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Study on the Surface Water Allocation for Domestic, Agricultural and Hydropower for Myogyi Dam in Myanmar

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Abstract

This study presents surface water allocation for domestic, agricultural, and hydropower sectors in the Kyaukse District of Myanmar, focusing on the Myogyi Dam as the primary water source. Myogyi Dam is constructed across the flow of Zawgyi river and divided into four canals such as Ngabyaung Canal, Thindwe Canal, Minye Canal and Zeedaw Canal. As domestic water distribution network, Zawgyi river is connected to Kyaukse township. Utilizing the CROPWAT 8.0 and WEAP models, the research analyzes water demand, unmet demand, and site coverage from the year 2024 to the year 2054. Crop water requirements are estimated using long-term meteorological data and local crop parameters and WEAP simulations evaluate allocation efficiency across interconnected demand sites. According to the results of reference scenarios, the domestic supply zone and most irrigated areas are able to meet their respective water demands. However, the Ngabyaung irrigated area face a significant shortfall, requiring an additional 6900 million gallons to fulfill its demand. While all other areas achieve full demand site coverage, Ngabyaung lag behind with only 25% coverage. The total unmet demand of hydropower is approximately 35,000 megawatt-hours, and the demand site coverage remains at 100% throughout the year, except during the months of November and December.

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A. Introduction

Water allocation is a critical aspect of integrated water resources management, especially in basins where surface water must satisfy diverse and often competing demands. Effective water allocation strategies must account for multiple water use sectors including domestic consumption, agricultural irrigation, and hydropower generation while responding to the inherent variability in hydrological inflows and future water requirements driven by socio-economic development and climate change [1]. The challenge is further compounded by increasing population growth, rapid agricultural expansion, and the rising need for sustainable energy. Hence, ensuring a fair and efficient allocation of limited water resources has become a priority for water managers and policy makers around the world [3]. In Myanmar, reservoir projects play a key role in regulating surface water availability and supporting regional development. The Myogyi Dam, constructed on the Zawgyi River in Kyaukse District, is one of the most significant multipurpose reservoirs, serving as a major water source for domestic supplies, irrigation schemes, and hydropower production. However, the demands placed on the reservoir's water resources continue to grow due to ongoing rural and urban expansion, agricultural intensification, and increasing energy demand. This has led to heightened pressure on water allocation decisions, especially during the dry season, when water scarcity is most acute [5]. This study addresses these challenges through a comparative assessment of surface water allocation for the Myogyi Dam using the Water Evaluation and Planning (WEAP) model. By simulating water demand and reservoir operation under various scenarios, the research explores trade-offs and evaluates alternative water allocation policies that aim to improve the efficiency and equity of water distribution. The findings highlight the potential for more sustainable reservoir management that balances the water requirements of domestic, agricultural, and hydropower sectors under existing and future conditions [8]. Ultimately, this comparative study provides insights into the current water allocation practices for the Myogyi Dam and identifies areas for improving water use efficiency. The results will support decision-makers and stakeholders in making informed policy choices that help to enhance water security, promote socio-economic development, and ensure the long-term sustainability of water resources in the Zawgyi River basin [4].

B. Research Method

Study Area

Kyaukse is located in the central region of Myanmar between 20˚ 26' 0" & 22˚ 2' 0" north latitude and 95˚ 97' 0"& 96˚ 58' 0" east longitude. The city has an estimated population of four lakhs and the district of Mandalay Region. The study area is about 900 square miles. In Kyaukse district, two townships, Kyaukse and Sintkhaing are considered as study area. The domestic water supply system is managed by the engineering department of Kyaukse Township Development Affair under the supervision of Mandalay Regional Development Affair. Presently, piped domestic water supply is being provided to eleven wards in Kyaukse and is distributed by three sub-water sources, Zawgyi water supply, Zeetaw water supply and Minye water supply. Around Kyaukse area, most of the water supply is controlled by the Myogyi multipurpose reservoir and used for irrigation, hydropower and domestic purposes. Most of irrigated areas are located downstream of the Myogyi reservoir. This reservoir is constructed across the flow of Zawgyi river and divided into four canals such as Ngabyaung Canal, Thindwe Canal, Minye Canal and Zeedaw Canal. Myogyi hydropower plant is an integral part of the irrigation and domestic supply utilizing the surface water of the Zawgyi River by construction of a storage dam and related facilities. The design capacity of the hydropower station is 15 MW x 2 units of turbines. As the irrigation supply is the main purpose of the reservoir, the outflow from hydropower plant is used for irrigation and domestic purposes by Ngabyaung Canal, Thindwe Canal, Minye Canal and Zeedaw Canal. The location of the study area is shown in figure 1.

