Utilization of Water Hyacinth to Reduce Sedimentation and Evapotranspiration in the Saguling Reservoir by PT PLN Indonesia Power Saguling POMU

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Abstract

Water hyacinth is an aquatic plant with wide leaves and fast growth in conditions of many nutrients, causing them to thrive in the waters of the Saguling Reservoir, West Bandung. Dead water hyacinth will settle to the bottom of the waters, resulting in an increase in reservoir sedimentation. In addition, the wide leaves and roots that absorb water make water hyacinth increase reservoir evapotranspiration, namely water loss due to evaporation and transpiration. Therefore, PT PLN Indonesia Power Saguling POMU initiated a program to utilize water hyacinth by local communities to process it into various products, such as handicrafts, fuel, animal feed, and compost. This study used secondary data analysis. Geospatial analysis through digitizing satellite imagery was used to measure the trend of water hyacinth numbers in the Saguling Reservoir with the utilization of water hyacinth. Then, a sedimentation analysis was carried out using utilized water hyacinth numbers approach, while evapotranspiration analysis was carried out using water hyacinth distribution numbers approach and meteorological data. The water hyacinth utilization program by PT PLN Indonesia Power Saguling POMU in the Saguling Reservoir from 2013 to July 2023 effectively reduced 8,382,572 kg of water hyacinths, reduced sediment in the reservoir by 829,875 kg, reduced sedimentation rate by 0.09%, and played a role in reducing the evapotranspiration of the reservoir, thus increasing the life of the reservoir.

Keywords: *Evapotranspiration, Saguling Reservoir, Sedimentation Water Hyacinth.*

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A. INTRODUCTION

Water hyacinth (*Eichornia crassipes*) is a floating aquatic plant that has thick and bubbled leaves (Rorong & Suryanto, 2010) and reproduces very quickly, making it considered a plant that can damage the aquatic environment (Stefhani et al., 2013). Water hyacinth can grow very fast, especially in waters that contain lots of nutrients. Within 7-10 days, water hyacinth can multiply to double. This fast growth rate causes water hyacinth turn into aquatic weeds (Reddy & DeLaune, 2008) and causes losses, including accelerating siltation of waters, reducing fish production, complicating irrigation canals, blocking boat traffic, becoming a media for spreading disease, and causing water evaporation by 3 to 7 times greater than water evaporation in open water (Fakultas Pertanian Untirta, 2016).

To increase the life of the reservoir, PT PLN Indonesia Power Saguling POMU makes several mitigation efforts to control the growth of water hyacinth in the reservoir by empowering the community around the reservoir to utilize water

hyacinth into various products. The water hyacinth utilization is expected to reduce the sedimentation of the Saguling Reservoir caused by the biomass of water hyacinth and reduce the water loss caused by the process of evapotranspiration of the reservoir, namely the evaporation of water from transpiration of water hyacinth leaves and evaporation of water from the reservoir itself.

The research location was in the Saguling Reservoir in West Bandung with an area of 3467.69 ha, at coordinates 6°54'51.07"S 107°22'4.80"E. The purpose of this study was to determine the effect of water hyacinth utilization on increasing the life of the reservoir. This research will discuss the amount of sedimentation and evapotranspiration in the reservoir reduced by the existence of water hyacinth utilization program by PT PLN Indonesia Power Saguling POMU.

B. LITERATURE REVIEW

1. Reservoir Sedimentation

Water hyacinth can cause sedimentation in reservoirs. Dead water hyacinth will settle to the bottom of the waters and decompose, which increases the acceleration of sedimentation in the waters (Worqlul et al., 2020). In addition, the reduced flow rate of water in the lake due to the clogging of water hyacinth causes sedimentation, deoxygenation, and a decrease in water quality. This increases water turbidity, reduces temperature variability, as well as causes water quality issues (Tobias et al., 2019). As a result, there is a decrease in the population of fish and other aquatic organisms due to decreased oxygen levels in the water and unfit conditions of water bodies. Conversely, the proliferation of disease vectors such as mosquitoes and snails will occur because plants are hosts for these various species (Honlah et al., 2019).

