

Enhancing Efficiency of the Minipe Left Bank Canal Irrigation System: A Strategic Approach

U.H.M.S. Silva, S. Ranwala and K.D.W. Nandalal

Abstract: Minipe left bank canal faces a head-tail water imbalance due to insufficient water availability and inefficiency in water distribution. To address this issue, Minipe anicut is raised by 3.5m. Though ample water could be released, irrigation water would not be dispersed adequately along the canal due to mis-usage and mismanagement. The study aims to establish an operational pattern for the canal to deliver adequate water to the entire command area during both the Yala and Maha seasons. Simulation models were used to model the canal's operational pattern, including inflows and irrigation demands. Catchment areas, which bring water to the Minipe Left Bank canal, were delineated using ArcGIS software, and inflows were estimated using HEC-HMS software. Crop water requirements were estimated using CROPWAT program. A system simulation model developed using WEAP software was used to simulate irrigation system operation. Nine management scenarios were evaluated, including introducing new cropping patterns, shifting sowing dates, increasing Minipe anicut discharges, and reducing the command area. The study found that introducing a 70% paddy crop pattern, advancing the sowing date by two weeks, and raising the Minipe anicut discharge by 15% significantly reduce unmet demands. Implementing these improvements could result in a 75% reduction in unmet demand.

Keywords: HEC-HMS, CROPWAT, WEAP, Scenario, Operational Pattern

1. Introduction

Irrigation is the process of applying irrigation water to crop plots artificially. Crop irrigation is necessary during the dry season when rainfall is insufficient to meet farmers' water needs. Irrigation schemes play a key role in supporting the development of the agricultural sector, which in turn fosters economic growth.

Irrigation systems have been important to Sri Lanka's development since the country's early history. The agricultural industry in Sri Lanka must be developed for the country's economy to expand, which requires irrigation. In Sri Lanka, paddy cultivation consumes more than 70 percent of the total water allotted for irrigation [1].

The demand for irrigation water has increased over time due to population expansion [2]. Thus, the limited availability of water resources has become a serious issue. Inefficiency and inequity in irrigation water distribution still exist in Sri Lanka [3]. The effectiveness of the irrigation infrastructure and fairness of water distribution have been identified as the main difficulties with irrigation water management in Sri Lanka.

Minipe Irrigation Scheme is located in the Central Province of Sri Lanka and has a command area of 7020 ha on the left bank of

Mahaweli River. It receives water diverted by Minipe Anicut situated across the Mahaweli River. However, a considerable head-tail disparity exists in the Minipe Irrigation Scheme resulting in canal tailend farmers suffering from frequent water inadequacy. Crop devastation and economic hardships result from this and more than one-third of the tailenders are impoverished. Further, it was found that tailend farmers have a three times worse economic situation than farmers in the head and middle reaches [4, 5].

The economic aspect of water discrepancy in the Minipe Irrigation Scheme has been studied previously, but the water deficits have not been quantified adequately [4]. As one of the measures to address the scarcity of water for

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tailend farmers, the Minipe anicut has been raised by 3.5 m recently to keep more water in storage upstream of it and effectively deliver to farmers in the scheme guaranteeing sufficient water for the tailenders. This paper presents an estimation of water deficiencies that exist in the scheme and proposes a procedure to efficiently operate the Minipe Irrigation Scheme to minimize such deficiencies.

2. Minipe Scheme

The Minipe anicut is the second significant diversion point in the Mahaweli Development Scheme and it diverts water for irrigation via canals at left and right banks. The left bank canal serves Mahaweli Irrigation System E while Mahaweli Irrigation Systems B & C receive water via the right bank canal. The Minipe anicut is a 225 m long ogee-type concrete gravity structure having a maximum height of 13 m at the crest level of 114 m MSL. The Minipe pool of storage capacity 0.18 MCM serves as the sole regulating reservoir for the Minipe left bank and right bank canals of design discharges of 22 m³/s and 64 m³/s, respectively. Rantambe reservoir, located immediately upstream of the Minipe anicut, releases water towards the Minipe anicut twice daily during the generation of hydropower to satisfy peak electricity demand. The 74 km long Minipe left bank canal is an unlined contour canal serving a command area of 7020 ha. This command area is divided into 4 stages for administrative convenience while each of the first 3 stages has 2 sub-sections. The sub-sections of the canal would be denoted as Stage 1.1, Stage 1.2, etc. Figure 1 illustrates the Minipe left bank canal irrigation scheme overlaid on 1:50,000 topo sheet of the Department of Survey. The different stages of the Minipe left bank canal command area are detailed in Table 1.