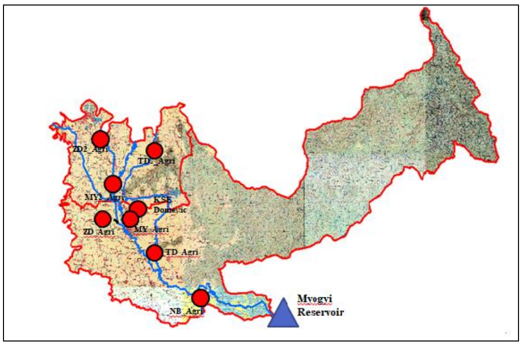

Figure 1. Location Map of Study Area

CROPWAT 8.0 Model Descriptions

CROPWAT 8.0 is a computer-based decision-support tool developed by the Food and Agriculture Organization (FAO) for calculating crop water requirements and simulating irrigation water needs under varying climate and management conditions [9]. The model is grounded in the FAO Penman-Monteith equation, which estimates reference evapotranspiration (ETo) using meteorological inputs such as temperature, humidity, wind speed, and solar radiation. Crop coefficients (Kc), which reflect crop-specific water uptake patterns at different growth stages, are then applied to calculate crop evapotranspiration under standard conditions (ETc). By employing CROPWAT 8.0, this study estimated the irrigation water requirements for major crops cultivated in the Kyaukse and Sintkhaing irrigation schemes. Input data included regional climate data, soil characteristics, crop calendars, and cropping patterns of the region. The model enabled the computation of crop-specific water deficits and effective rainfall, which were then aggregated into seasonal irrigation demand profiles [9].

Data Entry in CROPWAT 8.0 Model

In this study, 20-years (2005-2024) recorded local meteorological data (temperature, wind speed, humidity and sunshine) for Kyaukse and Sintkhaing meteorological station are used to calculate reference evapotranspiration (ETo). The calculated results of reference evapotranspiration (ETo) are shown in table 1 and 2.

Table 1. Reference Evapotranspiration (ETo) (Kyaukse Station)

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	13.9	30.3	73	23	8.6	16.9	2.67
February	15.7	33.6	62	27	8.5	18.7	3.21
March	20.6	36.9	55	39	8.1	20.3	4.08
April	25.2	38.5	59	58	8	21.5	5.02
May	25.9	37.1	67	54	7.6	21.4	5.02
June	26.1	35.5	72	85	6.3	19.4	4.73
July	25.9	35.2	73	77	5.1	17.5	4.29
August	25.5	34.4	79	54	4.8	16.8	3.89
September	25.4	34.4	78	31	5.2	16.4	3.67
October	24.2	33.6	79	23	6.9	17.1	3.59
November	20.7	32.2	75	19	8.2	16.7	3.14
December	16	30.2	75	27	7.5	14.9	2.56
Average	22.1	34.3	71	43	7.1	18.1	3.82

Table 2. Reference Evapotranspiration (ETo) (Sintkhaing Station)

