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The Effect of Land Use Changes on Availability of Water Resources in The Rupit Watershed

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Abstract

Water balance of a river watershed is significantly essential for estimating water availability to meet domestic and economic demands. In this context, several parameters such as rainfall, temperature, evapotranspiration, deficit, and surplus soil water content play a crucial role in determining water availability of a river watershed based on land use, soil type, seasonal variations, and other environmental factors. Therefore, this research aimed to estimate water balance of the Rupit watershed using the Mock method. The results showed that monthly soil water content (deficit or surplus) was significantly influenced by changes in rainfall, temperature, and land use patterns. The period from November to April experiences water surplus, while May to October is characterized by deficit. Specifically, a different response to land use was observed, where the maximum annual water content was not surplus. The total runoff for the Rupit watershed calculated from the Mock method runoff simulation was 134,42 mm/year.

Keywords: *Water Balance, Water Surplus, Deficit, Run-off*

INTRODUCTION

Several factors are responsible for exerting pressure on land use changes, including economic growth, urbanization, climate change, and population increase, leading to reduced water availability in river watershed. However, a decline in the economic quality of a rural area or small town can cause a reduction in the quality of land use and water availability. This phenomenon occurs due to forest encroachment to improve the economy population, through illegal mining. Changes in water storage of watershed are significantly determined by hydrological components such as rainfall, evapotranspiration, surface runoff, base flow, and groundwater infiltration (Rápalo et al., 2021), which vary with different land use.

LITERATURE REVIEW

Previous research reported that higher changes in land use of 22.2% in the impervious hilly areas of the Rawas Watershed, North Musi Rawas Regency, South Sumatra Province between 2010-2020, increased average annual runoff by 70% (Muchtar et al., 2022). The increase in surface runoff occurred due to illegal mining in the upstream area and the expansion of permits to open oil palm plantations. Meanwhile, there is an increase in flooding and evapotranspiration on agricultural land experiencing rapid land conversion. In North Musi Rawas Regency, where the primary sources of water for household and agriculture purposes are prevalent, a deficit water availability is outpacing aquifer replenishment in the Rawas watershed (Zainuddin et al., 2023). Research on land use changes using Landsat imagery (2005 and 2019) and SPOT Satellites taken in 2017, with the Mock method (1978) hydrological model in the Lematang river basin, also show an increase in maximum runoff (87.5 mm/month) and maximum surface flow (122.4 m3/sec) due to dominant forest encroachment (Yuono et al., 2020). Consequently, understanding water balance becomes crucial considering domestic and economic needs as well as availability of water in river watershed.

Water balance is a design activity that accesses the proportion of rainfall occurring in a river watershed, evapotranspiration, drainage, and groundwater recharge (Noerhayati, 2020). Estimating water availability is

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essential to meet demand and supply for irrigation, domestic use, and other activities (Ghandhari & Moghaddam, 2011).

Furthermore, water balance, which calculates availability and demand for water in a catchment area, is a strategy for understanding the hydrological conditions and function of water availability in watershed (Kampf et al., 2020). The Mock method is the most commonly used model to understand and analyze water balance of watershed. This model is widely used due to the simplicity of the formula, and availability of temperature, and rainfall data over a long period at several stations. The Mock method is the most widely used empirical formula in places where there are limited data and other meteorological factors (Tayebzadeh Moghadam et al., 2021).

Potential evapotranspiration (PET), along with rainfall is also the main driver of the hydrological cycle of a river watershed. Evapotranspiration is evaporation from the surface of short green plants that are elongated, actively growing, completely shaded in the soil, possess a uniform height, and are not water-deficient. The impact of PET on the annual water balance is significant due to its contribution to rainfall which determines the amount of discharge and infiltration (Xiang et al., 2020). Furthermore, PET from vegetation in hydrology is used with other hydrological data to determine water balance and soil water content to calculate actual evaporation and runoff (Milly & Dunne, 2016).

Several areas of the Rupit watershed experience water scarcity, which may be abundant in other regions. The Rupit River, which crosses Muararupit City, flows into the Rawas River, serving as the main channel for rainwater in the agricultural sector. The drying up of drinking water sources, predominantly river flows, is caused by changes in land use and climate variability (Eva et al., 2020). Therefore, effective river basin management is essential for the conservation of water resources and proper use through information systems. Based on the background, this research aimed to determine water balance in the Rupit watershed using the Mock method using remote sensing and GIS data. Additionally, the amount of watershed surface runoff was calculated using the simulated values obtained from the Mock method.The paper is organized as follows: the next section contains a comprehensive review of literature on social media and consumer decision making as well as customer engagement. Then, the hypothesis is developed based on the literature, and the following section discusses the methodology used. It is followed by the sections presenting the data analysis, findings, and conclusions of the study.

METHODOLOGY

Data Source

Spatial and non-spatial data were obtained from related institutions. While land use maps were taken using Satellite Imagery. Rainfall data was obtained from BMKG (Meteorology, Climatology and Geophysics Agency) Palembang City, for the last 10 years (2013-2022). Soil data, along with its parameters, were obtained from L-REP (Land Resource Evaluation and Planning Project,2000).

