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DISTRIBUTION AND AREA OF LEBAK MARSH BASED ON HYDROTOPOGRAPHIC CHARACTERISTICS IN GROGOL SUBDISTRICT,SUKOHARJO REGENCY

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ABSTRACT
This research aims to determine the distribution and extent of leaky swamps based on hydrotopographic characteristics. The method used is an empirical approach using the Thornthwaite Mather water balance. The research data comes from both primary and secondary sources. Primary data collection involves field observations, measurements, and mapping, which provide data on soil texture, vegetation, fauna, topography, and aerial photos. Secondary data is obtained from institutions/agencies. Soil texture data is obtained through purposive random sampling. The extent of the leaky swamp is +104,252 m2, and it can hold a maximum volume of +116,028.25 m3 of water. The research results indicate the presence of two types of leaky swamps based on their hydrotopographic characteristics: shallow swamps and deep swamps. Shallow swamps are located on the riverbanks with higher elevations, covering an area of 30,462.54 m2. Meanwhile, deep swamps are situated in the center of the swamp with lower elevations in the form of basins, covering an area of 37,733.08 m2. This research has implications for a better understanding of Lebak swamps in the Grogol District. The findings can be used to develop more effective water resource management strategies. Furthermore, this research can serve as a foundation for further in-depth studies, such as ecological studies of swamps, research on water quality, or analyses of the impact of climate change on hydrotopography and the distribution of Lebak swamps.

Keywords: leak swamp, hydro topography, distribution of swamps, water balance.

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INTRODUCTION

The increasing needs and welfare of the community are marked by regional development (Nurohman et al., 2019). The Bengawan Solo River Normalization Project (river straightening) to deal with floods between 1990 and 1996 left some former rivers in several sub-districts in Sukoharjo Regency, Central Java (Dianitasari & Purnama, 2017). The section of a former river in Grogol District, Sukoharjo Regency, Central Java, is stagnant water for most of the year and filled with weeds. The source of inundation on the former river section is runoff from the Bengawan Solo Baru River and rainwater input. The condition of the former river section fulfills the requirements to be called a leaking swamp, namely land far from the coastal area, including in the non-tidal watershed hydrological system with seasonal variations in water level, highest water level during the rainy season, basins flooded with water from runoff river water and rainwater periodically, concave or almost flat topography which always stagnates throughout the year or at least for about 3 months by fulfilling the minimum inundation height requirements of 25-50 cm (Suriadikarta, 2012).

Swamp leak, as an inland wetland ecosystem, has biodiversity, non-biological diversity, and high productivity value (Zakaria & Rachman, 2013). Based on PP No. 73 of 2013, leak swamps have the function of water catchment and water catchment areas as protected areas and land use as cultivation areas. Swamp swamps during the rainy season will be inundated by up to 1-2 meters of water. However, the water level will drop during the dry season, leaving much dry land that can be utilized. Swamp lebak in Grogol District is an abandoned land with various problems, such as fluctuations in inundation, weeds, and piles of garbage which cause a decrease in environmental quality.

Swamps that are not managed properly result in unproductive land; this shows that regional development (Normalization Project) is not sustainable. Meanwhile, RI Presidential Regulation Number 59 of 2017 explains that the development must support sustainable development in all sectors covered in the SDGs (Sustainable Development Goals) (Hasanah & Rosliana, 2019). One of the goals of the SDGs can be implemented through conservation, restoration, land use, and supporting the gradual use of terrestrial ecosystems. Land utilization efforts aim to manage land and increase its benefits for environmental quality, which can be done by utilizing abandoned land as swamps (Sari & Zahrosa, 2022).

Swamp swamps are classified based on their hydro topographic characteristics (height and duration of waterlogging), namely shallow swamps (<50 cm; approximately 3 months per year), middle low swamps (50-100 cm; 3-6 months per year), and lowland swamps. deep valleys (>100 cm; >6 months per year). Shallow swamps have greater potential for agriculture than middle and deep swamps. The characteristics of deep leak swamps are more suitable for the fisheries and tourism sectors (Fatah, 2017). The utilization of leak swamp land is carried out with technology. It approaches that follow each characteristic of the leak swamp. Management of leak swamps can be planned with water management and irrigation systems as well as land arrangements so that swamps can be used properly during the dry and rainy seasons. Land management can be done in areas that are not flooded (Luthfia, 2019). Thus, the research aims to determine the distribution and extent of leak swamps that have the potential to be managed based on hydro topographic characteristics. The benefits of this research are as follows: Information about the distribution and extent of leaky swamps that can be managed based on hydrotopographic characteristics will assist in more efficient and sustainable natural resource management. This knowledge can be used to identify leaky swamp areas that have the potential to become sources of floods or landslides. Additionally, the findings of this research can serve as a basis for further studies in various fields, such as ecology, hydrology, soil science, and climate change related to leaky swamps and their hydrotopographic characteristics.