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	12.8	28.9	73	18	8.6	16.8	2.53
February	13.2	32.1	62	24	8.5	18.7	3.04
March	18.9	35.1	55	37	8.1	20.2	3.89
April	24.1	36.6	59	57	8.0	21.5	4.82
May	25.1	35.7	67	54	7.6	21.4	4.90
June	24.7	33.5	71	83	6.3	19.4	4.56
July	24.9	33.4	73	76	5.1	17.5	4.15
August	24.0	32.9	79	49	4.8	16.8	3.74
September	25.0	32.7	78	30	5.2	16.4	3.58
October	22.5	31.2	78	23	6.9	17.0	3.40
November	19.6	30.3	75	17	8.2	16.7	2.98
December	14.2	28.1	75	24	7.5	14.9	2.38
Average	20.8	32.5	70	41	7.1	18.1	3.67

According to the CROPWAT 8.0 model, it was observed that the reference evapotranspiration (ET0) is the highest in the month of May which is due to the highest temperature and the minimum ET0 is in the month of December. The annual average reference evapotranspiration of Kyaukse township is 3.82 mm/day and Sintkhaing township is 3.67 mm/day. In this study, rainfall data based from 2005 to 2024 at Kyaukse station and Sintkhaing station are used. Effective rainfall data are calculated by using the fixed percentage of rainfall formulae because FAO suggested to select the option "Fixed percentage" and 80% of actual rain is affected for area in which most of the rainfall values are below 100 mm/month. The calculated results for effective rainfall are shown in table 3.

Table 3. Effective Rainfall (Kyaukse & Sintkhaing Station)

Month	Rain (mm) (Kyaukse Station)	Eff rain (mm) (Kyaukse Station)	Rain (mm) (Sintkhaing Station)	Eff rain (mm) (Sintkhaing Station)
January	8.6	6.9	8.4	8.3
February	1.3	1	0.7	0.7
March	6.7	5.4	9.1	9.0
April	52.6	42.1	53.6	49.0
May	135.1	108.1	162.4	120.2
June	68.7	55	74.0	65.2
July	56.1	44.9	63.5	57.0
August	114.2	91.4	127.6	101.5
September	148	118.4	169.3	123.4
October	206.2	165	212.9	140.4
November	35.3	28.2	38.9	36.5
December	6.3	5	5.7	5.6
Total	839.1	671.3	926.1	716.9

Several crops types and patterns are cultivated in Zawgyi irrigated area. The cultivated crop types are summer paddy, monsoon paddy, sesame, sunflower, green gram, cotton, groundnut and beam. In this study, Kyaukse district including Ngabyaung, Thindwae, Minye and Zeedaw irrigated areas is considered under Zawgyi irrigated area. In CROPWAT 8.0 model, crop characteristics such as length of crop growth stages, rooting depth, critical depletion, yield response factor and crop height at initial, development, mid-season and last-season stages and the crop coefficient Kc are required to input to calculate actual crop evapotranspiration and net irrigation requirement. Among the crop characteristics, length of crop growth stages, rooting depth and crop height at initial, development, mid-season and last-season stages data are taken from Agricultural Department. Critical depletion and yield response factor are taken from FAO publications of the Irrigation and Drainage series No. 33 and No. 56. Crop coefficient Kc is influenced mainly by the specific characteristics of the crop, including its stage of growth, wind speed, relative humidity and rainfall. The total net irrigation water requirement are calculated using CROPWAT 8.0 model as shown in table 4.

Table 4. Total Net Irrigation Water Requirement (MG/month) (Kyaukse & Sintkhaing Station)