Table1: Spatial and non-spatial data

Spatial and Non-Spatial Data	Source	Resolution
Land Use Map	SPOT Image from BBWS South Sumatera VIII, Years,2017 Sentinel Image 2020 and 2023	Scale 1 : 10.000 10 m
DEM	DEM Nas (National) (https://tanahair.indonesia.go.id/demnas/#/)	15 m
Soil Map	L-REP (Land Resource Evaluation and Planning Project, 2000) BAPPEDA, South Sumatera	Scale 1 : 50.000
Precipitation (2013-2022)	BBWS regions VIII South Sumatera	Day's Data
Temperature	BBWS regions VIII South Sumatera	Day's Data

Watershed boundaries and drainage networks in the research area were analyzed using 15 m resolution Digital Elevation Model (DEM) data obtained from DEMNAS (National Digital Elevation Model).

Rainfall and Temperature

The Rupit watershed is influenced by the subtropical climate zone. The average annual rainfall is 1,124.44 mm (2013 -2022) as in Figure 1, with average monthly rainfall reaching 112.44 mm. In the last two decades, the highest daily rainfall recorded was 240.5 mm per day, with September to April receiving the highest. Average monthly temperature varied between 21oC to 30oC, where June, July, and August are the hottest months of the year, and January being the coldest, as shown in Figure 2.

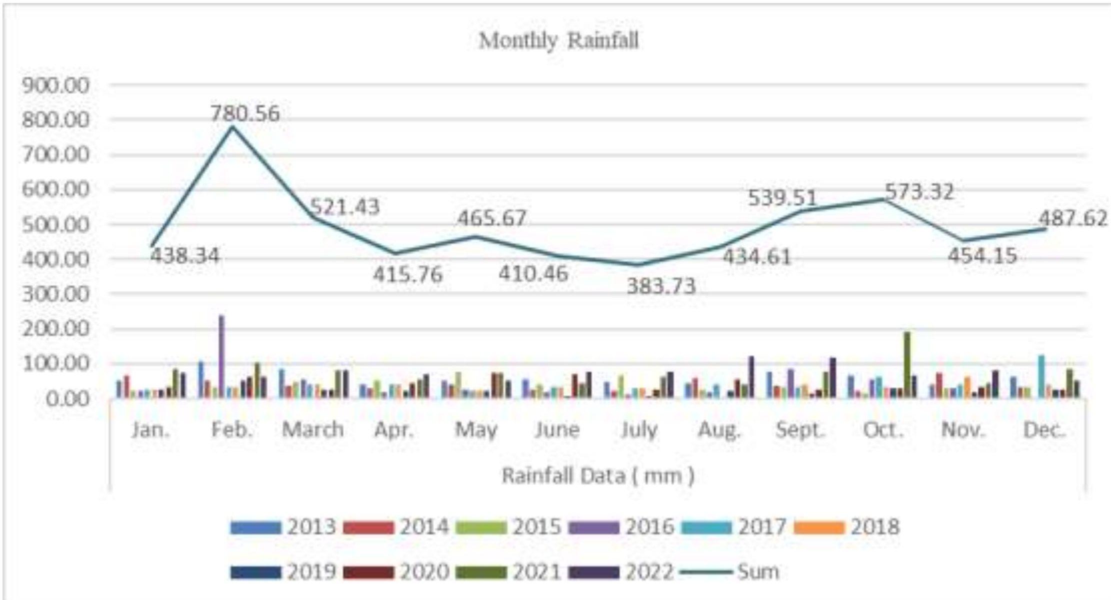

Figure 1: Average Monthly Rainfall

Source: BBWS regions VIII South Sumatera

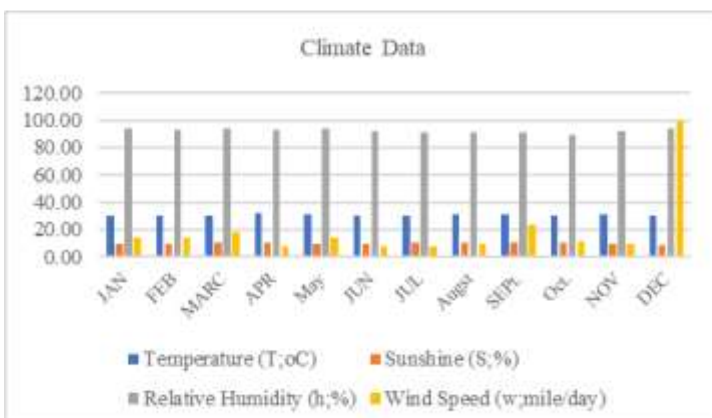

Figure 2: Average monthly temperature, wind speed, solar radiation and air humidity (RH)

Source: BBWS regions VIII South Sumatera

RESEARCH METHODS

The simplest and most widely used water balance model is the F.J. Mock method (Adatika et al., 2020)

$$GWS = k.IGWS + 0,5(1 + k)I \quad (1)$$

$$\Delta GWS = GWS - IGWS \quad (2)$$

where:

GWS = Groundwater storage in the n^{th} period,; k= Soil flow recession factor; I= Infiltration of the n^{th} month; ΔGWS= changes in groundwater storage (m^3); IGWS = groundwater storage for a period (n – 1)in m^3

The method applied to obtain water balance of the Rupit watershed uses a GIS and the Mock method. Moreover, the Mock method is simply used to determine water balance from the field level to a river watershed. This model requires monthly temperature and rainfall data as input, while the output is monthly potential and actual evapotranspiration, soil moisture storage, water surplus, and run-off (Amazirh et al., 2017). The amount of water that can be evaporated in the research environment with sufficient water availability in the soil is called PET, calculated using the equation:

$$Et=Eto-E \quad (3)$$

$$E=Eto.(m/20).(18-n) \quad (4)$$

Where:

Et = limited evapotranspiration (mm); Eto = potential evapotranspiration (mm); E = difference between potential and limited evapotranspiration ; m = land use; n = number rainy days

Factors that influence soil water surplus are as follows : (a) Soil water content (soil storage/mm/month); (b) Soil moisture capacity (SMC/mm/month); (c) Rainwater (ER). To calculate the rainwater that reaches the ground surface, it can be counted using the following formula.

$$ER = P - ETo \quad (5)$$

Where:

ER = rainwater reaching the surface; P = monthly rainfall and Eto = actual evapotranspiration

Water Surplus is run-off surface water and infiltration. To calculate Water surplus (+) is determined using the formula below (Singh et al., 2004) :

$$WS = (P-Ea)+ SS \quad (6)$$

Where:

P = monthly average rainfall; Ea = Actual evapotranspiration; SS = Soil Storage.

Soil moisture storage (SMS) consists of soil moisture capacity (SMC), zone of infiltration, surface runoff, and soil storage. Amount of Soil Moisture Storage (SMS) for each region depending on plant types, land cover, and soil type. In Mock, SMS is calculated as follows (Wang et al., 2021) :

$$SMS = ISMS + (P-Ea) \quad (7)$$

Where:

ISMS = Soil Moisture Storage; P = monthly average rainfall; Ea = Actual evapotranspitration,

Available water is often expressed as the depth of the root zone, consisting of 80%, which is expressed as a volume fraction (Andayono, 2018). AWC depends on soil properties, soil area, and root zone depth. Estimated data on root zone depth and available water capacity according to existing soil formations is determined based on the literature on soil or vegetation types that are suitable for the conditions of the Rupit River Watershed. Actual storage changes (ΔSM) for all months are calculated as follows (Senkondo et al., 2004)

$$\Delta SMmonth = STORmonth - STORprevious\ month \quad (8)$$

Where:

ISMS = Soil Moisture Storage; P = monthly average rainfall; Ea = Actual evapotranspitration

Moreover, for calculating Total Run-off (TRO) is obtained using the equation (Komariah & Matsumoto, 2019) :

TRO = BF + DRO + SRO (9)

Where:

BF = Base Flow; *DRO* = Direct Run-off; *SRO* = Storm Run-off.

The equation for calculating Debit is obtained using the equation :

Q=A x TRO (10)

Where:

Q = Debit; A = Watershed area; TRO = Total Run-off.

RESULTS AND DISCUSSION

Watershed Morphometry

Drainage analysis in watershed system determines the effectiveness of flow patterns, identifies areas prone to water pooling, and availability of water in the research area.