METHODS

The study was conducted in swamp swamps in Kadokan Village and Telukan Village, Grogol District, Sukoharjo Regency, Central Java, with a scale of 1:3.200. The research carried out is a type of applied research (applied research) with qualitative and quantitative research methods (Mulyatiningsih, 2015). The research data comes from primary and secondary data. Primary data collection was carried out by field observations, measurements, and mapping, which then obtained data from soil texture, vegetation, fauna, topography, and aerial photographs. Secondary data was obtained from institutions/institutions such as the Geospatial Information Agency and BBWS Bengawan Solo, with the data obtained as climatological data.

Soil texture is the ratio of the content of sand and clay in the soil. Soil texture will affect the rate of infiltration, water saturation level, and soil permeability. Soil texture characteristics are also influenced by other land characteristics, such as rock type, landform, and slope (Haryati, 2014). The collection of soil texture data was obtained using the purposive random sampling method (taking samples randomly through an area in populations that are assumed to be similar) (Arikunto, 2019) with point determination based on the land use of the research location. Soil texture sampling is carried out on disturbed soil samples, namely soils disturbed by human activities (Maschur, 2023). Determination of soil texture is carried out directly in the field using the quick soil characteristic survey method (Wulansari et al., 2022).

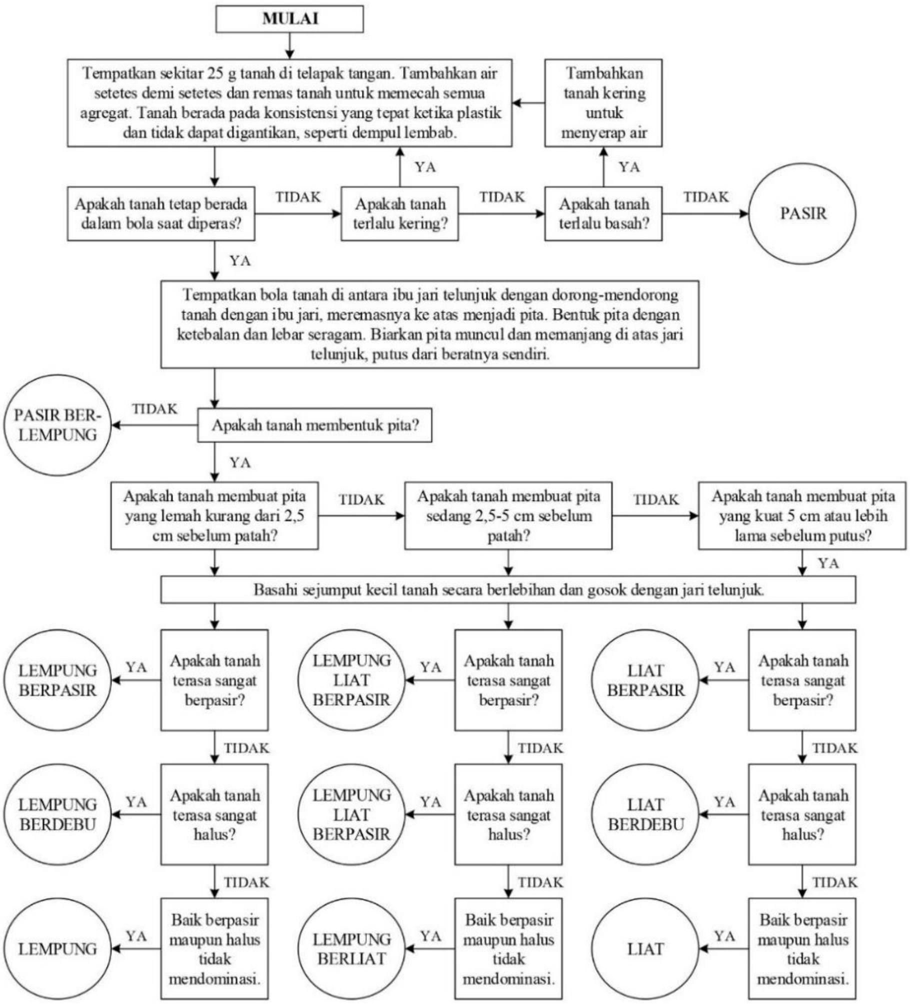

Figure 1. Quick Investigation of Soil Texture in the Field
Source: Notohadiprawiro, 1985