Month	Kyaukse township				Sintkhaing township		
	Ngabyaung	**Thindwae**	**Minye**	**Zeedaw**	**Thindwae**	**Minye**	**Zeedaw**
Jan	1544.63	451.35	554.3	50.33	140.23	390.2	1077.75
Feb	1730.9	505.77	621.13	56.44	181.03	503.9	1391.79
Mar	1558.07	455.33	559.17	50.85	175.36	488.13	1348.39
April	2835.08	828.45	1017.4	92.52	197.78	550.58	1520.9
May	145.21	42.44	52.12	4.74	11.51	32.03	88.5
June	1401.6	409.54	502.95	45.67	54.25	150.96	416.94
July	1725.98	504.33	619.36	56.25	99.42	276.65	764.09
Aug	919.83	268.8	330.12	30	51.08	142.2	392.83
Sept	52.26	15.28	18.77	1.72	0	0	0
Oct	0	0	0	0	0	0	0
Nov	619.54	181.08	222.39	20.23	60.58	168.53	465.56
Dec	799.02	233.51	286.77	26.04	82.10	228.28	630.62
Total	13332.12	3895.88	4784.48	434.79	1053.34	2931.46	8097.37

WEAP Model Descriptions

The Water Evaluation and Planning (WEAP) model is a robust, demand-driven water management software developed by the Stockholm Environment Institute for simulating water allocation across multiple sectors and analyzing policy interventions under different hydrological and socio-economic conditions [8]. WEAP integrates hydrological processes, water use data, and water policies into a flexible, user-defined framework for water balance modeling. Its core simulation engine is based on the principle of mass balance accounting, ensuring that all water entering the system (e.g., rainfall, inflows) and leaving the system (e.g., demand, losses, environmental flows) is accounted for in each time step. In this study, the WEAP model is applied to balance supply and demand across the Myogyi Reservoir and its supplied areas, including domestic water supplies for Kyaukse Township, irrigation water demands estimated using CROPWAT 8.0 for the Kyaukse and Sintkhaing irrigation areas, and hydropower production at the Myogyi hydropower plant. Input data comprised inflow time series, reservoir operation rules, and water demand estimates for the years 2015 to 2024. The model is calibrated and validated against historical data, allowing for the simulation of baseline and alternative water allocation scenarios under different demand and supply conditions [8].

Data Preparation and Entry in Current Accounts

To facilitate water allocation simulations for the study area, the setup of the time-step boundaries is completed first. The years 2024 series for the Myogyi reservoir are selected as the baseline reference period. These years establish the current status of water supply and demand in the study area, providing a foundation for subsequent model scenarios. The future scenarios extend to 2054 with the model running on a monthly time-step (12 time-steps per year), spanning from January to December of each year. Additionally, a georeferenced shape file of the area is prepared using QGIS software. In this study, supply source, Myogyi reservoir is considered as reservoir node. Under Myogyi reservoir, irrigated areas of Kyaukse and Sintkhaing township such as Ngabyaung, Thindwae, Minye and Zeedaw and Kyaukse domestic are defined as demand nodes. The data is input numerals directly in WEAP model and the output data are water demand, supplied delivered water, unmet demand and demand site coverage in domestic, aThe schematic map in WEAP model is illustrated in figure 2.