2. Reservoir Evapotranspiration

One of the causes of water reduction in the reservoir is a large evaporation (evapotranspiration) caused by the water hyacinth weed which has wide leaves and fast growth. Plants that experience a lot of transpiration require water that is taken up through the roots from the soil. Plants that grow in water such as lotus and water hyacinth suck water through their roots in the water. The combination of the two processes of loss of water through evaporation on the water surface and transpiration through the leaves is called evapotranspiration (Sri Harto, 1993). The presence of water hyacinth in lakes causes an increase in evapotranspiration, disrupts the hydrological balance of the water, and has the potential to disrupt local rainfall patterns (Tobias et al., 2019).

C. METHOD

The analysis of the effect of reservoir sedimentation and evapotranspiration was carried out using secondary data processing. The sedimentation was calculated using the number of water hyacinth utilized multiplied by the decomposition factor. As water hyacinth decomposes, it releases organic matter, which contributes to the

production of sediment. This sediment is an accumulation of dead plant matter and other organic matters in the water.

Sediment Production = (Water Hyacinth Utilized) x (Decomposition Factor)

The decomposition factor of water hyacinth can vary depending on environmental factors such as temperature, microbial activity, and water quality. The decomposition factor used was based on the literature for similar conditions. From the sediment production, the rate of sedimentation that can be retained by the sediment was determined by dividing the amount of sediment per year by the density. Then, the sedimentation rate from the water hyacinth utilization program was compared with the sedimentation rate of the Saguling Reservoir.

Then, the calculation of evapotranspiration was carried out using the following equation (Rashed, 2014).

$$ETc = ETo \times Kc$$

$$\text{Water Loss} = ETc \times \text{Surface Area} \times 0{,}001$$

ETc is crop evapotranspiration in mm/day, ETo is reference evapotranspiration in mm/day, and Kc is crop coefficient. Water loss is in m^3, and Surface Area is in m^2. The area of water hyacinth was taken based on the processing of satellite image data sourced from Sentinel Imagery 2. Climatological data such as temperature, air humidity, wind speed, and sunshine duration were taken from the Meteorology, Climatology and Geophysics Agency (BMKG) website. The data taken was 4 years as a research sample, namely in January in 2016, 2018, 2020, and 2023.

D. RESULT AND DISCUSSION

1. Water Hyacinth Utilization Program by PT PLN Indonesia Power Saguling POMU

The water hyacinth utilization program initiated by PT PLN Indonesia Power Saguling POMU involves nearly 100 communities around the Saguling Reservoir, especially in Mekarmukti Village and Cihampelas Village. The utilization of water hyacinth has produced several products, such as fuel, handicrafts, compost, and animal feed.

Water hyacinth utilization program as fuel for the Steam Power Plant (PLTU) began in 2019 and can transport 100 tons of wet water hyacinth per year. If converted, the need for water hyacinth is 274 kg/day.

The program for utilizing water hyacinth into woven handicrafts has been running since 2013. The estimated total need for wet water hyacinth is 32 kg per product. With 50 craftsmen in total where each of them can make at least 1 product per day, the total need for wet water hyacinth is 1,600 kg/day.

Water hyacinth utilization program as animal feed mixture began in 2021. The estimated amount of wet water hyacinth converted into animal feed mixture is 1,000 kg/day. After drying, the weight of the water hyacinth shrinks to 100 kg, then it is mixed with other animal feed constituents such as corn, rice bran, and concentrate, resulting in 300 kg of animal feed per day.

The program for utilizing water hyacinth to become compost started in 2021. The estimated amount of wet water hyacinth converted into compost is 500 kg/day. After drying and mixing the water hyacinth with soil, 200 kg of compost per day is obtained.

The following is the total utilization of water hyacinth.