Vegetation observations were carried out directly in the field for each land use. The aim of observing the types of flora and fauna, especially those that grow in the lebak swamps, is to describe the characteristics of the lebak swamps in the study area. Aerial mapping is carried out using drones during the dry season and rainy season, which is then obtained in the form of a topographic map, especially at locations where there are inundations, so that the difference in the depth of puddles during the rainy and dry seasons can be calculated. Data on the volume of inundation can be obtained.

The climatological data obtained is then combined with soil texture observations in the field for water balance calculations. In determining the water balance, the Thornthwaite Mather method is used with the equation (Wijayanti et al., 2015) :

CH = EP ± ΔS

Information :

CH = Rainfall
EP = Potential Evaporation
ΔS = Water Storage

The equation to get the potential evaporation value is as follows:

EP = PET × (S×Tz)/(30×12)
EP = Potential Evapotranspiration
PET = Monthly Potential Evapotranspiration
(S×Tz)/(30×12) = Exposure Time for 12 hours 30 days

To get the monthly evapotranspiration value, the equation is used:

PET = 1.6 × 〖10T/I)〗^a
I = 〖(Mr/5)〗^(1,514)
a = (675× 〖10〗^(-9)×I^3)-(771× 〖10〗^(-7)×I^2)+(1792× 〖10〗^(-5)×I) +0.49239
I = Monthly heat index
T = Monthly average temperature
a = Heat index coefficient

The next step is calculating the difference between rainfall (CH) and potential evapotranspiration (EP). Then the calculation of Water Holding Capacity is carried out, namely the ability of the soil to absorb water, so that the calculation of the WHC value takes land cover and soil texture factors (Wijayanti et al., 2015). The next thing to do is to calculate the value of the surplus/deficit of water with the equation:

a) Surplus = (CH - EP) - ΔStn
b) Deficit = EP – EP

The surplus data obtained is then compared with the maximum volume of swamps obtained from data processing in ArcGIS software so that the distribution of puddles during the rainy season and dry season can be obtained. The final result is the area of land that is flooded and not flooded during the rainy and dry seasons.

RESULTS AND DISCUSSION

Soil Texture

Soil texture testing was carried out for each land use unit at the study site, which produced data in the following table:

Table 1. Soil Texture Class

Land Use	Field Description	Soil Texture
Ricefield	Can ball and form ribbon plates <2.5 cm long; soil particles feel very fine	Silty *loam*
Moor	Can form balls and form ribbon plates with a length of <2.5 cm; the ratio of sand, silt, and clay particles is balanced, and none dominates	Clay (*Loam*)
Settlement	Can form balls and form ribbon plates <2.5 cm long, fine soil particles with a predominance of sand	loam (*Sandy loam*)
Swamp	Can form balls and form ribbon plates of 2.5-5 cm in length. The ratio of sand, silt and clay particles is balanced, and no one dominates	Clay loam (*Clay loam*)

Source: Observation and Field Testing, 2021

Figure 1. Measurement of Soil Texture in the Field
Source: Field survey, 2021

The role of soil texture is to show the porous level of the soil; the larger the size of the fraction, the smaller the power to hold water that enters the soil (Hanafiah, 2022). The less porous (the finer the fraction), the more difficult it is for water and air to circulate, which can affect drainage in the soil. Differences in texture will affect plant growth and production and the types of plants that can be cultivated in that location.