Table 1 - Stages of Minipe Left Bank Canal Irrigation Scheme

Stage	Section	Location (km)	Command Area (ha)
1	1	0 - 17	901
	2	17 - 31	1229
2	1	31 - 42	1007
	2	42 - 50	1076
3	1	50 - 58	832
	2	58 - 64	802
4		64 - 74	1083

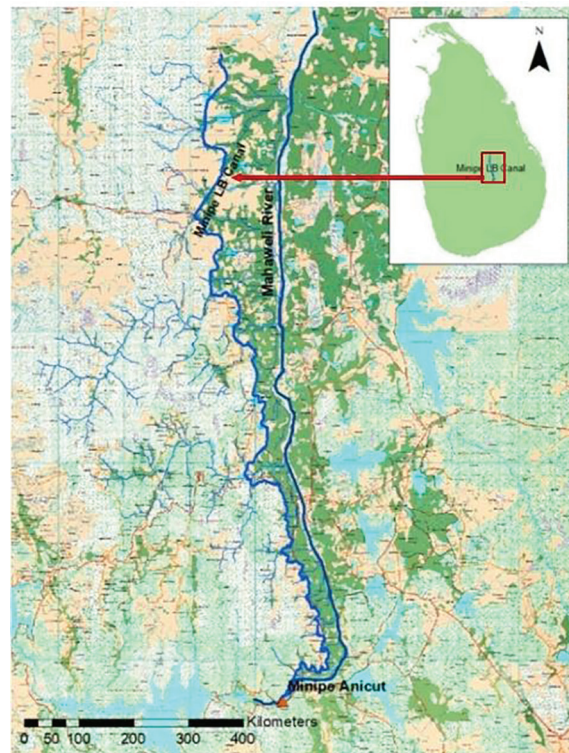


Figure 1 - Minipe Left Bank Canal

Figure 2 depicts the Minipe left bank canal scheme's current operational pattern. Stages 3 and 4 receive water supply throughout the first three days of the week. Water is provided to Stages 1 and 2 over the subsequent three days of the week. Water is not provided to any of the stages on the seventh day of the week. One cycle finishes in a week, and the second cycle begins in the following week.

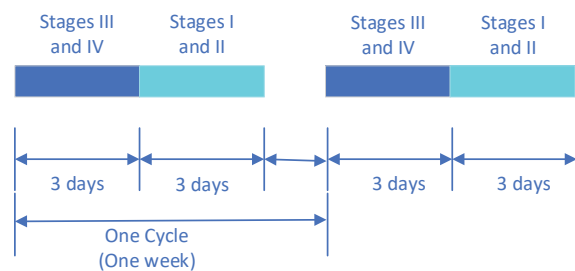


Figure 2 - Existing Operational Pattern

In the Minipe left bank irrigation scheme, paddy cultivation is exclusively undertaken during the Maha season. Although the primary focus is on paddy cultivation in the Yala season, plans to introduce upland crops during this period have not been implemented as intended [6, 7].

3. Methodology

Figure 3 illustrates the main procedure used to carry out the study. Data collection was the first phase of the study. Then, using HEC-HMS software, the inflows entering the Minipe left bank canal were computed [8]. Software called CROPWAT 8.0 was employed to estimate the irrigation requirements of the crops [9]. Finally, the operation of the irrigation system operation was simulated using WEAP software, which is based on the water balancing approach using the calculated irrigation demands, inflows, and Minipe anicut outflows [10].

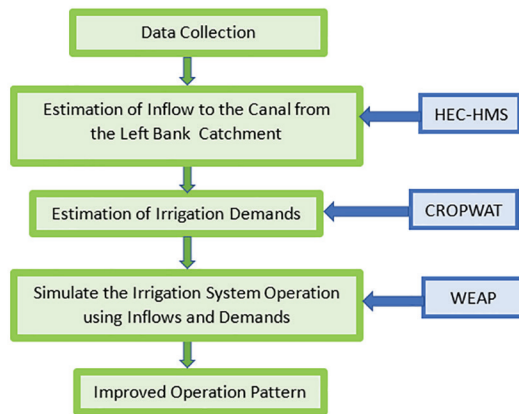


Figure 3 - Overview of the Methodology

3.1 Data Collection

The daily rainfall data were collected from rain gauge stations at Mapakadawewa and Girandurukotte (Figure 4). The data set of the study included Minipe anicut discharges, crop areas, cropping times, and sowing dates as well as daily meteorological data from Girandurukotte.

3.2 Estimation of Inflows

Hasalaka Oya, Heen Ganga, and numerous small streams bring water to the Minipe left bank canal from the catchment on its left bank. These inflows to the Minipe left bank canal from 2005 to 2019 were calculated employing a rainfall-runoff model developed for the catchments of all these streams using HEC-HMS software. The catchments were first delineated from a digital elevation model (DEM) using HEC-GeoHMS and ArcGIS software.