Table 1. Total Utilization of Water Hyacinth per Day

No	Types of Utilization of Water Hyacinth	Year of Initiation	Water Hyacinth Utilized (kg/day)
1	Handicraft	2013	1,600
2	Steam Power Plant Fuel	2019	274
3	Animal Feed	2021	1,000
4	Compost	2021	500

Table 2. Total Utilization of Water Hyacinth

Year	Total Utilized Water Hyacinth (kg)				TOTAL (kg)
	Handicraft	Steam Power Plant Fuel	Animal Feed	Compost	
2013	584,000	-	-	-	**584,000**
2014	584,000	-	-	-	**584,000**
2015	584,000	-	-	-	**584,000**
2016	584,000	-	-	-	**584,000**
2017	584,000	-	-	-	**584,000**
2018	584,000	-	-	-	**584,000**
2019	584,000	100,010	-	-	**684,010**
2020	584,000	100,010	-	-	**684,010**
2021	584,000	100,010	365,000	182,500	**1,231,510**
2022	584,000	225,000	365,000	182,500	**1,356,500**
July 2023	340,667	262,500	212,917	106,458	**922,542**
TOTAL (kg)	**6,180,667**	**787,530**	**942,917**	**471,458**	**8,382,572**

Based on the total utilization of water hyacinth, the amount of wet water hyacinth used from 2013 to July 2023 was 8,382,572 kg or 8,382.5 tons. This number can decrease or increase along with the increase in production capacity and the amount of water hyacinth biomass in the reservoir.

2. Water Hyacinth Distribution Mapping in Saguling Reservoir

Landsat – 8 satellite imagery of the Saguling Reservoir was obtained from the website https://glovis.usgs.gov (Rosyidy et al., 2019). Images were acquired in January in 2016, 2018, 2020, and 2023. Satellite imagery was determined considering <50% cloud cover. Data processing was carried out to determine the boundaries and surface area of the reservoir. The stages of data processing consist of normalizing data, creating RGB composite images, sharpening composite images, describing the surface boundaries of lake water, and calculating the surface area of water and water hyacinth

(Sasaqi et al., 2019). The following is the satellite imagery processing result of water hyacinth distribution.

