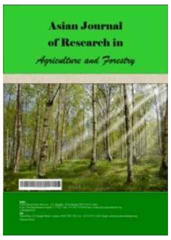

Asian Journal of Research in Agriculture and Forestry

8(4): 211-219, 2022; Article no.AJRAF.93757
ISSN: 2581-7418

Modeling the Water Balance of Agricultural Land in the Determination of the Growing Season in Buru Regency

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJRAF/2022/v8i4181

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/93757

Original Research Article

Received 18 September 2022
Accepted 24 November 2022
Published 29 November 2022

ABSTRACT

This study aims to determine the value of surplus and water deviation of agricultural land in Namlea District, Buru Regency. The study was conducted in Namlea Subdistrict, Buru Regency, Maluku Province. Materials used, questionnaires, climate data, air temperature, precipitation, humidity, solar rays 10-20 years. Tools used, computer equipment, writing stationery and location maps. To obtain the surplus value and water deficit of the land used data on the average amount of monthly precipitation and the average monthly temperature using the calculation of the Thornthwaite method. The calculation of the groundwater balance is carried out using a bookkeeping system. The data used are monthly potential evapotranspiration values, climate station data, monthly average rainfall, and rainfall at a 50 percent chance level. The observation parameters calculated in this study are rainfall, evapotranspiration, and determination of land water balance. The results of this study showed that the difference in rainfall and evapotranspiration in Namlea District was highest in June at 85.40 mm, and the lowest in October at -99.83 mm. This value indicates that the evapotranspiration value is greater than the average monthly rainfall value during the period 2010 – 2019. Namlea Subdistrict experienced potential water loss for evaporation (APWL) in May of 35.30 mm, in August to November of August of 65.26 mm, in September of 156.24 mm, in October of 256.07 mm and in November of 303.45 mm. The land water balance in Namlea Subdistrict, namely rainwater deviation, occurs in May, then August to November, while the water surplus occurs in

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December to July, and continues in June and July. Namlea district annual runoff is 854.01 mm. Regarding agricultural irrigation development policies, this study recommends that it is necessary to pay attention to weaknesses in each food crop sub-sector.

Keywords: Evapotranspiration; water balance; agricultural land; growing season; thornthwaite.

1. INTRODUCTION

The availability of water plays a very important role in an ecosystem environment [1]. The concept of environmental hydrological cycle states that the amount of water in a certain area of the earth's surface is influenced by the amount of water entering (input) and leaving (output) at a certain period of time. The balance of water input and output in a place is known as a water balance. Because water is dynamic, the value of the water balance always changes from time to time so that somewhere there may be an excess of water (surplus) or a shortage (deficit). If this excess and lack of water is in extreme conditions, it can certainly cause disasters, such as floods or droughts. These disasters can be prevented or addressed if good management of the land and the environment is carried out [2]. In addition, the water balance can also be used in agriculture, knowledge of the water balance in an area can increase production. On a synoptic scale, the presence of tropical storms near the territory of Indonesia will also affect the rains that occur in Indonesia [3].

According to Pasaribu et al, in terms of its use in the field of hydrology, the water balance is an explanation of the relationship between inward flow and out flow in a certain period of water circulation process [4]. The water balance is an absolute necessity for plants. Taufaila et al define the water balance as a breakdown of all inputs, outputs, and changes in water stores contained in a land to establish the amount of water contained in the soil that describes the water gain (surplus or deficit) over time [5]. Rainfall along with evapotranspiration supported by the physical properties of the soil will be able to provide important information about the amount of water that can be obtained to determine the period of surplus or deficit of land water, the water that cannot be accommodated and the time of occurrence of which the whole can only be analyzed through the calculation of the water balance [6]. In the field of Agroclimatology, the water balance is the difference between the amount of water received by plants and the loss of water from plants and soil through evapotranspiration [7].