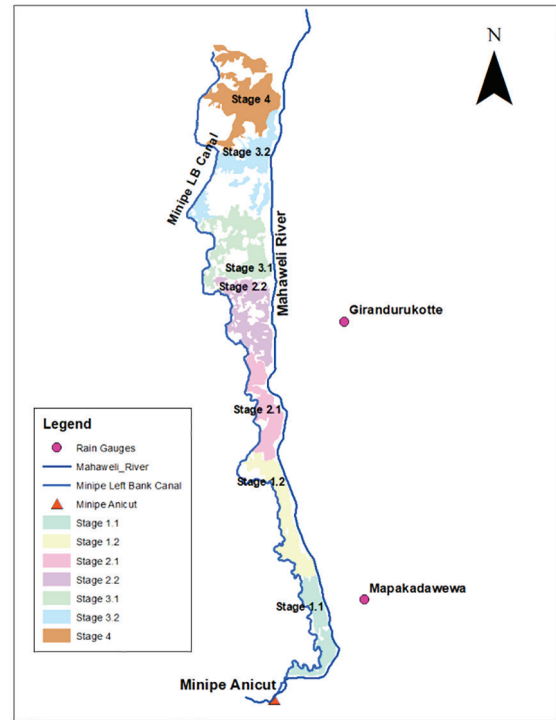


Figure 4 - Rain Gauge Stations in Minipeleft Bank Canal Irrigation Scheme

Out of the modeling options available in the HEC-HMS software, the Initial and Constant method was used as the loss method. The SCS Unit Hydrograph method was the transform method while the Recession method was used as the base flow method. These methods were selected after studying many applications of the HEC-HMS model to catchments in the country [11, 12, 13]. Initial loss, constant loss rate and imperviousness percentage were assumed to be 8 mm, 1.6 mm/h, and 1%, respectively. The initial type in the baseflow method was taken to be discharge per area and the initial discharge was taken as 5 m³/s.km², the recession constant and the ratio to peak threshold were taken as 0.6, and 0.4, respectively.

Equation 1 illustrates the Kirpich method's calculation of the time of concentration (t_c) of catchments. Lag times were determined by multiplying the calculated time of concentrations by 0.6.

$$t_c = kL^{0.77}S^{-0.385} \quad \dots(1)$$

t_c = Time of Concentration (min)

k = 0.0195

L = Channel flow length (m)

S = Main channel slope

Thiessen polygons were constructed to determine the rainfall gauging station relevant to the catchment of each inflow stream.

3.3 Estimation of Irrigation Demands

Irrigation water needs of the Minipe left bank canal command area were calculated using the CROPWAT 8.0 software based on the Penman-Monteith method. Daily climate data at Girandurukotte from 2015 to 2019 were used to compute reference evapotranspiration (ET_o). The necessary climatic data included the maximum temperature, minimum temperature, sunlight hours, wind speed, and relative humidity.

Effective rainfall was calculated using daily rainfall data from 2015 to 2019. Mapakadawewa rainfall data were used to calculate crop water requirements in Stages 1 and 2 of the command area while rainfall data at Girandurukotte were used to calculate water requirements in Stages 3 and 4. The effective rainfall was calculated using the method developed by the USDA's soil conservation program and available in the CROPWAT software. According to Sri Lanka's soil map, the Minipe region has reddish brown soil and it was used in the calculations.

In the Minipe Left Bank canal's command area, paddy is primarily grown during both the Yala and Maha seasons and thus crop factors relevant to paddy were used in the model to determine actual evapotranspiration (ET). The irrigation efficiency used is 60%.

Twenty fifth (25th) of April was used as the sowing date for the Yalaseason and 25th of November for the Maha season. The sowing dates were chosen after taking into account the Minipe anicut releases and Seasonal Summary Reports for several years [6,7,14,15].

The operational pattern of the Minipe left bank canal intended to be enhanced by reducing unmet demands. In order to do that, the sowing dates for both seasons were advanced by two weeks, and the effect of this move on crop water needs was investigated. During the Yala season, 70% of the command area was planted with paddy, while 30% of the command area was planted with other field crops. The other field crops considered were maize, green gram, and soya beans, 10% of each. The crop's water requirements were calculated with these modifications.

3.4 Simulation of Irrigation System Operation

The WEAP software was used to develop a simulation model for the Minipe Left Bank

canal irrigation system for the period 2015 to 2019, utilizing the calculated inflows to the canal and the irrigation water demands in the system. The simulation model is based on water balance in the system. The schematic representation of the WEAP model is shown in Figure 5. Irrigation demands of the command area are lumped at seven locations along the canal. Nineteen streams flow into the canal from the left bank catchment. The canal crosses the Heen Ganga as an aqueduct while the Hasalaka Oya is a level crossing. Annual activity levels for demand locations and the command area for each stage of the Minipe Left Bank irrigation scheme were provided for the data input to the WEAP. Also, the daily averages of the annual water use rates were entered into the WEAP model. The current operational pattern (3-day rotation) of the Minipe Left Bank canal was considered when creating the demand files. There was also a daily change in the demands. Since the CROPWAT results were obtained for 10-day periods, it was considered to be equally distributed according to the existing 3-day operational pattern of the Minipe left bank canal.

A variety of scenarios were taken into account to enhance the operational pattern. By lowering unfulfilled requests, the operating pattern can be improved. Water availability was examined for both the Yala and Maha seasons.

The following are the different management scenarios studied.

- Scenario 1: Business as Usual (BAU) Scenario. The cropping pattern of 100% paddy is considered for both the Yala and Maha seasons.
- Scenario 2: The planting date is advanced by two weeks. Both the Yala and Maha seasons had earlier planting dates. The anicut discharge data were considered when choosing the 2-week advancement.
- Scenario 3: While maintaining the 100% paddy cropping pattern in the Maha season, the cropping pattern in the Yala season is changed to 70% paddy and 30% other field crops. Maize, green gram, and soybeans are the other field crops (OFC) that are typically produced in this region.