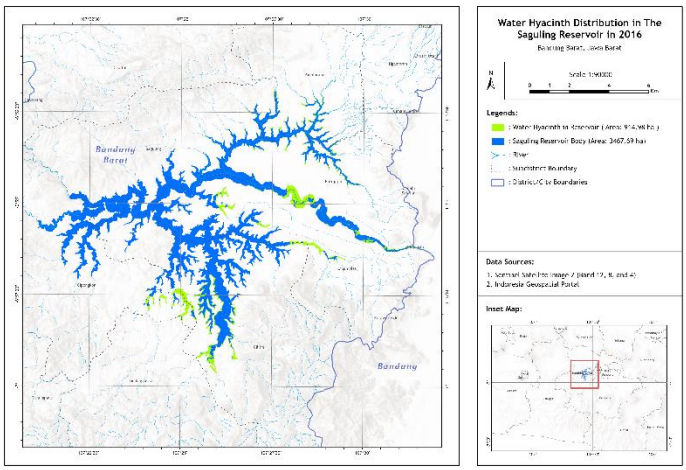

Figure 1. Water Hyacinth Distribution Map in the Saguling Reservoir in 2016

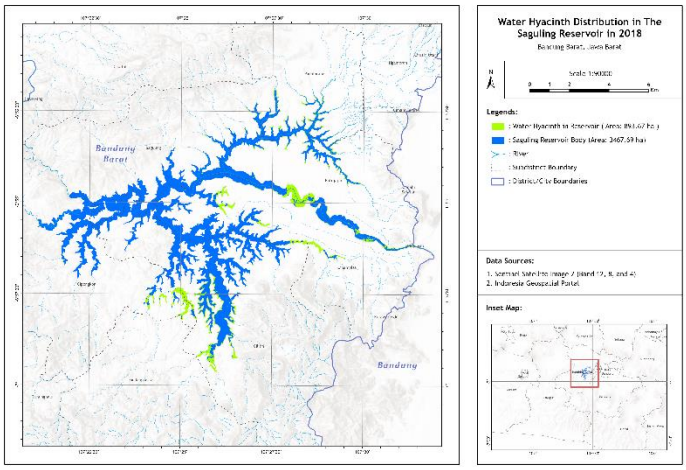

Figure 2. Water Hyacinth Distribution Map in the Saguling Reservoir in 2018

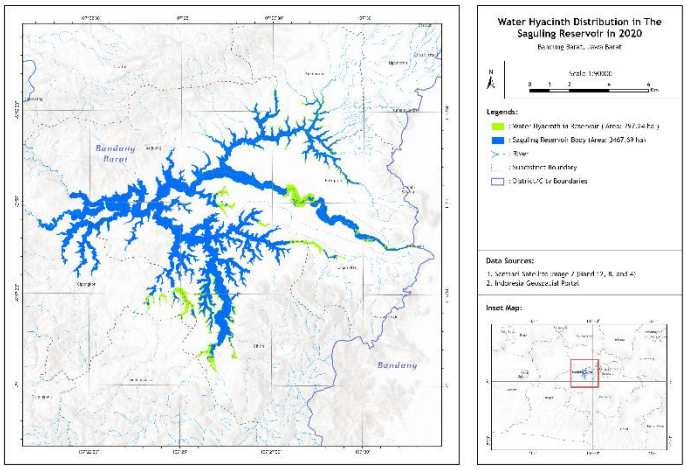

Figure 3. Water Hyacinth Distribution Map in the Saguling Reservoir in 2020

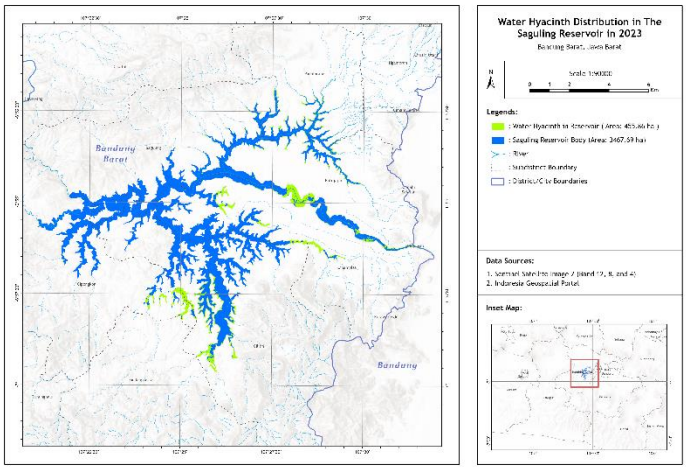

Figure 4. Water Hyacinth Distribution Map in the Saguling Reservoir in 2023

Using geospatial analysis, the area of the water body and the area of water hyacinth from the map are obtained as follows.

Table 3. Water Hyacinth Area in the Saguling Reservoir

Image Cover	Area (ha)			
	2016	2018	2020	2023
Water Body	2,552.71	2,574.02	2,670.45	3,011.83
Water Hyacinth	914.98	893.67	797.24	455.86
Total	3,467.69	3,467.69	3,467.69	3,467.69