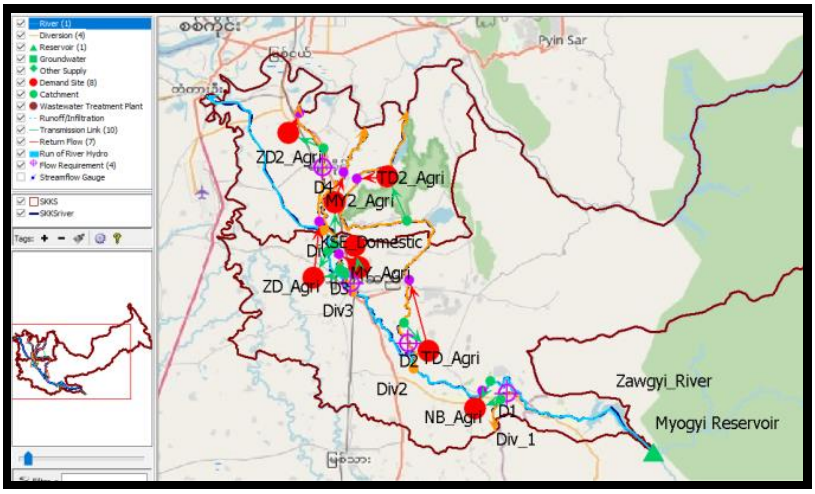

Figure2. Schematic Map in WEAP Model

Data Entry in Reservoir Nodes

In WEAP model, physical and operation data are needed for local reservoir node to simulate reservoir operation. The physical data include monthly inflows, storage capacity, initial storage, volume elevation curve, net evaporation, loss to groundwater and observed volume. The operation data needed to input are the volumes corresponding to top of conservation, top of buffer, top of inactive and buffer coefficient. In operation data of reservoir node, the volume of top of conservation represents the maximum volume of water in reservoir by leaving for flood control and it can be same with the total storage capacity. The volume of top of buffer can represent the reservoir release restricted zone, and if water amount is less than this level, the release will be constrained depending on the buffer coefficient. The volume of top of inactive zone means dead storage level in reservoir and the water in inactive zone is not available for water allocation. The buffer coefficient is assumed as 0.33 to reserve for the reservoir storage at the dry period and this means that one-third of the water below the top of buffer zone will release at each month.

Data Entry in Demand Nodes

Demand nodes can be lumped together into aggregate or individual demand sites for different water uses and the aggregation level is generally determined by the level of detail for water use data available and the level of detail for analysis. The various parameters which are fed to WEAP model are annual activity level, annual water use rate, monthly variation and consumption for demand nodes. Water consumption is calculated by multiplying the overall activity by a water use rate. Activity level are used in WEAP's demand analysis as population or household for Kyaukse and acres for agriculture areas. These data are taken from township development affair and irrigation department. The annual water use rate is the average annual water consumption per unit of activity. In this study, 30 gal per day is used as water use rate of people in Kyaukse city because of the city level demand. The monthly variation means monthly share of annual demand. Consumption for the demand sites are a fraction of their inflows, which represent the water loss from the system.

C. Result and Discussion

The current account reflects baseline conditions for the year 2024, encompassing the domestic, agricultural and hydropower sectors supplied by the Myogyi reservoir. This foundational setup provides a reference for evaluating water distribution and system performance under existing demands and infrastructure. Future scenarios, spanning the period 2025 to 2054, simulate sectoral behavior under under projected changes in demand, development, and climate influences. Upon inputting all necessary parameters into the Water Evaluation and Planning (WEAP) model, key metrics are computed for each sector across both timeframes. The model result of water demand and supply delivered in domestic and agricultural sector at reference scenarios are shown in figure 3 and 4.

