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Optimal Management of Water Resources among the Various Users of Lower Kanakarayanaru River Basin, Northern Sri Lanka

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Abstract: Though potential water availability in the Kanakarayanaru ungauged river basin of Northern Sri Lanka is significant, many users experience water inadequacy due to suboptimal management and climate variability. According to literature reviews and prior studies in this region, there has been little discussion on workable strategies for managing water resources; hence, a comprehensive approach is required. This study aims to propose optimal water management strategies to minimize water inadequacy for multiple users in the Kanakarayanaru River basin. Computer-aided hydrological analysis tools such as the Soil Water Assessment Tool (SWAT) and Water Evaluation and Planning (WEAP) are predominantly used to assess the water availability in the region and share the water resources among multiple users. The SWAT simulated runoff values were in good agreement with the observed runoff for the period of 2018 to 2023 andoil Conservation Service Curve Number (NRCS-CN) method. The present study also evaluated the supply and demand of available water for the year 2023 and future scenarios (2024–2050) using WEAP for the application of optimal management strategies. The outcome of the WEAP simulation shows that there is no shortage of water for the reference Scenario. However, Scenario 1 predicts a notable increase in unmet water demand beyond 2033, due to increased water demand. Conversely, Scenario 2 exhibits no unmet water demand during the simulation time frame up to the year of 2040 due to the improved irrigation efficiency scenario. Also, Monthly Unmet demand was observed in both Scenarios 1 & 2 due to supply delivery issues. In the meantime, the introduction of demand management strategies significantly reduced the annual unmet water demand, highlighting the importance of efficient allocation and use of water resources.Our study provides a framework for policymakers and water-related institutions to sustainably address supply and demand imbalances for social, economic, and environmental benefits.

Keywords: Kanakarayanaru River Basin, Water Resources, Scenario, Strategies, Sectoral Demand

1. Introduction

1.1 Background

Despite being a dry zone, Northern Sri Lanka is rich in water resources, with 24 of the island's 103 river basins, including the largest, the Kanakarayanaru River Basin, harvesting annually 3460MCM water.[1]. When Northern Province had a predominantly agriculture-dependent rural economy, with a few industries and only a limited population, integrated water resources management was not a pressing need. However, this picture has been changing over the past few decades. The water demand in the Northern Province is rapidly increasing. In 2019, the water requirement was 2,137 MCM [2]. In the meantime, in certain regions, the demand is exceeding sustainable supply levels. For instance, in Kilinochchi district, the water demand is 527 MCM, with a potential available water supply of 753 MCM, indicating excess of water where demand is relatively low. Conversely, in Jaffna, the demand is 343 MCM, while the potential available water is only 462 MCM, however, water demand cannot be met due to the depletion and degradation of the groundwater, owing to the unregulated exploitation in Jaffna district. [3].

Presently, the main issue facing the water sector is meeting the growing sectoral water demands (domestic, irrigation, and industrial needs) while protecting the agriculture sector, which is the main livelihood of the province, due to mainly population increase. Owing to inadequate allocation and usage of water resources, as well as periodic climate disturbances like floods and droughts, the

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region is confronted with significant problems in achieving effective water management.

In conclusion, despite potential water availability, many users experience inadequate water in this region. This scenario is no exception to the Kanakarayanaru River Basin, which is the study area of this research.

The Kanakarayanaru River Basin has no river flow data due to ungauged basins and there have been no advanced optimalwater resource management approaches to address the water adequacy to the growing sectoral demand; accordingly, this research study has been taken up. Accordingly, the overall objective of this research is to propose optimal water management strategies to minimize water inadequacy for various users in an ungauged basin. The study aims to develop optimal solutions for managing water resources in regions where water resource flow is not regularly managed, ensuring sustainable and equitable water distribution among various stakeholders.

To achieve this overall objective, the research focuses on three specific objectives: assessing the water resources in the study area to understand their availability and variability; evaluating the demand and supply for various users, including agricultural, domestic, and industrial needs; and recommending an optimal management strategy that balances demand and supply to ensure efficient and sustainable water use across different sectors.

1.2 Study Area

The Kanakarayanaru River Basin in Northern Sri Lanka covers 906 square kilometers and stretches 86 kilometers through Vavuniya, Mullaitivu, and Kilinochchi districts[1].

