	0.72	Poor	0.21	Poor	0.32	Poor	0.38	Poor

supply for the years 2005, 2007 and 2009 are presented in Fig. 13, 14 and 15.

Efficiency (PI_{EF}):

The efficiency of the canal system for Zone-B during the years 2005, 2007 and 2009 were worked out and are presented in Table 4.

The lower values of PI_{EF} indicated that the system was not efficient to meet the requirements of the zone.

Conclusion:

The delivery system presents a poor performance relative to adequacy ((PI_A) in all years except in the year in 2007 in Zone-B and 2010 in Zone-A. The values of equity (PI_E)in the delivery system varied from 0.25-0.62 indicating 'poor' allocation of water to meet the crop demand except in years 2006 and 2010 (Zone-A). The reasons for inequity may be attributed to poor water delivery against crop demand in the canal system.

The minimum and maximum PI_D values were 0.21-0.48 imply that the distribution of this indicator was not consistent. The farmers were not assured of adequate water supply at the time of need. The reasons for poor dependability performance were due to limited supply of irrigation water and poor managerial problems which led to severe water shortage problem in tail end areas. The dependability ratio has to be increased in order to deliver required quantity of water in correct time.

The efficiency of the system over the years irrespective of their turn/zone is rated as 'poor' (0.21-0.62), as the canal system is unable to meet the requirements of crops grown. The farmers mostly depend on groundwater to supplement the crop water requirements. The performance assessment study revealed that the system performance was 'poor' over the years and it deteriorated further during deficit rainfall years.

In order to improve the performance of the system, farmer may be educated through extension training programmes about optimal crop water requirement so that; they can apply water only as per requirement. The performance measures can be incorporated in an irrigation system monitoring program and can provide a framework for assessing system improvement alternatives. The system performance could be improved upon by suitably altering the cropping pattern with less water requiring crops coupled with better groundwater utilization plans to augment the irrigation water supply during water deficit periods.

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