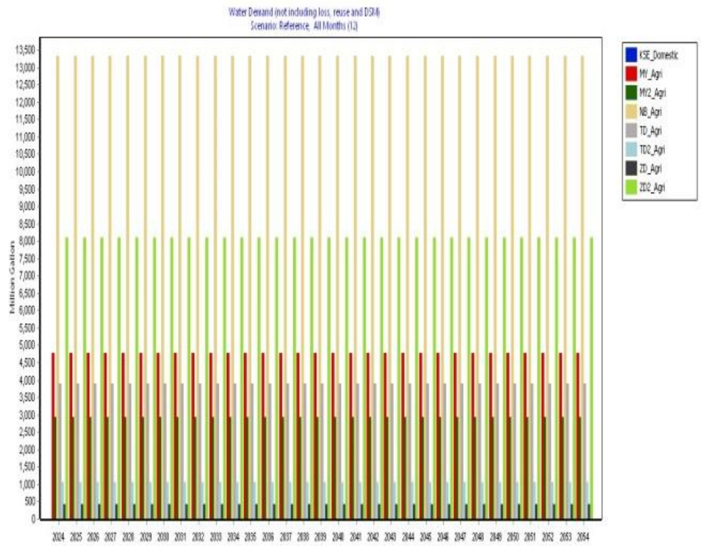

Figure 3. Water Demand of Domestic and Agricultural Sector at Reference Scenario

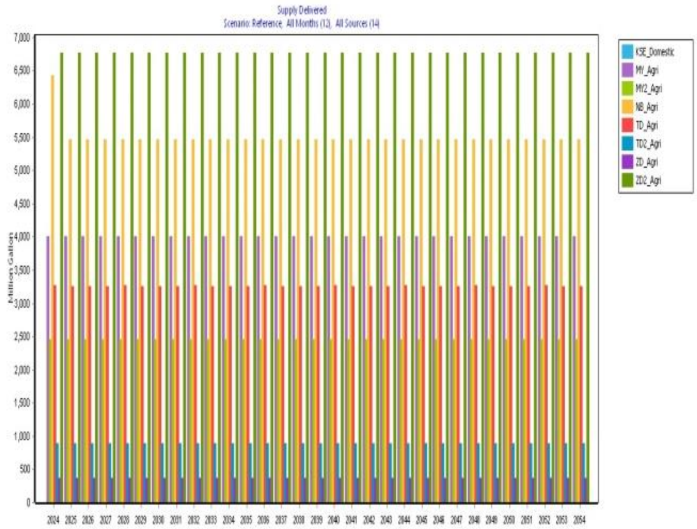

Figure 4. Supply Delivered of Domestic and Agricultural Sector at Reference Scenario

According to the model results, the domestic water demand in Kyaukse Township is 1.2 million gallons (MG), while the supply delivered was 1.0 MG. The Minye agricultural area has a water demand of 4784.5 MG, with 4006.5 MG delivered. In Ngabyaung agricultural area, the demand is 13,332.13 MG, but only 6432.3 MG is supplied. Thindwae agricultural area required 3895.9 MG, and 3261.5 MG is delivered. For Zeedaw agricultural area, the demand is 434.79 MG, and 364.3 MG is delivered. In Sintkhaing Township, the Minye agricultural area has a water demand of 2931.5 MG and receive 2457.6 MG. Thindwae agricultural area's demand is 1053.3 MG, with 890.9 MG delivered. Zeedaw agricultural area requires 8097.4 MG, and the delivered supply is 6773.7 MG. The model result of unmet demand and demand site coverage in domestic and agricultural sector at reference scenarios are shown in figure 5 and 6.