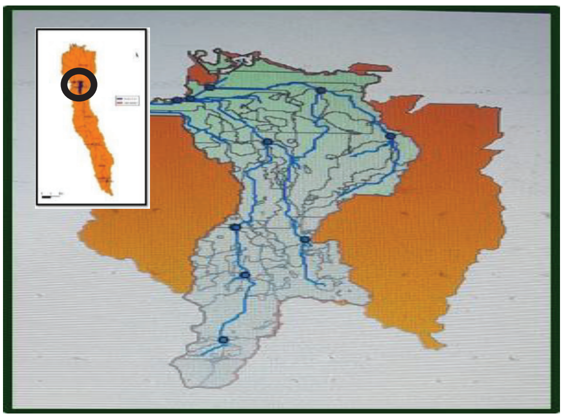

Figure 1 - Study Area

The average annual rainfall is 1380 mm, including at the rainfall gauge station in Iranaimadu. The average temperature is 26°C, with a maximum of 38°C and a minimum of 12°C. The area has many closely connected waterbodies. [4]. The soil complex is characterized by dominantly reddish Brown Earth and Low Humic Gley Soils, Red Yellow Latosols, and Solodized Solonetz and Solonohaks flat terrain[5].

Due to the recent augmentation of Iranamadu, inflow from the upper catchment has exhausted considerably. Water potential in the lower reaches of Kanakarayanaru below the Iranamdu tank should be considered for water resource management for the immediate need for irrigation, water supply, and other subsidiary needs. The lower part of the Kanakarayanaru River Basin, along with the command area of Iranamadu Dam, has been chosen as the study area for this research. The study area covers 154.88sq.km in Karachchi and Kandawalai DS divisions in Kilinochchi.

2. Literature Review

2.1. Optimal Water Management Approaches

The pre-literature highlights the need for an integrated approach to water resource management that involves various sectors, stakeholder engagement, and equitable policy frameworks to optimize water allocation amid limited resources and growing sectoral demands. According to findings presented at the International Conference on Northern Water (ICNW), the potential water availability in the Northern Province is considered fairly sufficient to meet its needs. However, for optimum utilization, the province's water resources must be developed in an integrated manner, efficiently managed, and equitably allocated among stakeholders. This integrated approach is vital for satisfying societal needs while also conserving the environment[3].

To address the critical issue of drinking water supply in the Northern Province, particularly in the Jaffna District, extensive hydrological studies have been conducted. Notably, the "Feasibility Study on Water Resources Development within Northern Province for Supply of Irrigation and Drinking Water Requirements" by the Mahaweli Consultancy Bureau (Pvt) Ltd[6], indicates significant water yield potential in the region. The study found that the total inflow in the catchment areas downstream of Iranamadu is approximately 84.3 million cubic meters (MCM) annually, predominantly during the monsoon period. This finding underscores the high potential to meet water requirements across various sectors throughout the year[6].

While substantial research has been conducted on water resources in the Northern Province[7][4], there is a notable gap in specific studies focusing on the Kanakarayanaru area. This gap highlights the need for a sustainable approach to water management in Kanakarayanaru, which is the foundation of this research. The study aims to propose effective and equitable water allocation strategies tailored to the unique challenges and conditions of this area.

2.2. Application of Computer-Aided Hydrological Tools (SWAT & WEAP)

According to the literature, traditional methods for hydrological and water allocation modeling are not fully appropriate for addressing the complex issues in the study area. Therefore, modern tools such as the Water Evaluation and Planning System (WEAP), Soil and Water Assessment Tool (SWAT[8], Geographic Information System (GIS) are considered more suitable for developing optimal water management strategies[9]. These tools provide a comprehensive framework for assessing water resource availability, evaluating different management scenarios, and ensuring sustainable water allocation. SWAT is chosen over the other models like HEC-HMS because it offers a more comprehensive approach to watershed management systems.

2.2.1 SWAT

Estimating direct runoff for ungauged river basins using traditional hydrological methods is a tedious and time-consuming process[10].Rainfall-generated runoff is influenced by the intensity, duration, and distribution of rainfall. Additionally, factors such as soil type, vegetation, and land use patterns significantly impact the runoff behaviour. Recent advances in technologies have led to computer-based hydrologic models for these purposes[11]. Any conceptual models or black box models seem to be not ideal for basin-scale studies. The distributed or semi-distributed models provide a perfect tool though they require additional data[12]. With the introduction of remote sensing techniques and Geographic Information Systems (GIS) interface, input files can be created for these distributed models[4]. One such model available for water resources professionals is the Soil and Water Assessment Tool (SWAT) developed by the United States Department of Agriculture[11]. SWAT is currently one of the world's leading spatially distributed hydrological models to predict runoff, erosion, sediment, and nutrient transport from agricultural watersheds under different management practices. Particularly, this model has widely been used as an effective tool for estimating runoff quantities[10]. In India, it was applied in different basins and found to be reasonably satisfactory[13]. As such, ArcSWAT2012 is used as the main software in the present study.