Water Balance

The Thornthwaite Mather water balance method uses the evapotranspiration factor as a climate factor and uses soil moisture as a variable. The climate factor is obtained through monthly average rainfall data from 2011-2021. Rainfall data is shown in the following figure:

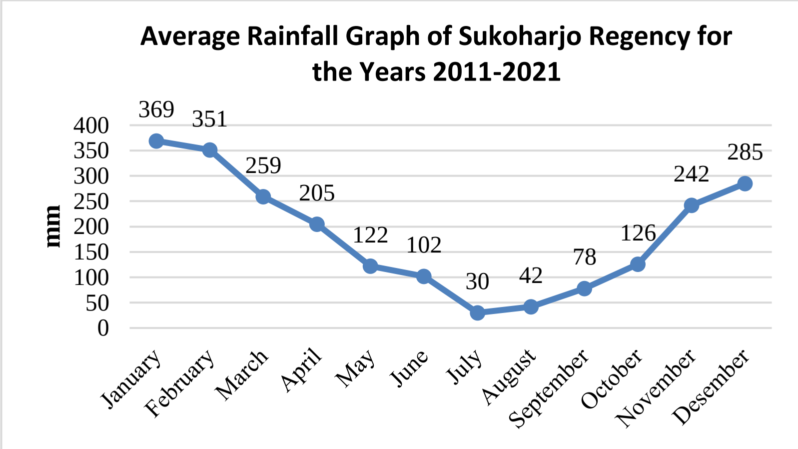

Figure 2. Graph of Average Monthly Rainfall for 2011-2021 in Sukoharjo Regency
Source: BBWS Bengawan Solo

Rainfall intensity based on data from the Peren ARR BBWS Bengawan Solo station in the Lebak swamp area includes a wet climate with an average rainfall of 2245 mm/year, dry months (CH <100 mm) for 3 months and wet months (CH > 200 mm) for 4 months in a row. The rainy season starts from November to March, with peak rainfall from December to February. Rainfall data shows the highest rainfall is in January, with an average of 369 mm, while the lowest rainfall is in July, with an average of 30 mm. A significant decrease in the average amount of rainfall occurs from March to July. The amount of rainfall greatly affects the amount of water input into the swamp directly or indirectly from the Bengawan Solo river runoff and groundwater. The increase in rainfall will be directly proportional to the volume of water reserves in the Lebak swamps and the volume of water in the soil.

The use of soil moisture is influenced by the ability of the soil to hold water or WHC (*Water Holding Capacity*). The WHC value is a function of root depth and soil texture obtained from land cover values, land use, and soil texture classes (Dianitasari & Purnama, 2017). Soil texture will determine infiltration and the ability of the soil to hold water. In contrast, differences in vegetation will determine the depth of soil roots. The following is the WHC value of the research location based on the results of measurements and observations:

Table 2. WHC Data on Each Land Use

LAND USE	SOIL TEXTURE	VEGETATION	VALUE Sto
Ricefield	Dusty sweat	medium root	200,000
Moor	Loam	deep root	150,000
Settlement	sandy sobs	spinach etc	150,000
Swamp	clayey clay	deep root	250,000

Source: Analysis Results, 2021

A water balance according to the climate is needed to assess the availability of rainwater in an area, especially to find out when and at what level a surplus and a deficit are under review. Rainwater meets evaporation needs, while other excess is counted as excess and diverted as surface runoff. Water balance calculations are carried out for each land use with the total result of the surplus value for each land use. The results of the water balance for one of the land uses can be seen in Table 3.

Table 3. Water Balance with WHC Paddy Land Use

Month	T°C	CH	PET (mm/ b ln)	EP (mm/ b ln)	CH-EP	AP WL	ST_o	st	ΔSTn	EA	S	D
January	24,9	368.8	110.4	117,9	250.8	0, 0	200	200	0.0	117,9	250.8	0.0
February	25,1	350.5	113,3	109,2	241.2	0.0	200	200	0.0	109,2	241.2	0.0
March	25,4	258.9	117,8	123.0	135.9	0.0	200	200	0.0	123.0	135.9	0.0
April	25.5	205.0	119.3	118.8	86,1	0.0	200	200	0.0	118.8	86,1	0.0
May	25,2	121.9	114.8	116,6	5,2	0.0	200	200	0.0	116,6	5,2	0.0
June	24,8	101.7	109.0	105.9	-4,1	4,1	200	195.8	-4,1	105.9	-0, 1	0, 1
July	24.0	30.0	97.9	99.1	-69.1	69,1	200	141.5	-54.3	84.3	-14.8	14,8
August	24,2	42,1	100.6	102.8	-60.7	60,7	200	147,6	6.0	48,2	-66.7	54,6
September	25.0	78, 2	111.8	111.8	-33.7	33,7	200	168.9	21,3	99.5	-55.0	12,3
October	25,6	126.0	120.8	127,4	-1,3	1,3	200	198.6	29,6	155.6	-31.0	-28.2
November	25,4	241.5	117,8	124,1	117,3	0.0	200	200	0.0	124,1	117,3	0.0
December	25,3	284.6	116,3	125,1	159,4	0.0	200	200	0.0	125,1	159,4	0.0