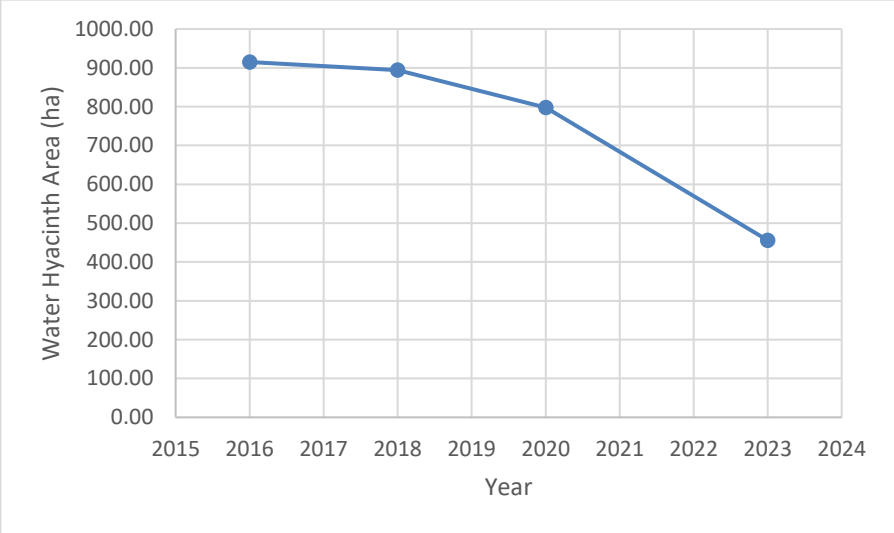

Figure 5. Graph of Water hyacinth Area in the Saguling Reservoir

Based on the mapping results, the water hyacinth area tends to decrease every year. One of the reasons for that is the water hyacinth utilization program initiated by PT PLN Indonesia Power Saguling POMU since 2013 which was the water hyacinth utilization into handicrafts. In addition, in 2019 the utilization of water hyacinth as fuel for Steam Power Plant (PLTU) was also initiated. Based on the graph, there has been a significant decrease in the number of water hyacinths from 2020 to 2023. This is predicted due to the addition of products resulting from the utilization of water

hyacinths in quite large quantities, namely the use of water hyacinths as animal feed and compost with a total of 1,500 kg/day.

3. Reservoir Sedimentation Reduction

Calculation of the amount of sediment produced by water hyacinth involves several factors, including the growth rate of water hyacinth, the size of the water body it covers, and its decomposition factor. Because the amount of water hyacinth utilized in kg/day has been calculated, the growth rate of water hyacinth and the size of the water body covered were not used. As water hyacinth decomposes, it releases organic matter that contributes to the production of sediment. This sediment is an accumulation of dead plant matter and other organic matters in the water.

The decomposition factor of water hyacinth can vary depending on environmental factors such as temperature, microbial activity, and water quality. Based on Xie et al. (2004), the decomposition constant (k) of water hyacinth varies widely, ranging from 0.006 to 0.099 per day. Hence, the value of the decomposition factor was taken using the highest value, which was 0.009 per day or 9,9% per day. The sediment production was calculated using the following formula:

Sediment Production = (Water Hyacinth Utilized) x (Decomposition Factor)

Then, the density value of water hyacinth was needed to get the sedimentation rate from the water hyacinth. The bulk density of water hyacinth leaves with a moisture content of 8% is 0.048 g/cm^3 (Davies & Mohammed, 2011). Dead water hyacinth contains very little moisture content. Therefore, the dead water hyacinth density was assumed to be 0.048 g/cm^3. To get the volume, the mass of water hyacinth was divided by its density as follows.

$$\text{Sedimentation Volume } (m^3/\text{year}) = \frac{Mass\ of\ Water\ Hyacinth\ (kg)}{Bulk\ Density\ of\ Water\ Hyacinth\ (\frac{kg}{m^3})}$$

Based on the 2022 Inspection Report for the Saguling Hydroelectric Reservoir by PT Indra Karya, the estimated actual sedimentation rate of the Saguling Reservoir that occurred at the bottom of the intake was 1,616,740.27 m^3/year. Thus, the estimated sedimentation rate (m^3/year) which can be reduced by water hyacinth utilization program by PT PLN Indonesia Power Saguling POMU was obtained by comparing the water hyacinth sedimentation rate to the actual sedimentation rate of the Saguling Reservoir. The results are as follows.