SWAT uses the water balance equation to simulate the movement and distribution of water within a watershed[14]. The water balance equation is fundamental for understanding how water inputs, outputs, and storage change over time within the model. Here's a general overview of how the water balance is formulated in SWAT:

$$P = Q + AET + GW + DS \qquad \ldots(1)$$

P is precipitation; Q is runoff;
AET is actual evapotranspiration;
GW is exchanged with groundwater aquifer; and DS is a change in soil storage.

In order to confirm satisfaction with the developed SWAT Model, the Soil Conservation Service Curve Number (NRCS-CN) method is used to compare the runoff coefficient obtained from SWAT Simulation[15], [16]. According to the theoretical documentation, SWAT uses as one of its methods to estimate runoff[17] Basically, the NRCS-CN method is widely used in hydrology to predict runoff by a given rainfall event based on the following equation:

$$Q=(P-l_a)^2 / ((P-l_a) +S) \qquad \ldots (2)$$

Q = runoff (in)
P = rainfall (in)
S = Potential Maximum retention after runoff begins
l_a = Initial losses

$$l_a = 0.2\,S$$

$$Q = (P-0.2S)^2/(P+0.8S)$$

$$S = (1000/CN) - 10$$

2.2.2 WEAP

WEAP is an effective instrument for managing water resources, and it plays several crucial functions in our analysis. Understanding the present and future demands of many sectors, including home usage, industry, and agriculture, depends on the correct estimation of water demands, which is made possible by WEAP. Finally, the ability to generate scenarios is critical for the construction of models since it enables us to examine multiple possible futures and evaluate the effects of various interventions and policies. To sum up, WEAP plays a crucial role in our analytical framework, facilitating thorough analysis and well-informed decision-making on the management of water resources.

3. Materials and Methods

3.1. Research Process

Figure 2 illustrates the research methodology for the study on optimal water resource management, integrating SWAT and WEAP models. The diagram details the entire process from data input and SWAT model validation to scenario analysis and formulation of optimal management strategies.

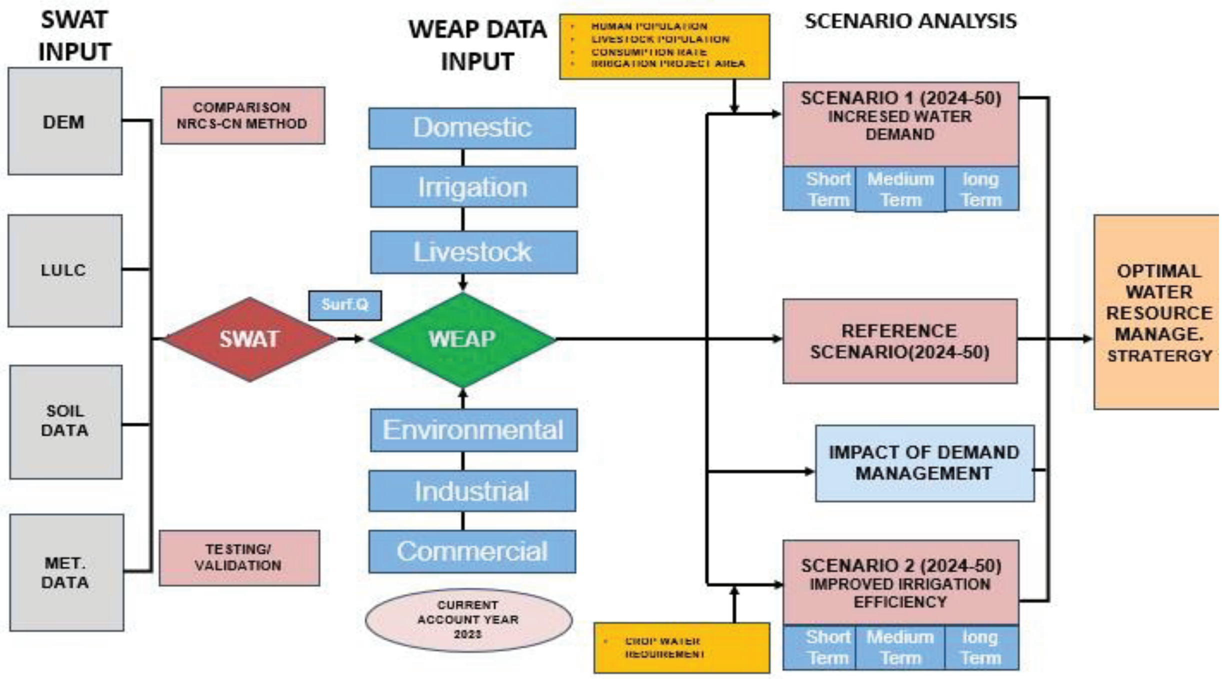

Figure 2 - Research Process Flow Chart

Initial SWAT input data collection includes topographical data (DEM from STRM), land use maps, soil properties, and climatic data. This data is gathered from various sources, including weather stations, satellite imagery, and field surveys.