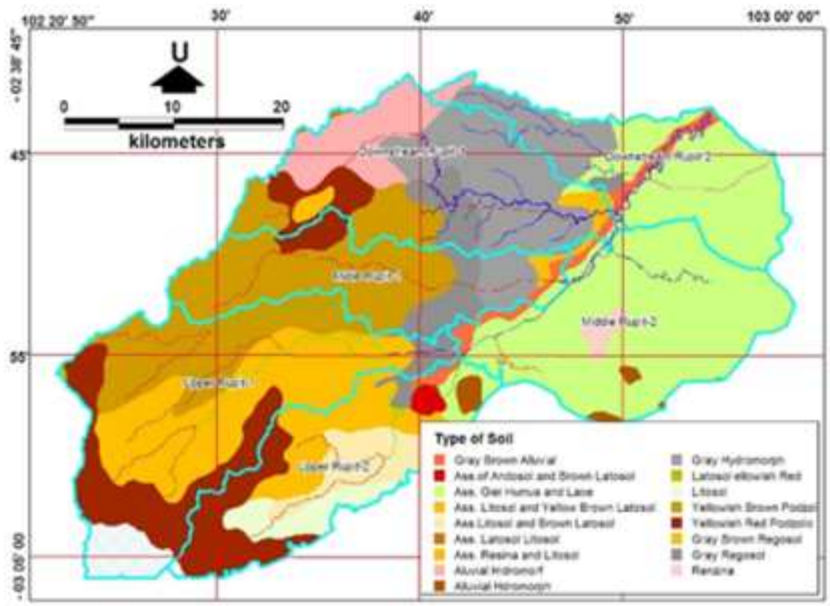

Figure 3: Rupit watershed morphometry

Source : DEM Analysis

Flow Length

Stream length is one of the most important hydrological characteristics in watershed areas, providing information about surface flow characteristics. Generally, the total length of the upstream and middle sections of the Rupit River is the longest, accounting for approximately 136, 417 Km, with the upstream section, consisting of 131,260 km. All drainage channels in the Rupit river sub-system in the upstream section are a branching, dendritic pattern. Therefore, it can be concluded that the Rupit watershed has a slope of > 45% upstream and <8% downstream, serving as a basin with alluvial deposits of former sediment or river overflow.

Basin Area (A)

Watershed area is an important parameter, complementing the river drainage length. Average watershed area in the Rupit watershed upstream of the Rupit River covers 450.77 km2. Meanwhile, the middle part (Rupit Midle 2 sub watershed) has an area of 334.35 km2, with watershed circumference being 96.16 km. The downstream area (Rupit Downstream 1 sub watershed) has an area of 337.64 Km2, with a circumference of 120.14 Km.

Drainage Pattern

In watershed, drainage patterns serve as indicators of slope, lithology, and structure, which helps to identify stages in the erosion cycle when analyzed. Drainage pattern presents several watershed characteristics through patterns and textures, which can infer the geological condition of watershed, rock strike, and deposition, including the presence of faults. Furthermore, drainage texture reflects climate, rock permeability, vegetation, and relief ratio by linking patterns with geological information.

The drainage pattern of the Rupit watershed is longitudinal and dendritic, showing a sloping area upstream and wavy downstream, with a large river system, which is a floodplain basin..

Drainage Density

Drainage density is the length of flow per unit area of a basin or watershed, which is widely used for analysis as a quantitative expression for landform estimation. However, climate functions, structural lithology, and regional relief history can be used as indirect indicators to explain the variables and landform morphogenesis. Based on the results, the drainage basin density of the Rupit watershed is 0.314 Km/Km2.

Geomorphology

The Rupit watershed has unconsolidated sediments from clay to sand of different grades. Geologically, the Rupit watershed is a highland and the downstream part is a lowland with a height of 43 m above sea level. The soil material is Quaternary alluvial deposits from the Pleistocene to recent ages. Furthermore, some parts of the basin have clayey sand formations due to mud deposits which are interspersed with sand. Shallow aquifers also occur mainly in river deposits and are meandering.

Geology

Geologically, the Rupit watershed is located along the foothills of the Barisan hills, including lowlands which are Quaternary alluvial deposits from the Pleistocene to recent ages. According to previous research, flash floods at the mouth of the Rupit River have occurred repeatedly, posing a serious threat to residents and urban areas.

Geohydrology

Availability of groundwater in the alluvial zone is controlled by the thickness of the sand and clay zones. Furthermore, groundwater near the surface occurs under unconfined aquifer conditions, while deeper aquifers are observed under confined-to-confined aquifer conditions. In the Rupit watershed, aquifer levels occur in semi-limited and limited conditions. Groundwater in basins is primarily recharged by Rainfall, with some areas experiencing a worsening trend. In this research, average hydraulic gradient is 0.35 m/km, showing the porous nature of the near-surface formations of the area.

Land Use and Vegetation

The Rupit watershed has a land cover of more than 53.264%, predominantly consists of broadleaf forest, and 37.6% of the area is used for smallholder plantations. In the downstream of water catchment area, built-up and cultivation areas dominate approximately 2% of the Rupit urban area. The built-up area consists of rural households, which are majorly occupied by non-irrigated rice fields, rivers/lakes/situ/ponds, open land, and settlements. Different land uses are shown in Figure 4, while the coverage area and magnitude of other parameters are presented in Table 3.

Table 3 Area and type of land use distribution in the Rupit watershed

Land Use	Area_(Ha)	Area_Km2	C_Coefficient	RD	ET_ET0	A_%
Thicket Forest	33.703,350	337,037	0,010	0,100	0,800	20,000
Dense forest	64.863,230	648,633	0,010	0,100	0,900	20,000
Land not planted	6,520	0,065	0,100	0,100	0,800	15,000
Industrial Plantation	13.058,940	130,590	0,040	0,780	0,850	20,000
People's Plantations	69.575,830	695,757	0,070	0,100	0,800	20,000
Settlement	225,160	2,250	0,510	0,050	0,600	30,000
Non-irrigated rice fields	995,410	9,954	0,430	0,100	0,900	20,000
River/Lake/Pond	1.264,260	12,642	1,000	0,000	0,000	46,000
Open Field	1.347,800	13,479	0,832	0,050	0,400	10,000