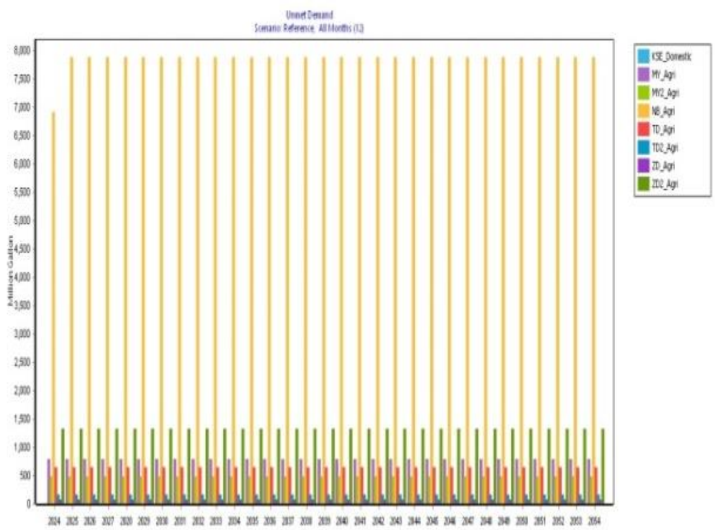

Figure 5. Unmet Demand of Domestic and Agricultural Sector at Reference Scenario

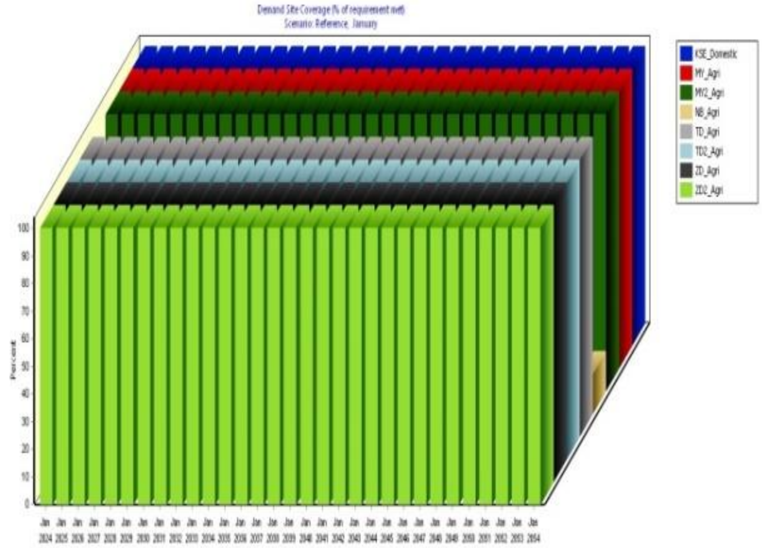

Figure 6. Demand Site Coverage of Domestic and Agricultural Sector at Reference Scenario

According to the model results shown in Figure 5 and 6, the domestic supply area and all irrigated areas nearly met their required water demand, except for the Ngabyaung irrigated area, which still required an additional about 6900 million gallons to meet its demand. All areas achieved 100% demand site coverage, except Ngabyaung, which had only 25% coverage. The model results of hydropower sector are shown in figure 7 to figure 10.