The collected data is used to set up and configure the SWAT model, which simulates watershed (study area at the proposed reservoir near Elephant Pass Lagoon) processes to estimate surface runoff and other hydrological variables. Simulated Surface Runoff is considered as a monthly inflow / water potential / supply source for the demand of various users.

Then apply the NRCS-CN method to estimate surface runoff independently. These estimated values will be used to compare with the SWAT model outputs to evaluate the model's performance and validity, particularly in the absence of river flow data as it is an ungauged basin[17].

The SWAT model is validated from 2019-2023 using observed data from the new river gauge established in Olumadu with the study area in Iranamadu Dam. Application of the Modelled SWAT Hydrological tool for this ungauged basin is used to estimate runoff coefficient and surface runoff in this study. In the meantime, in order to obtain average values for these parameters, SWAT model simulated case scenarios were developed for different weather data combinations without changing the other input data (DEM, land use maps, soil properties,). Validation assesses the model's performance and reliability in predicting hydrological responses. Kanakarayanaru River Basin is an ungauged basin without any river discharge measurement until studies commenced. However, different approaches have been used in this study to ensure the model performances, such as the area above the study area in Olumadu, is used to develop and validate the model. Also, NRCS-CN method is used to validate the model. Accordingly, this model was tested during the real-time extreme hydrometeorological event that happened in 2018 December. Similarly, this model was validated from 2019 to 2023 during the monsoon period (now gauged from the year 2019) using flow measured at Iranamadu and Olumadu in the Basin.

The validated SWAT model is applied to the study area to estimate surface runoff and other hydrological outputs. These estimates serve as input data for the subsequent WEAP model.

Surface runoff data from the SWAT model, along with demand-side data such as irrigation, domestic, livestock, environmental, commercial, and industrial water requirements, are incorporated into the WEAP model. Then sectoral demand for Domestic, Irrigation, Livestock, Commercial, Industrial, and Environment was calculated based on the data obtained from the relevant institutions for the current account year of 2023. Various management scenarios are developed to explore different strategies in order tounderstand what happens to the future water demands using the WEAP model for the modelling period 2024 to 2050. These scenarios include:

- Reference or Baseline Scenario: This scenario assumes that current water usage and availability trends continue without significant changes. However, Human and Animal Population changes are considered.
- Scenario 1: This scenario primarily focuses on the increased water demand caused by changes in human and livestock populations, along with a rise in consumption rates and the expansion of irrigation projects. To achieve more accurate results, the modelling periods were divided into short-term, medium-term, and long-term projections.
- Scenario Two; This scenario is mainly considered for Improved Irrigation Efficiency by reducing Crop water requirements in the Short Term, Medium Term, and Long Term in irrigation efficiency, which could reduce water usage.
- Demand Management Scenario: This scenario considers the impacts of a reduction in demand by imposing Demand Management practices.

Based on the results of the scenario analysis, optimal water management strategies are formulated. These strategies aim to balance water supply with demand, improve efficiency, and address potential challenges.

4. Results and Discussion

4.1 SWAT Final Output- Runoff Co-efficient and Surface Runoff

SWAT simulation for the different weather data is shown in Table 1.

Table 1 - SWAT Simulation for different weather data

S. No	Weather data combination	SWAT Output (Annual)				
		Ave. Annual Rainfall (mm)	Curve no	SUR. Q	Run off Coeff	Surface Runoff in MCM
1	PCP, TMP, WIND, HR, SOL	1625.4	73.98	338.12	20.8	236.3
2	PCP, TEM only	1625.4	73.98	351.00	21.6	214.1
3	PCP Only	1625.4	74.05	352.08	21.6	216.4
Average		**1625.4**	**74.0**	**347.07**	**21.3**	**222.2**

PCP – Precipitation
TMP – Temperature
HR – Related Humidity
SOL – Soil

As per the output of SWAT, the average runoff coefficient is 21.3 and the average surface runoff is 222.2 MCM.

4.2 Comparison of Runoff Coefficient

Using the above NRCS-CN equations, the annual runoff coefficients computed for 5 rainfall stations in close vicinity of the study area for the period 2011-2018 are shown in Table 2.