Source :Sentinel Image Interpretation, 2022

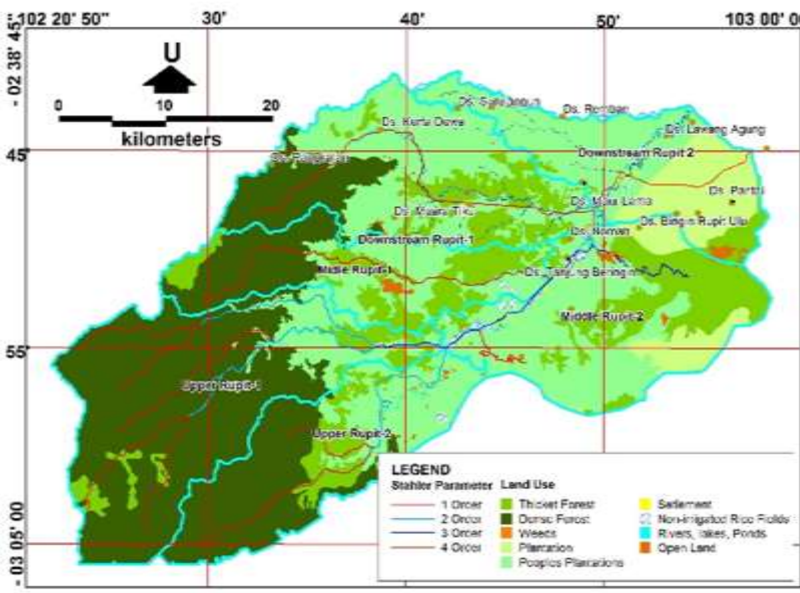

Figure 4: Distribution of land use in the Rupit

Source: Sentinel Image Interpretation, 2023

Hydrology

Rain Intensity

From the existing rainfall data, rain intensity for every 10-minute interval during extended periods of 2, 5, 10, 50, and 100 years is depicted in the form of an IDF (Intensity Duration Frequency) curve, graphically shown in Figure 5.

Variations in Water Availability

APWL in watershed is obtained from monthly rainfall and temperature. Based on the results, several deficits and surpluses of soil water content were observed during the dry season and rainy season.

The results showed that plants from October to April have access to soil water content. Meanwhile, in May and September, plants experienced a relative lack of water, predominantly remaining dry as shown in Table 4.