Source: Calculation Results, 2021

The total surplus value in the use of paddy fields, dry fields, settlements, and swamps, which are assumed to enter the surface water, the results are as follows:

Table 4. Total Surplus Water Balance

Month	CH	Surplus (mm/month)				Total Surplus	
		Ricefield	Moor	Settlement	Swamp swamp	(mm/month)	(m/month)
January	368.8	250.8	250.8	250.8	250.8	1003,4	1.003
February	350.5	241.2	241.2	241.2	241.2	965,1	0.965
March	258.9	135.9	135.9	135.9	135.9	543.9	0.544
April	205.0	86,1	86,1	86,1	86,1	344.6	0.345
May	121.9	5,2	5,2	5,2	5,2	137,3	0.137
June	101.7	-0, 1	-0, 1	-0, 1	-0, 1	- 0.4	-0.017
July	30.0	-14.8	-14.8	-14.8	-14.8	-276.5	-0.276
August	42,1	-66.7	-66.7	-66.7	-66.7	-242.8	-0.243
September	78, 2	-55.0	-55.0	-55.0	-55.0	-134.8	-0.135
October	126.0	-31.0	-31.0	-31.0	-31.0	-5,6	-0.006
November	241.5	117,3	117,3	117,3	117,3	469.3	0.469
December	284.6	159,4	159,4	159,4	159,4	637,8	0.638

Source: Calculation Results, 2021

In a year, the research area will have a surplus of water for six months, namely January to May and November to December. The water deficit occurred for four months, from July to October. In total, there is still a water surplus of 996.3 mm/year in one year.

Distribution and Area of Lebak Swamp

The characteristics of the leak swamps in the research area were analyzed using PP No. 73 of the 2013 swamps (Luthfia, 2019). The parameters to describe the characteristics of the leak swamps are based on the Minister of PUPR Regulation Number 16/PRT/M/2015. The leak swamp typology was determined based on the height and duration of the inundation; then, a visual match was made to determine the characteristics of the leak swamp. The area of leak swampland is ± 104,252 m^2 and can hold water with a maximum volume of + 116,028.25 m^3. The characteristics of the lebak swamps in the study area include the things in the following table:

Table 5. Characteristics of Swamp Lebak in the Study Area

Characteristics	Information
Appearance of Lebak Swamp	
Topography	Located in a flat, concave, and waterlogged area.
Type Land	Land alluvial
Plant Diversity	Water hyacinth, purun grass, elephant grass, shrubs
Water Management and Irrigation Buildings	Semi-technical (irrigation network with well-controlled water regulation but not yet measured with permanent building construction)
Hydrological Conditions	
Climate	C3 wet tropical climate (3-4 wet months with >200mm rainfall; 2-3 dry months with < 100mm rainfall), daily temperature ranges from 24-25.6 ℃ annual rainfall ranges from 1500-4000 mm.
River Influence	Half-enclosed Lebak (The high and low inundation is determined by the amount of rainfall, seepage, and also the surrounding rivers)
Source water input	(1) Rain, (2) install water river
Output water	(1) surface runoff, (2)evapotranspiration, And (3) seepage

Source: Analysis Results, 2021

Hydrological conditions in the study area are determined by (1) rain and (2) river tides. Rain is the main factor affecting the hydrological conditions in the Lebak swamp area; water conditions tend to fluctuate with topographic conditions that tend to be flat. Water stored in leak swamps is obtained from an empirical approach to the surplus value of the water balance with the volume capacity of the water storage at each elevation (St. Laksanto Utomo, 2019). The results of calculating the water storage volume each month are shown in Table 6.