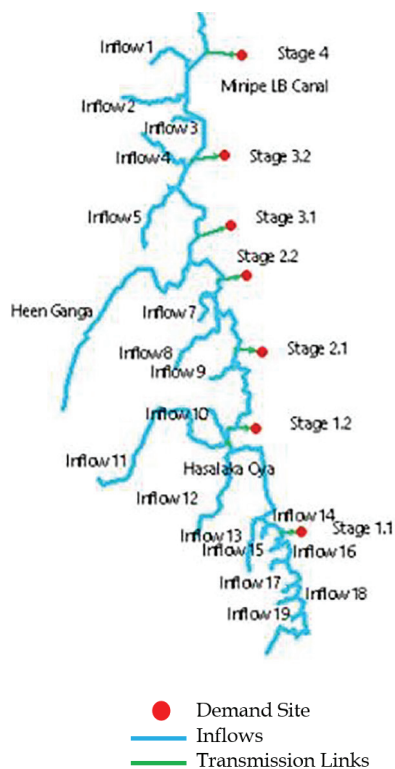


Figure 5 - Schematic Diagram in WEAP

- Scenario 4: 30% of other field crops and 70% of paddy had their planting dates advanced by two weeks. This scenario was chosen after considering the outcomes of Scenario 2 and Scenario 3.
- Scenario 5: Minipe anicut discharges are increased by 15%. By meeting the limitation of the Minipe left bank canal's capacity of 22 m³/s, the percentage of increase was determined.
- Scenario 6: 70% of paddy and 30% of other field crops had their planting dates advanced by two weeks, while anicut discharges were raised by 15%. This scenario was created by combining Scenario 4 and Scenario 5.
- Scenario 7: 25% reduction in the command area during the Yala season.
- Scenario 8: A 40% reduction in the command area during the Yala season.
- Scenario 9: Reducing the command area in the Yala season by 40% in Stages 1 and 2 and 50% in Stages 3 and 4.

A summary of the scenarios considered are shown in Table 2.

Table 2 - Scenario Summary

Scenario	Cropping Pattern		Sowing Date Advancement	Anicut Discharge Increase	Command Area Reduction in Yala	
	Yala	Maha			Stage 1 & 2	Stage 3 & 4
1	100% Paddy	100% Paddy	-	-	-	-
2	100% Paddy	100% Paddy	2 weeks	-	-	-
3	70% Paddy 30% OFC	100% Paddy	-	-	-	-
4	70% Paddy 30% OFC	100% Paddy	2 weeks	-	-	-
5	100% Paddy	100% Paddy	-	15%	-	-
6	70% Paddy 30% OFC	100% Paddy	2 weeks	15%	-	-
7	100% Paddy	100% Paddy	-	-	25%	25%
8	100% Paddy	100% Paddy	-	-	40%	40%
9	100% Paddy	100% Paddy	-	-	40%	50%

4. Results and Discussion

4.1 Left Bank Catchment Inflows

The watershed delineation revealed 19 catchments, including the Heen Ganga and Hasalaka Oya (see Figure 6). Their areas and lag times are given in Table 3. It presents rainfall-runoff coefficients obtained from the hydrological models, too. The lack of observed streamflow data presented a challenge for the study's HEC-HMS hydrological model calibration, which affected the precision of the findings. The runoff coefficient obtained was compared with that of the Mahaweli River basin, which was previously estimated to be around 30.9% [16], in order to confirm the accuracy of the data. Since the estimated runoff coefficients are deemed accurate and roughly coincide with the runoff coefficient of the Mahaweli River basin, the model's parameters can therefore be considered reasonable.

In Figure 7, the calculated inflows are displayed.