Table 4. Total Estimated Sedimentation Reduction from Water Hyacinth Utilization

Year	Total Estimated Sediment Production (kg)				TOTAL (kg)	TOTAL (m^3)	Reservoir Sedimentation Reduction
	Handicraft	Steam Power Plant Fuel	Animal Feed	Compost			
2013	57,816	-	-	-	57,816	1,204.50	**0.07%**
2014	57,816	-	-	-	57,816	1,204.50	**0.07%**
2015	57,816	-	-	-	57,816	1,204.50	**0.07%**
2016	57,816	-	-	-	57,816	1,204.50	**0.07%**
2017	57,816	-	-	-	57,816	1,204.50	**0.07%**

2018	57,816	-	-	-	57,816	1,204.50	**0.07%**
2019	57,816	9,901	-	-	67,717	1,410.77	**0.09%**
2020	57,816	9,901	-	-	67,717	1,410.77	**0.09%**
2021	57,816	9,901	36,135	18,068	121,919	2,539.99	**0.16%**
2022	57,816	22,275	36,135	18,068	134,294	2,797.78	**0.17%**
July 2023	33,726	25,988	21,079	10,539	91,332	1,902.74	**0.12%**
TOTAL	**611,886**	**77,965**	**93,349**	**46,674**	**829,875**	**17,289**	**0.09%**

The total estimated water hyacinth that was reduced in the Saguling Reservoir due to the water hyacinth utilization program from 2013 to July 2023 was 829,875 kg or 17,289 m^3. The estimated average sedimentation rate of the Saguling Reservoir that can be reduced by using water hyacinth is 0.09% per year. However, this is a simple approach to total sediment production without considering complex ecological interaction factors, as well as other factors such as nutrient content, water flow, and sediment resuspension which can also affect the overall dynamics of sediment in a water body.

4. Reservoir Evapotranspiration Reduction

Reservoir evapotranspiration is calculated from the amount of water lost due to evaporation on the surface of the water and transpiration through the leaves (Sri Harto, 1993). Estimation of water loss due to water hyacinth evapotranspiration was calculated using the following equation (Rashed, 2014).

$$ETc = ETo \times Kc$$

$$\text{Water Loss} = ETc \times \text{Surface Area} \times 0{,}001$$

The ETo was calculated using the ETo Calculator, a software developed by the Land and Water Division of FAO. Its main function is to calculate the reference evapotranspiration (ETo) according to FAO standards. ETo represents the evapotranspiration rate from a reference surface that is not deprived of water. Reference plants completely cover the surface, are well watered, and are actively growing under optimal agronomic conditions. The ETo Calculator assesses the ETo from meteorological data via the FAO Penman-Monteith equation.

Crop coefficient (Kc) is defined as the ratio of crop potential and vegetation evapotranspiration reference, which represents the specific crop evaporation parameter. The coefficient value of water hyacinth is 1.1 (light to moderate wind) and 1.15 (strong wind) (Dooenboss and Pruitt, 1992).

The area of water hyacinth was taken based on the processing of satellite image data sourced from Sentinel Imagery 2. Climatological data in the form of temperature, air humidity, wind speed, and sunshine duration were taken from the Meteorology, Climatology and Geophysics Agency (BMKG) website. The data taken was 4 years as a research sample, namely in January in 2016, 2018, 2020, and 2023. The following is the result of water loss calculation due to evapotranspiration in the Saguling Reservoir.

Table 5. Calculation of Crop Evapotranspiration (ETc)

No	Date	Temperature (°C)	Relative Humidity (%)	Wind Speed (m/s)	Sunshine (%)	Eto (mm/day)	Etc (mm/day)
1	January 2016	23.94	81.35	1.65	4.23	3.5	3.85
2	January 2018	23.31	77.62	2.71	2.86	3.4	3.74
3	January 2020	23.98	81.29	2.06	3.55	3.4	3.74
4	January 2023	23.96	76.48	1.53	4.58	3.7	4.07

Table 6. Calculation of Water Loss from Reservoir Evapotranspiration

No	Date	Surface Area of Water Hyacinth		Water Loss (m^3/day)
		Hectare	m^2	
1	January 2016	914.98	9,149,750.78	35,226.54
2	January 2018	893.67	8,936,667.11	33,423.13
3	January 2020	797.24	7,972,404.59	29,816.79
4	January 2023	455.86	4,558,594.13	18,553.48