No	Calculation	Jan.	Feb.	Marc	Apr.	May	June	July	Augt.	Sept.	Oct.	Nop.	Dec.	Year
	Metereological Data													
1	Precipitation (P.mm/month)	**31,05**	**56,85**	**43,75**	**40,80**	**39,25**	**36,90**	**27,65**	**34,25**	**37,25**	**42,15**	**37,54**	**36,88**	464,3
2	Rain Days (n;days)	10	10	10	10	10	10	10	10	10	10	10	10	
3	Days of Month (Hr;days)	31	28	31	30	31	30	31	31	30	31	30	31	365,0
4	Temperature (T;°C)	29,90	30,05	30,50	31,90	31,10	30,40	30,05	30,90	30,80	30,75	31,50	30,50	
5	Sunshine (S;%)	9,3	9,50	10,30	10,20	9,70	9,30	10,50	10,90	10,30	10,30	9,60	8,60	
6	Relative Humidity (h;%)	94,50	93,50	94,50	93,20	93,80	91,80	91,10	91,00	91,10	89,90	91,80	93,80	
7	Wind Speed (w;mile/day)	14,0	14,0	18,0	8,0	14,0	8,0	8,0	10,0	24,0	12,0	10,0	99,3	
	Potential Evapotranspiration (mm/month)	2,2	2,0	1,8	1,5	1,6	1,8	2,0	2,2	2,1	1,8	1,6	1,9	
8	Solar Radiation (R;mm/day)	15,38	15,74	15,66	15,03	13,99	13,39	13,59	14,43	15,16	15,54	15,38	15,21	
9	A (mm Hg/°F)	0,78	0,78	0,79	0,80	0,79	0,78	0,78	0,79	0,79	0,79	0,80	0,79	
10	B (mm H_2O/day)	16,68	16,72	16,85	17,18	17,02	16,82	16,72	16,97	16,94	16,93	17,10	16,85	
11	ea (mm Hg)	42,17	42,53	43,65	47,33	45,17	43,40	42,53	44,65	44,40	44,28	46,25	43,65	
12	ed (mm Hg) = hxea	39,85	39,76	41,25	44,11	42,37	39,84	38,74	40,63	40,45	39,80	42,46	40,94	
13	F1 (T;S) = Ax(0.18+(0.55xS))/(A+0.27)	0,52	0,17	0,18	0,18	0,17	0,17	0,18	0,18	0,18	0,18	0,17	0,17	
14	F2 (T;h) = AxB(0.56-(0.092x(ed^0.5)))/(A+0.27)	-0,26	-0,25	-0,39	-0,66	-0,49	-0,26	-0,16	-0,33	-0,32	-0,26	-0,50	-0,36	
15	F3 (T;h) = (0.27)(0.35)(ea-ed)/(A+0.27)	0,21	0,25	0,22	0,28	0,25	0,32	0,34	0,36	0,35	0,40	0,34	0,24	
16	*Reflection Coefficient (r)*	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	
17	E1 = F1x(1-r)xR;	6,39	2,17	2,21	2,12	1,95	1,84	1,92	2,06	2,14	2,19	2,14	2,06	
18	E2 = F2x(0.1+(0.9xS))	-0,24	-0,05	-0,07	-0,13	-0,09	-0,05	-0,03	-0,07	-0,06	-0,05	-0,09	-0,06	
19	E3 = F3x(k+0.01w); k=	0,24	0,28	0,25	0,31	0,28	0,34	0,37	0,39	0,44	0,45	0,37	0,48	
20	Ep (mm/day) = E1-E2+E3	6,88	2,50	2,53	2,55	2,32	2,23	2,32	2,52	2,64	2,69	2,60	2,61	
21	Epm (mm/month) = HrxEp	213,2	70,06	78,58	76,62	72,02	67,01	71,87	78,23	79,10	83,32	78,05	80,76	
	Limited Evapotranspiration (mm/month)													
22	*Exposed Surface (m;%)*	50,00	50,00	50,00	50,00	50,00	50,00	50,00	50,00	50,00	50,00	50,00	50,00	
23	n (number of rain days)	10	10	10	10	10	10	10	10	10	10	10	10	
24	DE/Epm = (m/20)(18-n);(%)	20,00	20,00	20,00	20,00	20,00	20,00	20,00	20,00	20,00	20,00	20,00	20,00	
25	DE (mm/month)	42,63	14,01	15,72	15,32	14,40	13,40	14,37	15,65	15,82	16,66	15,61	16,15	
26	Eactual (mm/month) = Epm - DE	170,5	56,05	62,86	61,30	57,62	53,61	57,49	62,59	63,28	66,65	62,44	64,61	839,0
	Water Surplus (mm/month)													
27	P-Ea ; (mm/month)	-139,48	0,80	-19,11	20,50	-18,37	-16.71	-29.84	-28,34	-26,03	-24,50	-24,90	-27,73	
28	SMS = ISMS+(P-Ea) ; (mm/month)	60,52	61,32	180,89	160.39	142,02	125.31	95,47	67,13	41,10	16,59	-8,31	-36,04	
29	ISMC (mm/month);	60,52	200	180,89	160.39	142,02	125.31	95,47	67,13	41,10	16,59	-8,31	-36,04	
30	SS (mm/month), *if P-Ea >= 0,SS=0*	139.48	0,00	19,11	20,50	18,37	16,71	29,84	28,34	26,03	24,50	24,90	27,73	
31	WS (mm/month); [(27)+(30)]	0,00	0,80	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
32	TOR (mm/month)													
33	*IC(if)*	0,30	0,40	0,30	0,27	0,30	0,40	0,30	0,35	0,25	0,50	0,35	0,30	
34	Infiltration (i); (31)x if, (mm/month)	0,00	0,32	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,32
35	*K (monthly flow recession constant)*	0,90	0,85	0,75	0,88	0,95	0,90	0,75	0,90	0,80	0,92	0,70	0,85	

36	*PF (Percentage Factor)*	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	
37	1/2 x (1+K) x i	0,00	0,30	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
38	K x (Gsom);	90,00	76,50	57,60	50,68	48,15	43,34	32,50	29,25	23,40	21,53	15,07	12,81	
39	GS (mm/month) ; [36] + [37] Gsom	90,00	76,80	57,60	50,68	48,15	43,34	32,50	29,25	23,40	21,53	15,07	12,81	
40	DGS = GS - Gsom (mm/month)	-10,00	-13.20	-19,20	-6,91	-2,53	-4,82	-10.83	-3,25	-5,85	-1,87	-6,46	-2,26	-87,19
41	Base Flow = i - DGS (mm/month)	10,00	13,52	19,20	6,91	2,53	4,82	10,83	3,25	5,85	1,87	6,46	2,26	87,51
42	DRO = WS - i (mm/month)	0,00	0,48	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
43	SRO (mm/month); *if P>=200, SRO=0 ; SRO=PxPF*	3,11	5,69	4,38	4,08	3,93	3,69	2,77	3,43	3,73	4,22	3,75	3,69	
44	TRO = Bflow + DRO + Storm (mm/month)	13,11	19,69	23,57	10,99	6,46	8,51	13,60	6,68	9,58	6,09	10,21	5,95	134,42
45	CA (km^2)	1.850,	1850,4	1850,4	1850,4	1850,4	1850,4	1850,4	1850,4	1850,4	1850,4	1850,4	1850,4	
46	**Stream Flow (m^3/second)**	**9,05**	**15,06**	**16,29**	**7,85**	**4,46**	**6,07**	**9,39**	**4,61**	**6,84**	**4,21**	**7,29**	**4,11**	**95.23**

Source: Results of Analysis (add year)

Soil water content deficit was observed to be minimal in dense forest (129.73 mm), thicket forest (134.58 mm), land not planted (89.63 mm), and non-irrigated rice fields (94.85 mm) as well as settlement, and water bodies (0.675 mm). Similarly, annual moisture surplus in the soil was minimum in dense forest (234.68 mm), followed by thicket forest (237.61mm), land not planted (239.415mm), non-irigated rice fields (239.936mm), as well as settlement and water bodies (243.079 mm). The weighted annual watershed deficit was – 400.000 l/days, while the surplus was 0.0089 mm at February – March.