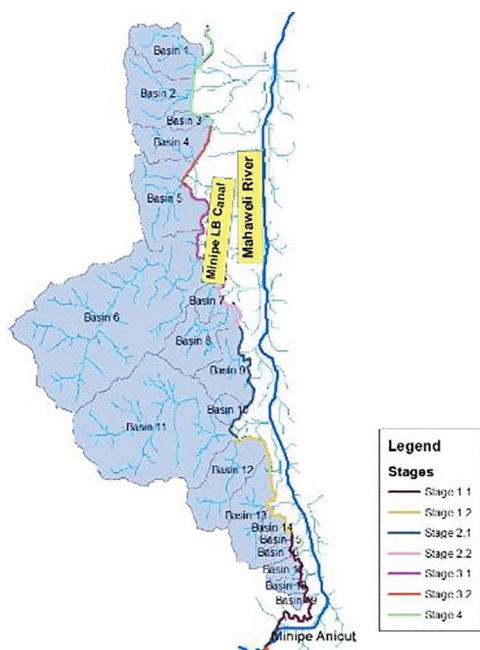


Figure 6 - Catchments of Streams on MinipeLeft Bank Canal

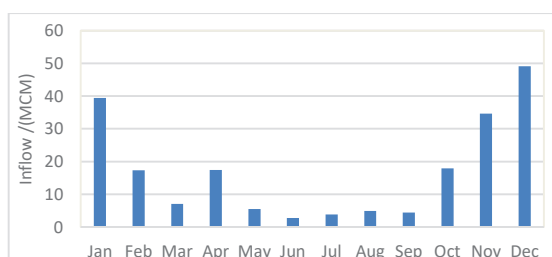


Figure 7 - Average Monthly Inflows to the Canal

Table 3 - Details of Catchments

Sub-Catchments	Area (km ²)	Lag time (min)	Rainfall/Runoff
1	17.0	60	0.31
2	20.6	48	0.31
3	1.5	17	0.31
4	11.4	50	0.31
5	23.2	49	0.31
6	117.1	79	0.31
7	3.8	25	0.31
8	17.8	24	0.32
9	7.8	24	0.32
10	2.7	24	0.33
11	87.0	60	0.33
12	20.5	32	0.33
13	15.4	26	0.33
14	1.8	12	0.33
15	1.4	11	0.33
16	2.5	13	0.33
17	1.6	10	0.35
18	2.5	12	0.35
19	1.0	7	0.35

4.2 CROPWAT Results

Table 4 shows the estimated crop water requirements (CWR) for the Maha season based on rainfall data from the gauge stations at Mapakadawewa (Mapa) and Girandurukotte (Gira).

Table 4 - Crop Water Requirements in MahaSeason

Year	CWR/ (mm/season)			
	100% Paddy		Sowing date 2 weeks advanced	
	Mapa	Gira	Mapa	Gira
2015 -2016	333	347	280	277
2016 -2017	293	273	277	280
2017-2018	362	373	329	365
2018 -2019	374	401	321	389
Average	341	349	302	328

Advancing the sowing date by two weeks in the Maha season, the average seasonal CWR was reduced by 11% and 6%, respectively, for the data at the gauge stations Mapakadawewa and Girandurukotte.

Tables 5 and 6 show, respectively, the estimated CWR for the Yala season using rainfall data from the two rain gauge stations, considering 100% paddy and a cropping pattern of 70% paddy and other field crops.

Table 5 - Crop Water Requirements in YalaSeason with 100% Paddy

Year	CWR/ (mm/season)			
	100% Paddy		Sowing date 2 weeks advanced	
	Mapa	Gira	Mapa	Gira
2015	674	678	576	621
2016	735	724	723	679
2017	708	703	740	704
2018	698	685	626	606
2019	752	575	701	528
Average	713	673	673	628

Table 6 - Crop Water Requirements in YalaSeason with 70% Paddy

Year	CWR/ (mm/season)			
	70% Paddy		70% Paddy + Sowing date 2 weeks advanced	
	Mapa	Gira	Mapa	Gira
2015	563	560	512	512
2016	618	609	603	568
2017	592	584	613	582
2018	588	568	530	507
2019	580	464	586	431
Average	588	557	569	520

By advancing the sowing date by two weeks, the average seasonal CWR is reduced by 6% and 7% for Mapakadawewa and Girandurukotte, respectively. The percentage average seasonal CWR reduction in the Yala season for a cropping pattern of 70% Paddy and 30% OFC are 18% and 17%, for Mapakadawewa and Girandurukotte, respectively. The percentage average seasonal CWR reduction in the Yala season by advancing the sowing date by two weeks and by giving a crop pattern of 70% Paddy and 30% OFC are 20% and 23%, respectively.

The summary of the reduction of average seasonal crop water requirement is shown in Table 7.

Table 7 - Summary of the Reduction of Average Seasonal Crop Water Requirement

Scenario	Season	Average Seasonal Crop Water Requirement Reduction /(%)	
		Mapakadawewa	Girandurukotte
Sowing date advanced by 2 weeks	Maha	11	6
Sowing date advanced by 2 weeks	Yala	6	7
70% paddy, 30% OFC cropping pattern	Yala	18	17
Sowing date advanced by 2 weeks + 70% paddy, 30% OFC cropping pattern	Yala	20	23

4.3 Simulation Results Business as Usual Scenario

The estimated annual average monthly variation of irrigation demand, supply delivered, and the unmet demand from 2015 to 2019 for the whole command area are shown in Figure 8. The average unmet demand for the Maha season is 5.3 MCM and 13.4 MCM for the Yala season.

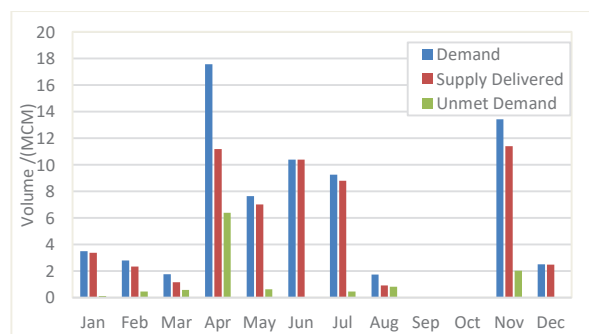


Figure 8 - Demands, Supply, and Unmet Demands for Business-as-usual Scenario

A stage-wise analysis and a section-wise analysis were carried out to understand the Minipe Left Bank canal irrigation system more

comprehensively in the business-as-usual scenario. For better accuracy and to obtain a clear picture, the unmet demands were considered per km². Figure 9 illustrates the section-wise unmet demands in the Yala and Maha seasons.