The land water balance is the water balance for the general use of agricultural land. This balance sheet is useful in considering the suitability of agricultural land, arranging planting and harvesting schedules, and regulating the provision of irrigation water in the right amount and time. Determination of planting time based on water balance calculations is used to determine the impact of climate change on water availability in an area [8]. The calculation of the water balance makes it possible to quantitatively evaluate the dynamics of groundwater and water use by plants and spatially calculate the availability of water in a particular region [9]. The water balance is closely related to rainfall, surface temperature and evapotranspiration. In the calculation of the land water balance, rainfall is an ever-changing variable [10]. Surface air temperature is the temperature of free air at an altitude of 1.25 to 2.00 meters from ground level. Temperature affects the growth and productivity of plants, depending on their type [11].

In practice, it is difficult to determine water loss separately through both processes, so the measurement of the amount of water lost is calculated as the total water lost through evaporation and transpiration, which is called evapotranspiration. Evapotranspiration that occurs at a potential rate (ETP) increases to the point of withering and will drop drastically after that [12]. However, the rate of evapotranspiration will follow a linear line with rising water pressure. Meanwhile, other experts blend the opinion between the two, that ETP occurs at a potential rate for a while, then decreases exponentially rapidly [13].

2. METHODS

The study was conducted in Namlea Subdistrict, Buru Regency, Maluku Province. The site selection is based on the consideration that Namlea District as an area that has natural resource potential that is able to develop agricultural commodities in Buru Regency, Maluku Province. The materials used in this study were questionnaires and climate data from the Buru Regency Meteorology and Geophysics agency in Namlea, air temperature, rainfall, humidity, solar rays for 10-20 years. The tools used are computer equipment with excel programs, writing stationery and location maps to conduct site observations / surveys. At the place of study, it is necessary to know the texture of the soil, the moisture content of the soil. To obtain the value of surplus and deficit of land water used data on the average amount of monthly rainfall and the average monthly temperature using the calculation of the Thornthwaite method spelled out. This Thorntwaite method ETP estimation uses only monthly average temperature data. The calculation of groundwater balance is carried out using a bookkeeping system according to the way of Thornthwaite and Mather which is modified in a monthly interval. The data used are monthly potential evapotranspiration values of measurement results data in the field (climate station data) and monthly average rainfall and rainfall at a 50% chance level. The observation parameters calculated in this study are rainfall, evapotranspiration, and determination of land water balance.

3. RESULTS AND DISCUSSION

3.1 General State of the Research Location

Referring to some secondary data in the field, it is known that the geomorphological conditions of Buru Regency are controlled by the regional geology of Maluku Province, where this area is the western end of the Non-Magmatic Islands Arc of the Pacific Circumference Circle. Namlea Subdistrict belongs to the geomorphological unit of the Hills/Mountains of the Fault Folds. The hydrological condition is with the flow pattern of the river which includes the Namlea watershed which flows towards the East at a high to very high speed level and its tributaries are found in several villages, namely Jamilu village, Bata Boy village and Lala village. Rivers with dendritic and radier flow patterns flow towards the coast, and are controlled by geological structures (faults, fracturing and rock folding systems). The density level of the river is very intensive with flow patterns being permanent and intermittent. The shape of the Namlea subdistrict area is based on a physiographic approach (macro relief), namely plains, beaches, hills and mountains with low elevation marbles with gentle to rather steep slopes.

The climate data of Namlea Subdistrict was obtained from the Namlea Meteorological and Geophysical Station located at an altitude of 6 m from sea level. The length of recording time is 10 years from 2010 – 2019. The results of the analysis show that the average annual rainfall for 10 years from 2010 – 2019 was 1652.66 mm / year. According to the rainfall criteria set by the Directorate General of Watershed Management and Social Forestry in 2013, the annual rainfall in Namlea District is low with a range between 1500 - <2000 mm / year. The average monthly rain intensity is 9.74 mm / month, and according to the Regulation of the Directorate of Watershed Management and Social Forestry (2013), the rain intensity in Namlea district is classified as very low, which is around < 13.60 mm / day.