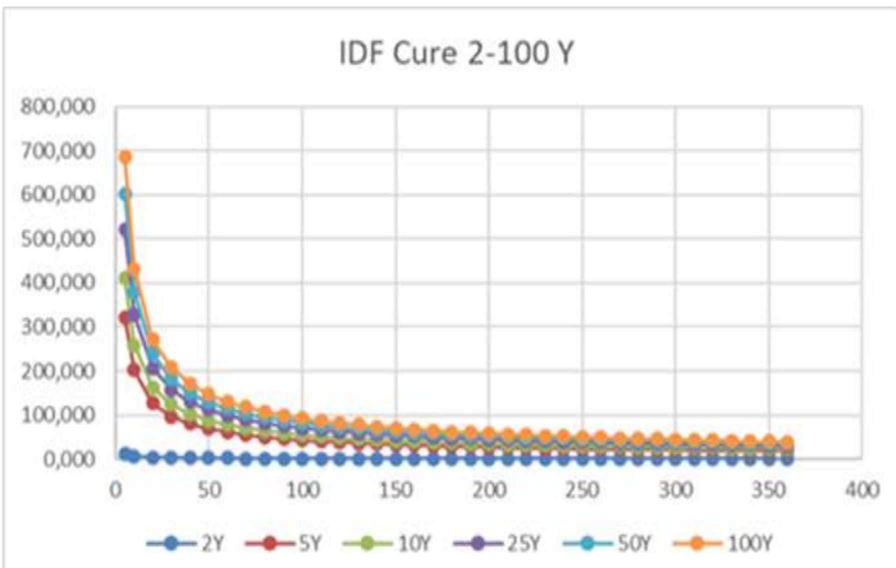

Figure 5: IDF curve for return period 2-100 years

Source: Precipitation Data Analysis

The Rupit Watershed Run-off Surface

Surface runoff (Run-off) simulations from the Mock model were compared with runoff obtained from existing data in BWWS Region VIII, South Sumatra, and routine visits to the research area. The observed runoff value was 134,42 mm/year and Stream Flow was 95.23 m3/sec.

Analysis of Raw Water Needs

Raw water needs are based on the projected population of the Rupit sub-watershed for the last ten years of data starting in 2022 in 2 sub-districts that are included in the Rupit sub-watershed area, namely Rupit and Karang Jaya sub-districts. Analysis of raw water needs in this research includes domestic and non-domestic water needs. From the results of calculating clean water needs in Rupit and Karang Jaya sub-districts, the recapitulation of clean water needs is 4,790,899.1 liters/second in 2021 and in 2031 (10 year projection) the total clean water need in Rupit and Karang Jaya sub-districts is equal to 7,085,181.4 liters/second.

Fig 6: Availability and Needs in the Rupit sub-watershed

Source: Results of Analysis

CONCLUSION

In conclusion, this research focused on estimating water balance to monitor the management of watershed such as the Rupit Watershed. The area is a new urban center designated as the capital of North Musi Rawas Regency, South Sumatra Province. Furthermore, North Musi Rawas Regency has administrative boundaries, the same as the Rawas watershed boundaries. The Rupit watershed is the downstream part, which often experiences flooding at the mouth of the Rupit river. During the analysis, water balance of the Rupit watershed was calculated using the Mock method.

The highest rainfall and evapotranspiration only occur in January, while other months recorded average of 56-66 mm/month. It was discovered that excessive water during the wet months (November-March) led to flooding, causing damage to infrastructure, such as residential buildings, roads, and bridges.

In the months of April-October, there was water shortage, with forest destruction and encroachment through illegal gold and coal mining causing a decline in the quality of surface water and protected forest environment.

The weighted annual watershed deficit obtained was 400.000 l/days, while the surplus was almost non-existent. Simulations of runoff against rainfall showed a significant and coherent catchment response to rainfall patterns.

Due to low rainfall and soil water content levels from previous months, February showed the highest discharge of 56.85 m3/second, with a runoff coefficient of 0.73.

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Conflicts Of Interest

The author and all the authors of this paper have no conflict of interest in any form regarding the data, research results and articles in the paper written and proposed for publication in the journal.

REFERENCES

Adatika, L., Suripin, S., & Darsono, S. (2020). Water Balance Analysis of Dolok Reservoir using Mock Method. International Research Journal of Advanced Engineering and Science, 5(4), 194–200.