Table 6. Water Storage Conversion with Lebak Swamp Area

Month	CH-EP (mm/month)	CH-EP (m/month)	Conversion with an area of 104. 252 m ^{2}
January	1003,4	1.003	104. 605,809
February	965,1	0.965	100. 609,859
March	543.9	0.544	56 . 705,292
April	344.6	0.345	35 . 928,394
May	137,3	0.137	14. 314,537
June	- 0.4	-0.0 004	-1 . 737,021
July	-276.5	-0.276	-28. 820,733
August	-242.8	-0.243	-25. 315,729
September	-134.8	-0.135	-14. 053,462
October	-5,6	-0.006	-578,875
November	469.3	0.469	48 . 922,292
December	637,8	0.638	66 . 495,367

Source: Calculation Results, 2021

Lebak swamps in the study area have several inundated points for 3-6 months each year. During the dry season, the leak swamps experience a decrease in the water level, but the soil remains saturated with water. The condition of this leak swamp land is included in the ecology of wetlands (*wetland*s), characterized by an atmosphere of inundation for a long time. In one year, January's water storage conversion value in the Lebak swamp area was 104. 605,809 m3 as the highest value. The volume calculation results using the surplus value are then compared with the volume that can be accommodated at each elevation or contour value. The lowest elevation value is 85.5 masl, which can accommodate a maximum volume of 14,726 m ^{3}; the highest elevation is 87 masl, which can accommodate a maximum volume of 116,028 m ^{3}. The distribution of stagnant water throughout the year is the basis for determining that the study area has three zonings, namely a dry land area of 21,307.67m2 throughout the year, a temporarily flooded area of 30,462.54m2, and an inundated area of 37,733.08m2 throughout the year.

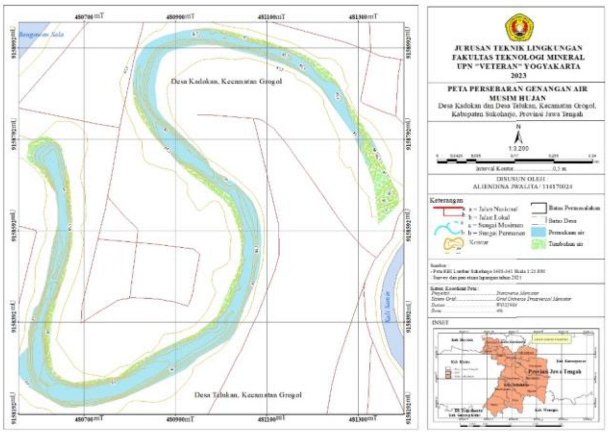

Figure 3. Rainy Season Puddle Distribution Map

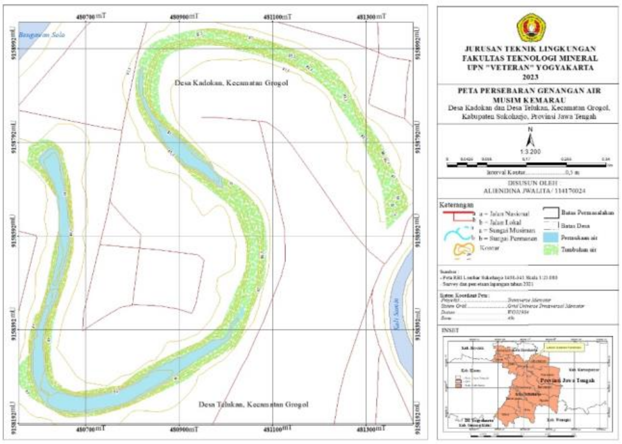

Figure 4. Map of Distribution of Puddles in the Dry Season

The deficit condition of the leak swamp water level has decreased by up to 40%, some of which are still inundated by as much as 40% of the total area of the study area. The decrease in the water level in the leak swamp or the study area was due to the taking of water to irrigate the irrigated rice fields and moor areas using pumps. Based on the distribution of puddles, it can be seen that there are 2 types of leak swamps based on their hydro topographic characteristics, namely shallow swamps and deep swamps. Shallow swamps are characterized by temporarily inundated land with 85.5 – 86 meters above sea level elevation. Shallow swamp swamps have an area of 30,462.54m2. Deep low swamps are characterized by land inundated most of the year with a depth of more than 1 meter. The area of deep swamp swamps is 37,733.08m2. The distribution of shallow leak swamps is around the edge of the leak swamp area. In contrast, deep leak swamps are located in the basin with a lower elevation.

CONCLUSION

The distribution of the leak swamps is obtained by comparing the large water holding capacity each month with the area of the leak swamps. Based on the classification of hydro topographic characteristics, there are 2 types of leak swamps, namely shallow swamps and deep swamps. The distribution of shallow swamps is located on the edge of the swamps with a higher elevation; the area of shallow swamps is 30,462.54m2. Meanwhile, the deep leak swamp is located in the middle of the swamp with a lower elevation in the form of a basin, with an area of 37,733.08m2. Lebak swamp management is carried out differently based on the type of leak swamp.

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