Referring to Tables 1and2, the average value for the runoff coefficient obtained using the NRCS-CN method is 20.84 whereas it is 21.3

from the SWAT simulation. The results show that SWAT results seem most realistic and the developed SWAT model works satisfactorily[17]. However, results evaluation cannot be done by just comparing direct results visually, which is not sufficient. So, it is tested and validated as below.

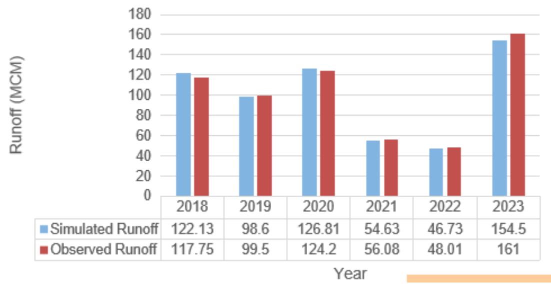

Figure - 3 Validation of Surface Runoff Observed and Simulated using SWAT

4.3 Testing/Validation of the Developed Model at Iranamadu

In the Iranamadu river gauge, simulated runoff received from SWAT output is mostly nearby observed runoff, which is calculated by real-time data collected from the Irrigation Department.

Surface runoff observed and simulated using SWAT at the newly established River Gauge at Olumadu is shown in the Figure 4.

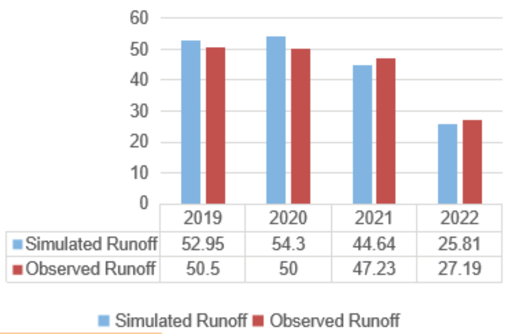

Figure 4 - Surface Runoff Observed and Simulated using SWAT

In the same way, a river gauge is established at Olumadu, for monitoring purposes by the Irrigation Department, and it is continuously monitored and the data was used to validate the output of SWAT, in the same way it is realistic with the output.

Referring to Figures 3 and 4, the simulated surface runoff/ runoff coefficient is approximately the same during the period of the model run at both locations. Comparing both methods seems acceptable, with a Coefficient of Correlation R2=0.992.

Table 2 - Runoff Coefficients using NRCS-CN method.

Year	Runoff Coefficient Using NRCS-CN-Method				
	Irana madu	Man kula m	Vavun iya	Vavuni kulam	MIK
2011	23.10	16.22	19.96	22.77	19.08
2012	29.47	27.24	24.91	28.67	34.53
2013	10.46	15.63	8.07	8.74	16.86
2014	25.95	18.53	22.09	20.16	22.09
2015	14.00	15.79	18.88	10.33	15.48
2016	44.08	26.65	23.00	3.03	25.09
2017	12.63	7.09	13.81	13.67	12.29
2018	23.27	20.64	15.60	14.95	21.28
Avg	**24.91**	**18.47**	**18.29**	**15.29**	**20.84**

4.4 Application of SWAT to Study Area

By using the developed model, the total annual stream flow of the study area has been simulated. Accordingly, the catchment has a surface water availability of 119.383 MCM at the outlet of the catchment, from which all the demand sites abstract water to fulfill their demand. The peak flow in this river is occurring in October to December. The highest monthly average flow occurs in November and the lowest in June with values of 23.903 MCM and 0.208 MCM, respectively.

4.5 Sectoral Demand- Current Account Year/Base Year 2023

According to the data collected from relevant institutions, total water demand for all sectors such as Irrigation, Domestic Water supply, Livestock, Commercial, Institutional and Environmental demand in 2023 (base year/current account) was only 18.303 MCM. This result can be compared with WEAP for base year

4.6 WEAP Output -Base Year

The current account represents the basic definition of the water system as it currently exists. It is also assumed to be the starting or base year for all scenarios. Hence, it is important to look at the nature of the demand in the current account year as it is the base for all scenarios and future demands. The water demand and supply were modeled for the year 2023 by incorporating water requirements for the domestic, agriculture, and livestock sectors. It is noted that Environmental, Commercial, and Industrial demands were excluded from the WEAP modeling because they are considered factors of Inflow and Domestic water requirements. Therefore, the monthly average of available water in relation to demand was done using WEAP. As per the results, total of 6.162 MCM of water is required for three water sectors (domestic, livestock and agriculture) for the current account year. Accordingly, the water consumption in the current situation is around 5.16 % of the total surface water available in the study area, which is 119.383 MCM. From the total demand, 77.17 % is consumed by Irrigation, because of high demand for agriculture around the study area and the remaining 22.83 % is shared by domestic and Livestock usages.