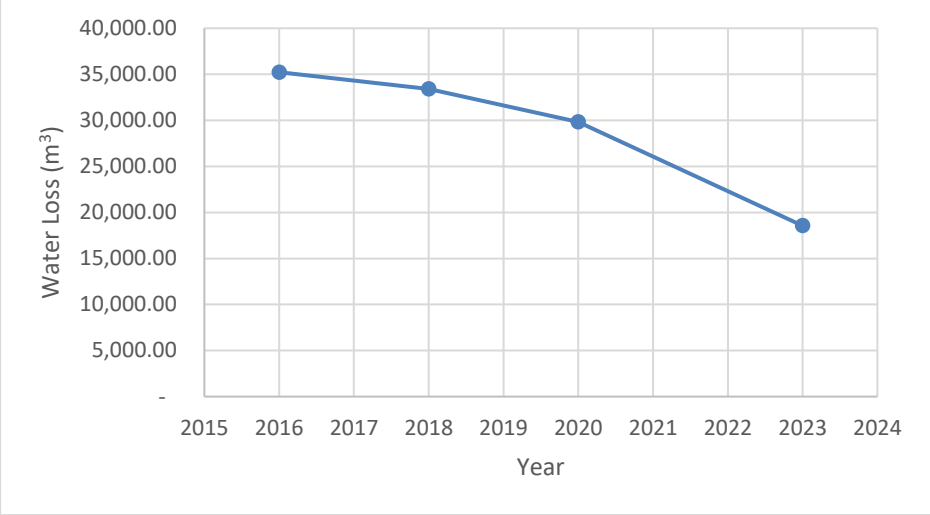

Figure 6. Graph of Water Loss from Reservoir Evapotranspiration

Based on the calculation of water loss due to evapotranspiration in the Saguling Reservoir from 2016-2023, the tendency for water loss decreases. This is because the amount of water loss due to evapotranspiration is directly proportional to the amount of water hyacinth in the water body. The smaller the number of water hyacinths, the smaller the amount of water loss due to evapotranspiration. The following is the equation used to determine the reduction in water loss due to evapotranspiration.

$$\triangle = \text{Evapotranspiration in 2016} - \text{Evapotranspiration in 2023}$$

$$\triangle = 35{,}226.54\ m^3/day - 18{,}553.48\ m^3/day$$

$$\triangle = 16{,}673.06\ m^3/day$$

According to research by Ali and Khedr (2018) on the Nile River, Egypt, the main cause of water loss is the evapotranspiration of water weeds from water hyacinth that is more than 90%. By reducing the number of water hyacinths in the reservoir, water loss due to evapotranspiration in the Saguling Reservoir can decrease by 16,673.06 m^3/day. Water hyacinths reduction can be obtained from water hyacinth utilization

programs, water bodies cleaning program, water quality improvement, and the natural decomposition ability of water hyacinth.

E. CONCLUSION

A multi-temporal map of the distribution of water hyacinth in the Saguling Reservoir from 2016 to 2023 shows that the cover of the reservoir by water hyacinth has decreased. This is partly due to efforts to suppress the growth of water hyacinth through the water hyacinth utilization program initiated by PT PLN Indonesia Power Saguling POMU. Based on estimates from 2013 to July 2023, the amount of water hyacinth utilized was 8,382,572 kg resulting in a reduction of sediment in the reservoir by 829,875 kg or 17,289 m^3. This is because the dead water hyacinth will decompose and become sediment at the bottom of the reservoir which makes the reservoir shallower. The estimated average sedimentation rate of the Saguling Reservoir that can be reduced by water hyacinth utilization is 0.09% per year. Based on the estimated water loss due to water hyacinth evapotranspiration in The Saguling Reservoir, evapotranspiration value from 2016 to 2023 decreased by 16,673.06 m^3/day. This is due to the reduced number of water hyacinths caused either by water hyacinth utilization, cleaning of water bodies, water quality improvement, or the natural decomposition ability of water hyacinth, which at last resulting in the reduction of water evaporation through the water hyacinth leaves. Therefore, efforts to control water hyacinth in the Saguling Reservoir effectively have positive impacts on reducing reservoir sedimentation and evapotranspiration which increases the life of the reservoir.

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