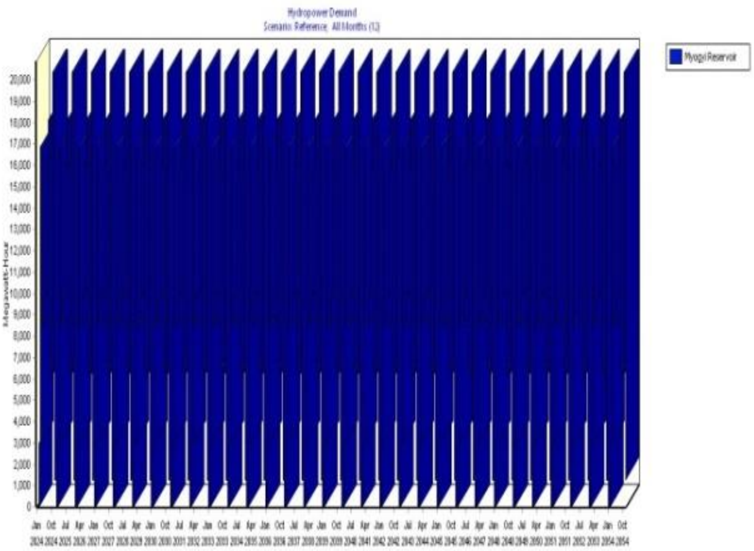

Figure 7. Water Demand (Energy) of Hydropower Sector at Reference Scenario

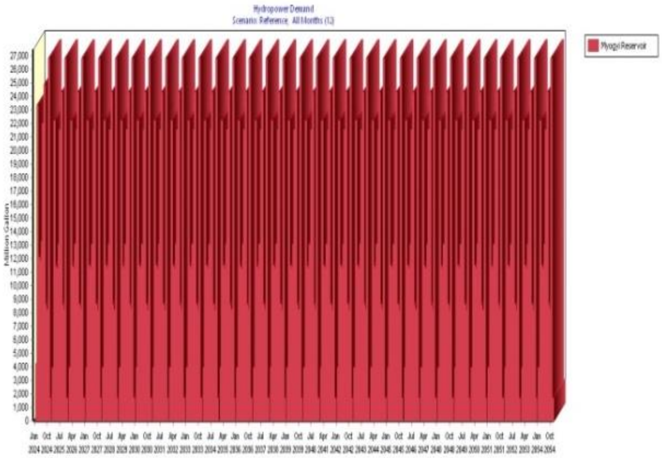

Figure 8. Water Demand (Flow) of Hydropower Sector at Reference Scenario

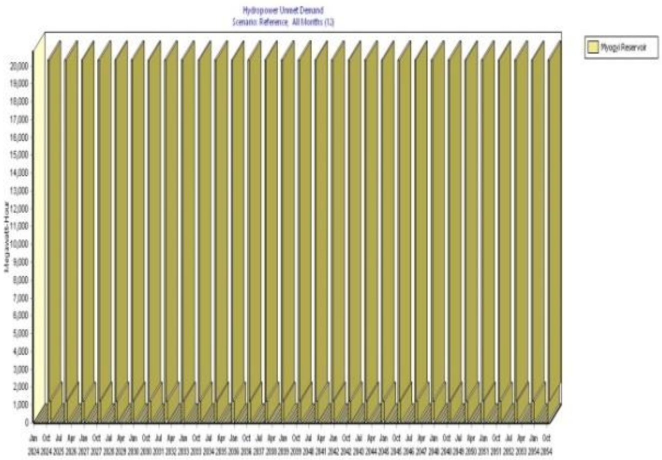

Figure 9. Unmet Demand of Hydropower Sector at Reference Scenario

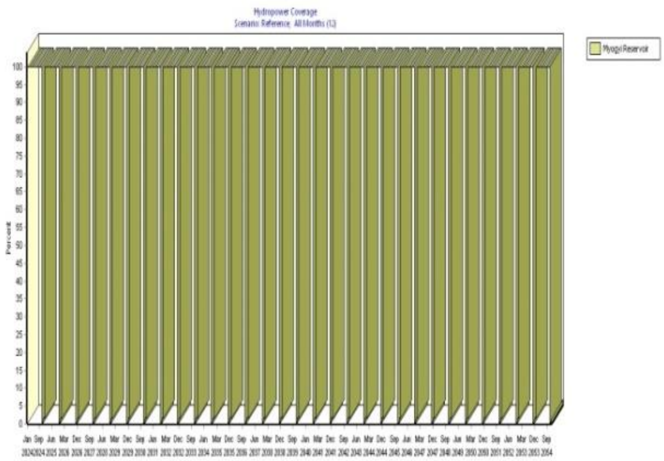

Figure 10. Demand Site Coverage of Hydropower Sector at Reference Scenario

The water demand (energy) of Myogyi hydropower sector is nearly 115000 megawatt-hour from 2024 to 2054. The water demand (flow) of Myogyi hydropower sector is nearly 150000 million gallons from 2024 to 2054. The unmet demand is nearly 35000 megawatt-hour and demand site coverage is 100% except November and December.

D. Conclusion

This study provides the amount of surface water allocation for the domestic, agricultural, and hydropower sectors of Myogyi Dam in Myanmar based on the current year 2024. Using CROPWAT and WEAP models, water demand and supply of study area are analyzed from the current year of 2024 to the reference scenarios 2054. The CROPWAT 8.0 model is applied to evaluate crop water requirements and the WEAP model effectively simulate water demand, supply delivered water, unmet demand and demand site coverage of domestic, agricultural and hydropower sectors of the study area. In domestic sector of Kyaukse township, the results demonstrate that the supply area for domestic water distribution met its water demand and reach 100% demand site coverage. In agricultural sectors of Ngabyaung, Thindwe, Minye and Zeedaw supplied by Myogyi Reservoir, the Ngabyaung irrigated area consistently face significant shortfalls, with unmet demands surpassing 6,000 million gallons in some scenarios although other three irrigated areas achieve high levels of demand site coverage. In the hydropower sector, Myogyi hydropower gets an unmet demand of about 35,000 megawatt-hours in November and December due to lower water availability in the dry season compared to the wet season. According to the model results, these findings highlight the urgent need to prioritize more efficient and equitable water allocation strategies, particularly for vulnerable irrigation zones, Ngabyaung irrigated area.

E. Acknowledgment

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