4.7 Reference Scenario (2024-2050)-Projected Human and Animal Population

Reference scenarios represent the changes that are likely to occur in the future without any intervention or no new policy measures. Thus, this scenario examines what will happen to future water demands between 2024 and 2050 if no policy changes are implemented during this period.

However, human and animal populations have been considered even in this scenario. Accordingly, the projected human population with an annual growth rate of 0.28% and the Projected Livestock population with an annual growth rate of 3% were analyzed using WEAP.

It is observed that the annual total water requirement of agriculture from 2023-2050 to be constant while domestic and livestock water demands change with the changes of the human and livestock population number.

4.8 Reference Scenario (2024-2050)-AWD for Agriculture, Domestic and Livestock

The annual total water demands in 2023 are simulated by using WEAP to be 6.162 MCM of which 4.750 MCM is required by the agricultural sector. Agricultural water demand in the entire reference scenario is assumed to be constant. In 2050, the total annual water demand is estimated to be around 7.188 MCM of which 4.750 MCM is extracted by agriculture. It can be seen that agriculture requires much more water than any other water user. This is because in the study area farmers largely depend on irrigated agriculture instead of rainfed agriculture due to lack of rainfall throughout the year which can satisfy any crop growth.

4.9 Scenario 1 (2024-2050)-Increased Water Demand Scenario

In this scenario, the previous irrigation areas that are currently not under irrigation (abandoned) were assumed to be resumed and the other new areas to be established were considered based on the district agricultural strategic plan and Annual reports.

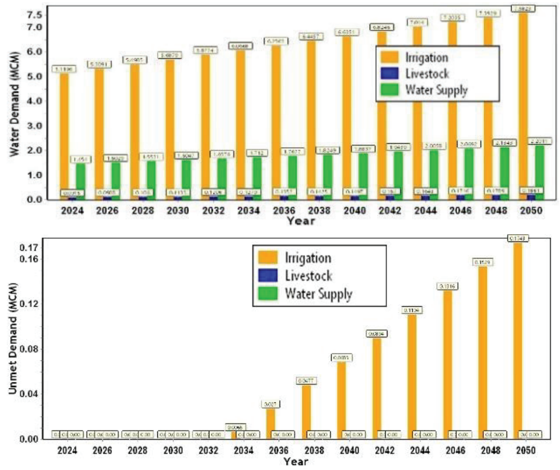

Figure 5 - Annual Water Demands and Unmet Demand for Agriculture, Domestic and Livestock in Scenario 1

The total water demand simulation reveals that the water demands in the Study area under this scenario reach up to 9.97 MCM excluding environmental, industrial and commercial, and institutional water demands in 2050 which would make up 8.35 % of the total river flows. Figures 5 illustrates the estimated rise in the overall water demand under Scenario 1 for the irrigation, domestic, and livestock sectors due to population growth, rising rates of consumption, and possible irrigation expansion. By 2050, water demand for agriculture is projected to be around 7.58 MCM, increasing from the current demand of around 4.750 MCM per year. This means the agricultural water demand would increase by around 1.5 times from now to 2050. As depicted from the result of Figure 5 above, Scenario 1 predicts a notable increase in unmet water demand beyond 2033. If present water management techniques continue, this points to a possible shortage of water. This demonstrates how important it is to have proactive water management plans.

4.10 Scenario 2 (2024-2050)-Improved Irrigation Efficiency Scenario

In this scenario, unlike Scenario 1, the crop water requirement is reduced by 10% for the short term (2024-2027), 20% for the mid-term (2028-2035) and 25% for the long term (2036-2050).

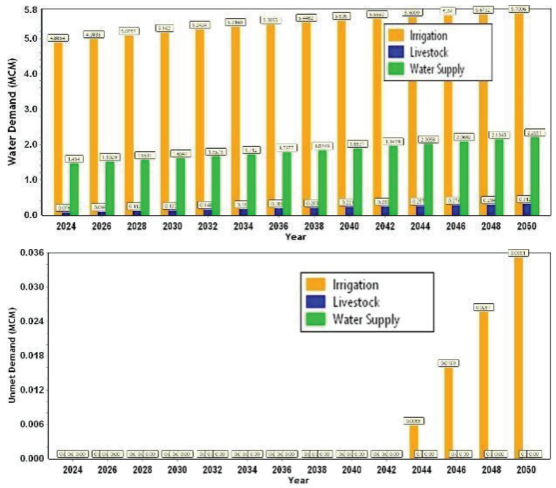

Figure 6 - Annual Water demands and Unmet demand for Agriculture, Domestic and Livestock in Scenario 2