Analysis indicates that the unmet demands for Stage 3 and Stage 4 were relatively higher than the unmet demands for Stage 1 and Stage 2. Further, the unmet demands in the Maha season were relatively lower than in the Yala season, because of higher rainfalls during this period. While the unmet demands in Stages 1.1, 1.2, 2.1 and 2.2 during the Yala season were about 150,000 m³/km² the unmet demands in Stages 3.1, 3.2 and 4 ranged from 200,000 to 300,000 m³/km². For the Maha season, a similar pattern could be observed with different values. Stage 1.1, Stage 1.2, Stage 2.1, and Stage 2.2 have unmet demands of around 50,000 m³/km² and Stage 3.1, Stage 3.2, Stage 4 have unmet demands of around 100,000 m³/km². Therefore, it is needed to reduce the unmet demands in the Yala season for Stage 3 and Stage 4.

Other Scenarios

The major WEAP model results were the unmet demands in each of the scenarios. The results obtained for all the scenarios in the Yala season and Maha season by WEAP modeling are shown in Figure 10 and Figure 11, respectively. According to the analysis in the Business-as-Usual Scenario, the average unmet demands in the Yala season and Maha season were 13.4 MCM and 6.4 MCM, respectively. It is essential to reduce the unmet demands in the Yala season since the average unmet demands in the Yala season are much higher than in the Maha season.

Furthermore, the unmet demands for Stages 3 and 4 in the Yala season vary between 200,000 and 300,000 m³/km² and unmet demands for Stages 1 and 2 are in the range of 150,000 m³/km². Therefore, it is vital to propose an improved operational pattern to reduce the unmet demands of Stages 3 and 4 in the Yala season.

While the seasonal unmet demands were obtained using the simulation model, the section-wise analysis was also carried out for all the scenarios. Figure 12 and Figure 13 show the results obtained through the analysis.