Amazirh, A., Er-Raki, S., Chehbouni, A., Rivalland, V., Diarra, A., Khabba, S., Ezzahar, J., & Merlin, O. (2017). Modified Penman–Monteith equation for monitoring evapotranspiration of wheat crop: Relationship between the surface resistance and remotely sensed stress index. Biosystems Engineering, 164(September), 68–84. https://doi.org/10.1016/j.biosystemseng.2017.09.015

Andayono, T. (2018). The Effect of Soil Density on Infiltration Rate in The Urban Development Area of Padang. Jurnal Teknik Sipil Dan Perencanaan, 20(1), 1–5. https://doi.org/10.15294/jtsp.v20i1.12387

Eva, P., David, K., David, K., Jan, V., Pavel, N., Ladislav, M., & Vojtěch, B. (2020). The impact of the conservation tillage " maize into grass cover " on reducing the soil loss due to erosion. Soil and Water Research, 15(3), 158–165. https://doi.org/10.17221/25/2019-SWR

Ghandhari, A., & Moghaddam, S. M. R. A. (2011). Water Balance Principles: A Review of Studies on Five Watersheds in Iran. Journal of Environmental Science and Technology, 4(5), 465–479. https://doi.org/10.3923/jest.2011.465.479

Kampf, S. K., Burges, S. J., Hammond, J. C., Bhaskar, A., Covino, T. P., Eurich, A., Harrison, H., Lefsky, M., Martin, C., McGrath, D., Puntenney-Desmond, K., & Willi, K. (2020). The Case for an Open Water Balance: Re-envisioning Network Design and Data Analysis for a Complex, Uncertain World. Water Resources Research, 56(6), 1–19. https://doi.org/10.1029/2019WR026699

Komariah, I., & Matsumoto, T. (2019). Application of hydrological method for sustainable water management in the Upper-Middle Ciliwung (UMC) river basin, Indonesia. Journal of Water and Environment Technology, 17(4), 203–217. https://doi.org/10.2965/jwet.18-003

Milly, P. C. D., & Dunne, K. A. (2016). Potential evapotranspiration and continental drying. Nature Climate Change, 6(10), 946–949. https://doi.org/10.1038/nclimate3046

Muchtar, Z., Dwi, D., Putranto, A., Hadinata, F., & Bastian, L. (2022). THE EFFECT OF CHANGES IN LAND USE ON THE PREDICTION OF CRITICAL LAND DISTRIBUTION IN THE RAWAS WATERSHED (South Sumatra Province , Indonesia). November, 22–24.

Noerhayati, E. (2020). Neraca Air Dengan Metode Thornthwaite dan Matter di DAS Konto Hulu. Jurnal Rekayasa Sipil, 281–292.

Rápalo, L. M. C., Uliana, E. M., Moreira, M. C., da Silva, D. D., de Melo Ribeiro, C. B., da Cruz, I. F., & dos Reis Pereira, D. (2021). Effects of land-use and -cover changes on streamflow regime in the Brazilian Savannah. Journal of Hydrology: Regional Studies, 38(October), 100934. https://doi.org/10.1016/j.ejrh.2021.100934

Senkondo, E. M. ., Msangi, A. S. ., & Hatibu, N. (2004). Profitability of Rainwater Harvesting for Agricultural Production in Selected Semi-Arid Areas of Tanzania. Journal of Applied Irrigation Science, 39(1), 65–81.

Singh, R. K., Prasad, V. H., & Bhatt, C. M. (2004). Remote sensing and GIS approach for assessment of the water balance of a watershed / Evaluation par télédétection et SIG du bilan hydrologique d'un bassin versant. Hydrological Sciences Journal, 49(1), 131–141. https://doi.org/10.1623/hysj.49.1.131.53997

Tayebzadeh Moghadam, N., Abbaspour, K. C., Malekmohammadi, B., Schirmer, M., & Yavari, A. R. (2021). Spatiotemporal Modelling of Water Balance Components in Response to Climate and Landuse Changes in a Heterogeneous Mountainous Catchment. Water Resources Management, 35(3), 793–810. https://doi.org/10.1007/s11269-020-02735-w

Wang, J., Zhao, W., Wang, G., Yang, S., & Pereira, P. (2021). Effects of long-term afforestation and natural grassland recovery on soil properties and quality in Loess Plateau (China). Science of the Total Environment, 770, 144833. https://doi.org/10.1016/j.scitotenv.2020.144833

Xiang, K., Li, Y., Horton, R., & Feng, H. (2020). Similarity and difference of potential evapotranspiration and reference crop evapotranspiration – a review. Agricultural Water Management, 232, 106043. https://doi.org/https://doi.org/10.1016/j.agwat.2020.106043

Yuono, A. L., Putranto, D. D. A., & Tukirun, S. (2020). Effect of land use changes of upstream komering sub watershed on declining water availability. Journal of Ecological Engineering, 21(2), 126–130. https://doi.org/10.12911/22998993/116331

Zainuddin, Putranto, D. D. A., & Hadinata, F. (2023). The Effect of Land Degradation on Changes in Water Availability in Watershed Areas BT - Proceedings of the 9th International Conference on Energy Engineering and Environmental Engineering (Z. Sun & P. Das (eds.); pp. 103–114). Springer International Publishing.