Specially, to improve the Irrigation efficiency, conversely, Scenario 2 (Figure 6) exhibits no unmet water demand during the simulation timeframe up to year of 2040. This demonstrates how effective enhanced irrigation efficiency is at reducing water scarcity despite rising demand. The substantial increase in water sustainability brought about by Scenario 2 highlights its effectiveness in addressing water management challenges. It clearly reveals that despite rising water demands, water scarcity can be avoided by implementing these measures.

4.11 Comparison of Scenarios-Monthly Water Demand

Figure 7 shows the comparison among scenarios based on a monthly average water demand to understand the significance of water management strategies. Due to increase in improved efficiency, there is a reduction in Monthly Water Demand in Scenario 2. Comparing the three scenarios, for the study area detects an increase in demand of 38.67% in Scenario 1 and 14.19% in scenario 2 as compared to the reference scenario, increasing the gap between demand and supply, even though available stream flows were assumed to be constant throughout the modeling period.

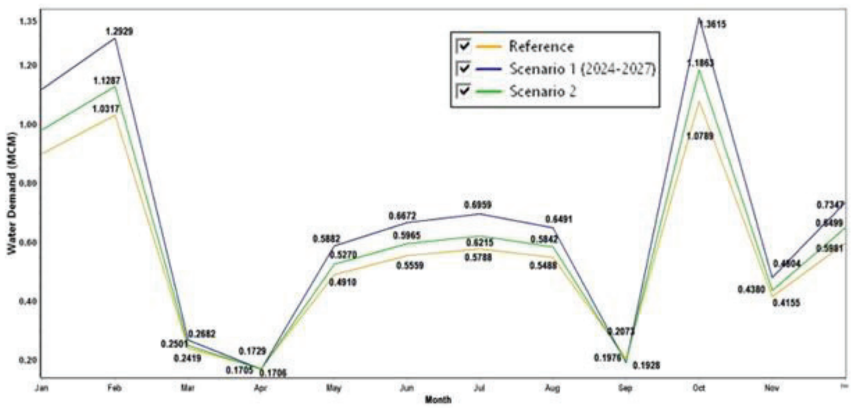

Figure 7 – Comparison of Scenarios-Monthly Water Demand

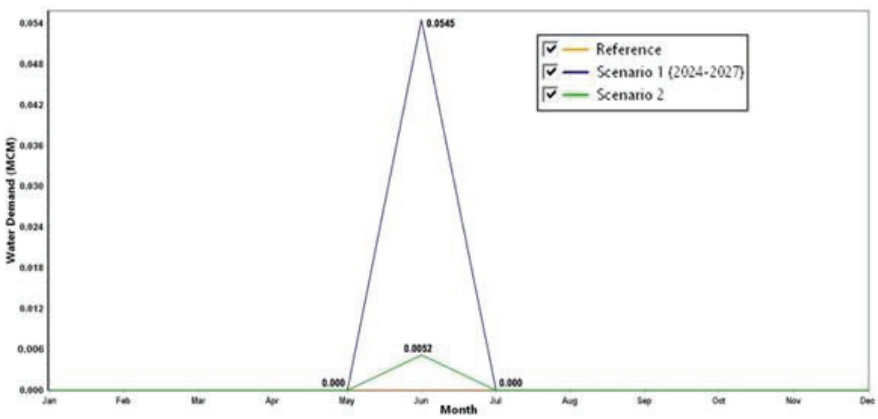

Figure 8 - Comparison of Scenarios – Monthly Unmet Demand

Monthly unmet demands for all three scenarios are portrayed in Figure 8. The result indicates that there is a scarcity of supply in all scenarios and unmet water demands were observed. The output of WEAP shows that during the Reference Scenario period, the water demand of all demand sites was fully satisfied. Of course, there is no wide absolute scarcity of water during this scenario. As indicated in Figure 8 above, the major water shortage was observed in Scenario 1 because of the increment of the irrigation area and the major demand site with unmet demand is the agricultural sector. The highest monthly unmet demand was observed to be about 0.054 MCM in June during Scenario 1. The second-largest unmet demand was simulated 0.005 MCM in May in this scenario. Even if irrigation water use efficiency has been improved in Scenario 2 to a smaller extent there is unmet demand in months May, June, and July. This shows that the existence of either supply delivery problem to a particular demand site or lack of enough storage structures rather than the water availability in the sub-basin.