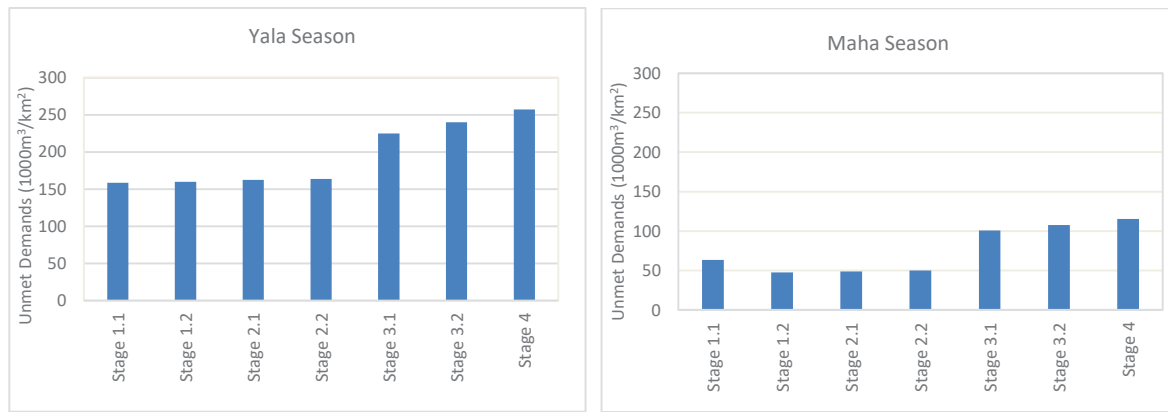


Figure 9 - Section-Wise Analysis for Unmet Demands in the Yala and Maha Seasons

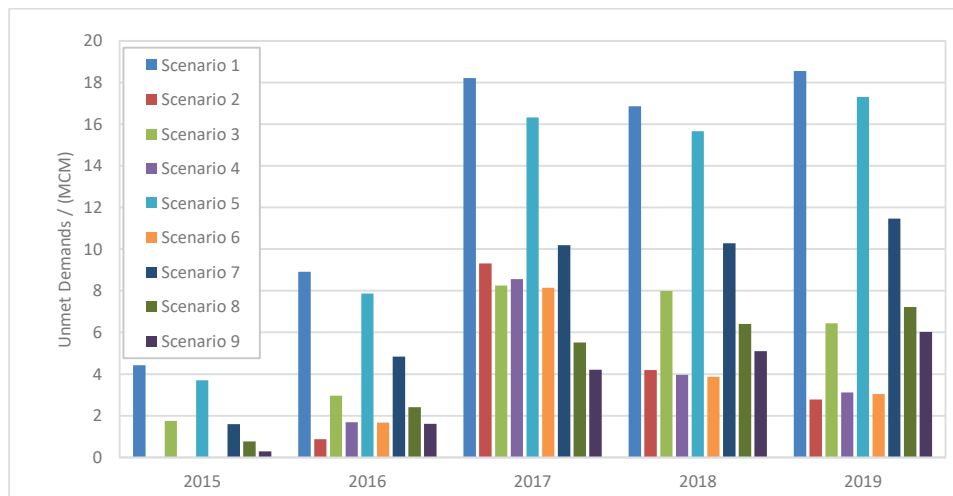


Figure 10 - Simulation Results for the Yala Season

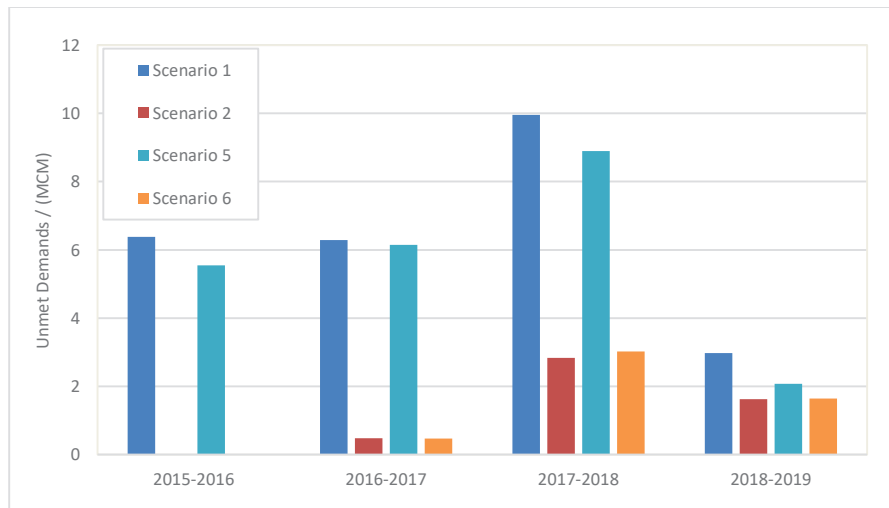


Figure 11 - Simulation Results for the Maha Season

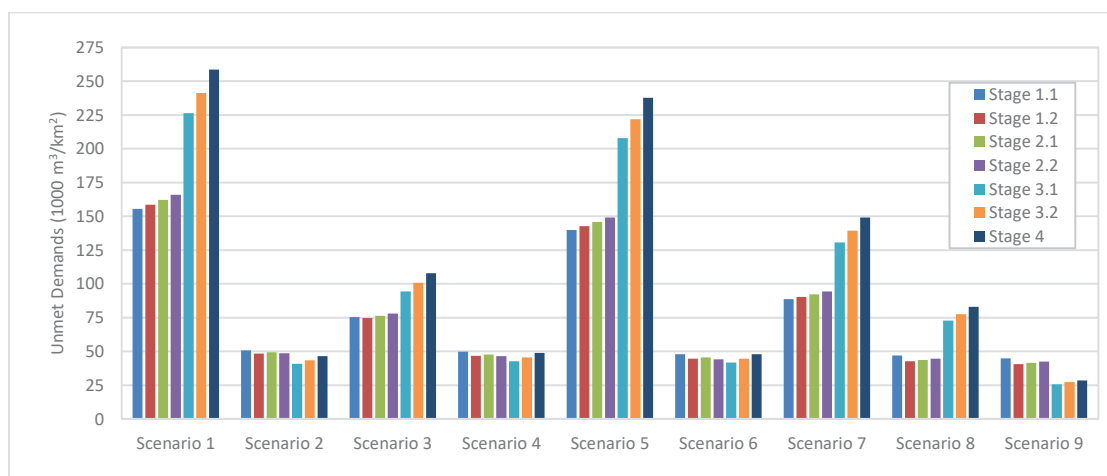


Figure 12 - Section-wise Analysis for all Scenarios in the Yala Season

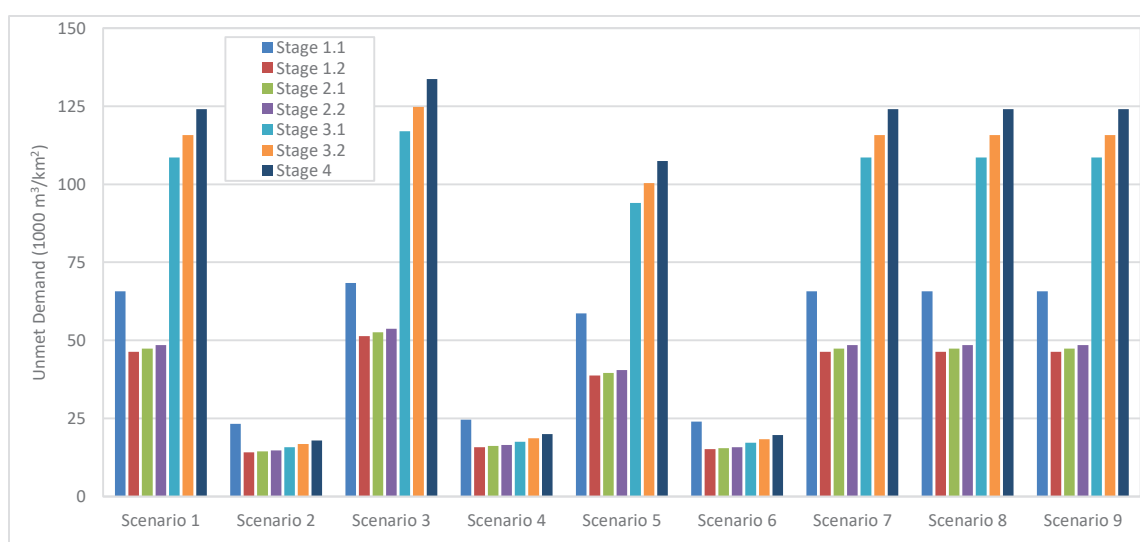


Figure 13 - Section-Wise Analysis for all Scenarios in the Maha Season

It is observed that the unmet demands in the Business-as-usual Scenario (Scenario 1) were reduced for all the sections by all the 9 scenarios considered. The percentage of unmet demand reductions is shown in Table 8 and Table 9.

By advancing the sowing date by 2 weeks in Scenario 2, the average seasonal unmet demands have been reduced by 74.4% in the Yala season and 80.7% in the Maha season. Therefore, advancing the sowing date by 2 weeks in both seasons improves the operational pattern.

Table 8 - Section-Wise Unmet Demands Reduction for the Yala Season

	Unmet Demands Reduction (%)								
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Stage 1.1	-	67.3	51.4	68.0	10.1	69.1	43.0	69.8	71.2
Stage 1.2	-	69.5	53.0	70.6	10.1	71.9	43.1	73.1	74.4
Stage 2.1	-	69.5	53.0	70.6	10.1	71.9	43.1	73.1	74.4
Stage 2.2	-	70.7	53.0	72.0	10.1	73.4	43.1	73.1	74.5
Stage 3.1	-	82.0	58.3	81.1	8.1	81.5	42.3	67.8	88.7
Stage 3.2	-	82.0	58.3	81.1	8.1	81.5	42.2	67.9	88.7
Stage 4	-	82.0	58.3	81.1	8.1	81.5	42.3	67.9	89.0

Table 9 - Section-Wise Unmet Demands Reduction for the Maha Season

Unmet Demands Reduction (%)						
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Stage 1.1	-	64.7	Demands Satisfied	62.6	10.8	63.5
Stage 1.2	-	69.6		65.9	16.4	67.4
Stage 2.1	-	69.6		65.9	16.4	67.4
Stage 2.2	-	69.6		65.9	16.4	67.4
Stage 3.1	-	85.5		83.9	13.4	84.1
Stage 3.2	-	85.5		83.9	13.4	84.1
Stage 4	-	85.5		83.9	13.4	84.1

Since the unmet demands in the Yala season are higher than the unmet demands in the Maha season, the cropping patterns of 70% of paddy and 30% were introduced to the Yala season in Scenario 3 and it resulted in a reduction in the unmet demands by 59.1%. Therefore, the operational pattern can be improved by introducing 70% paddy and 30% OFCs in the Yala season.

In Scenario 4, the reduction in the unmet demands compared to Business-as-usual Scenario was 74.1% in the Yala season.

In Scenario 5, by increasing the Minipe anicut discharge by 15%, the unmet demands have been reduced by 9.1% in the Yala season and 11.5% in the Maha season.

The percentage reduction of unmet demand in Scenario 6 by advancing the sowing date by 2 weeks, introducing 70% paddy 30% OFCs, and increasing the Minipe anicut discharge by 15% in the Yala season, was 75.0%. Thus, Scenario 6, which reduces the unmet demands in the Yala season considerably, could be regarded as the optimum operational pattern for the Yala season. In this scenario, by advancing the sowing date by two weeks, the percentage reduction obtained in the Maha season is 79.9%.

Since the unmet demands in the Yala season are higher than the unmet demands in the Maha season, the command area for the Yala season was reduced by different percentages for the analysis.

In Scenario 7, by reducing the command area by 25% in the Yala season, the unmet demands have been reduced by 42.7%.

Further, the unmet demands have been reduced by 66.7% when the command area is

reduced by 40% in the Yala season in Scenario 8.

Since the unmet demands in Stages 3 and 4 are higher than the unmet demands in Stages 1 and 2, the command areas for Stages 3 and 4 have been reduced by a high percentage in Scenario 9. In that scenario, the percentage reduction of unmet demands obtained by reducing the command area by 40% in Stages 1 and 2 and 50% in Stages 3 and 4 in the Yala season was 74.2%. It could be observed that by reducing the command area as in Scenario 9, the unmet demand reduction in the Yala season is closer to the unmet demand reduction in Scenario 6, which offered the optimum operational pattern.

5. Conclusions

The study proposes an improved operational pattern for the Minipe Left Bank canal by a scenario-based analysis changing the cropping patterns, sowing dates, Minipe anicut discharges, and command area reductions. The scenario with the highest unmet demand could be considered as the optimum operational pattern.

Since the unmet demands have been mostly reduced in Scenario 6 in both Yala and Maha Seasons, advancing the sowing date by 2 weeks, introducing 70% paddy and 30% OFCs, and increasing the Minipe anicut discharge by 15% significantly improves the operational pattern.

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