4.12 Impact on Demand Management-Comparison of the Annual Unmet Demand

Unlike the other scenarios, this scenario applies a demand management approach to analyse the impact of a 10% or 20% reduction in total monthly demand on future unmet water demands.This has been done by assuming that irrigation management applied shifting from high water demanding methods of irrigation to medium and low water demanding irrigation methods due to a shortage of water.

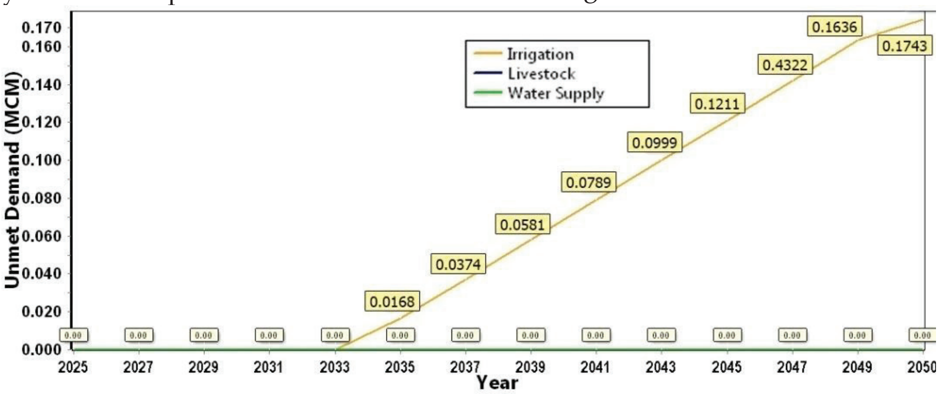

Figure 9 - Unmet Demand -Before Demand Management

Figure 9 shows the unmet demand in Scenario 1 due to irrigation requirement increasing. Therefore, it is recommended to go for a demand management strategy.

As mentioned above, the overall efficiency of demand management increases by 10%. This is evident in the graph, where the pattern of unmet demand shifts from 2033 to 2039. Additionally, a clear reduction in water requirement can be observed, with unmet demand decreasing from 0.174MCM to 0.093 MCM by 2050 after implementing demand management measures.

Continuously improving the efficiency of demand management results in a 20% increase. As a result, the pattern of unmet demand shifts further, extending to the end of 2050.

Demand started is shifted to the end of 2050. And also, the unmet demand will decrease to almost 0.01MCM by 2050.

This shows that drastic shift in unmet demand for Irrigation from 2033 to 2050 when a 20 % Reduction in total Monthly Demand; in the meantime, it further predicts a notable shift from 2047 to 2050.

5. Conclusions and Recommendations

5.1 Conclusion

In this research study, the SWAT Hydrological Computer-Aided tool was modeled to estimate inflow in the Ungauged Basin. Since there was no previous stream flow data, calibration could not be carried out. However, this developed model has been compared using the CN method,tested and validatedusing simulation. It clearly shows that the developed model for our study area works well for the assessment of water potential. Similarly, theWEAP model was established to evaluate the supply and demand of water for current account year (2023) in order to compare the sectoral demand derived from data obtained from relevant institution for the base year.

Further, three distinct scenarios were examined in the study, for the period (2024–2050): a reference, Scenario 1, and Scenario 2. In the meantime, overall, the study carried out with the WEAP model offered insightful information to the policy makers and water related institutions on the optimal water management strategies derived to resolve the Supply/Demand imbalances in a sustainable manner for social, economic, and environmental benefits by introducing Improved Irrigation Efficiency (Scenario2), Water Demand management techniques (Scenario -Specific) and propose appropriate storage structures and delivery systems.

5.2 Recommendations

Based on the results from the study, several recommendations can be set as is seen below. Feasibility studies on water infrastructure like dams, and weirs, and improving water-use technology should be developed to maximize the available water and distribute water to all users equitably in the Kanakarayanaru basin. This task can be assigned to the Irrigation Department, Northern Province. Also, this study is limited only to surface water resources. More research on groundwater potential and its Quality Analysis shall be carried out by engaging researchers, the Water Resources Board, and the University of Jaffna. On top, a holistic approach to Integrated Water Resources management mechanisms needs to be improved and/or developed for coordination among different water users, and stakeholders.

Also, climate change has a significant impact on water resource management in this context too and therefore it should be considered in future studies. Further, more encouragement of public participation and local awareness of water issues should be implemented. In particular, water data and information, including results of water monitoring, should be accessible for locals to increase their knowledge and involvement in more effective water management.

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