The state of the climate greatly affects the state of the land water balance [14]. As dictated that, the land water balance is the water balance for the general use of agricultural land. This balance sheet is useful in considering the suitability of agricultural land, arranging planting and harvesting schedules, and regulating the provision of irrigation water in the right amount and time. Determination of planting time based on water balance calculations is used to determine the impact of climate change on water availability in an area. According to Nasir et al, the water balance is the difference between the amount of water received by the plant and the loss of water from the plant and the soil through evapotranspiration [15]. The results of research in the field, showing some climatological data in Namlea district over a period of 10 years, namely from 2010 - 2019 can be seen in Table 2. It can be explained that November has the highest average sun rays of 84.11%/month, while January has the lowest average sun rays of 48.72%/month. The average monthly sunshine in Namlea subdistrict is 62.88%.

The air humidity can be explained that January has the highest air humidity which is 87.73% / month, and the lowest air humidity is in June which is 77.21 % / month. The average monthly air humidity in Namlea sub-district is 82.87%. The air pressure can be explained that September has the highest air pressure which is 1010.70 mb / month, and the lowest air pressure is in December which is 1008.00 mb / month. The average monthly air pressure in Namlea district is 1009.40 mb. The wind speed can be explained that August has the highest wind speed of 7.00 knots/month, and the lowest wind speed is in December, which is 4.00 knots/month. The average monthly wind speed in Namlea district is 5.00 knots.

3.2 Measurement of Evapotranspiration Value (ETP)

Evapotranspiration is a combination of two processes of the hydrological cycle namely evaporation and transpiration [16]. Evapotranspiration is one part of the water cycle, and has an important role for agriculture, hydrology, ecology and other fields. Wang et al [17], define evapotranspiration as the change of form from liquid H_2O to steam or gas as well as moving from vaporizing planes (ground surface and vegetation) to the atmosphere. Evapotranspiration calculations are among others necessary to determine the amount of consumptive water use for plants, analysis of water availability, pump capacity for irrigation, water flowed through irrigation canals and reservoir capacity [17]. In this study, the measurement of the evapotranspiration value was carried out directly in the field using the Lysimeter tool. The data obtained from the lysimeter is the true value of evapotranspiration. However, because the lysimeter tool used often experiences problems and is not practical, it also requires large costs, so in this study to then get the evapotranspiration value, researchers did it based on estimation through empirical equations.

Regarding the determination of the evapotranspiration value used by the study as described above, strengthened by Putrid an Sipayung, that the evapotranspiration value can be determined through direct measurements or calculations. In simple terms, the measurement of evapotranspiration values can be done directly using the Lysimeter measuring instrument. However, lysimeters are less practical, both in use and in cost, so various approaches are carried out using empirical equations to determine the value of evapotranspiration. One of the methods used is the Thornthwaite method. The data used in the Thornthwaite method are air temperature data and correction factors for day length and latitude to calculate its potential evapotranspiration [18]. Based on Table 3, it is known that the highest monthly corrected evapotranspiration value occurred in October at 15.28 cm / month and the lowest corrected evapotranspiration occurred in June, which was 8.93 cm / month.

3.3 Land Water Balance

The calculation of land water balance in this study uses several parameters such as Accumulation of potential water loss for evaporation (APWL), Groundwater Content (KAT), Changes in Groundwater Content ($^{\Delta}$KAT). The accumulation of potential water loss for evaporation was obtained by rainfall data minus evapotranspiration data, then the summation of negative CH-ETP values sequentially month after month. The APWL (Accumulated Potential Water Loss) values can be seen in Table 4. The difference in rainfall and evapotranspiration was highest in June at 85.40 mm, and lowest in October at -99.83 mm. A negative value indicates that the evapotranspiration value is greater than the monthly rainfall value during the period 2010 – 2019 in Namlea Village.

Table 1. Rain data in Namlea district (2010 – 2019)

No	Month	Average rainfall (mm)	Monthly rainy days	Monthly rain intensity
1	January	214.49	19	11.29
2	February	185.14	17	10.89
3	March	199.90	18	11.11
4	April	161.32	15	10.75
5	May	111.90	13	8.61
6	June	174.70	13	13.44
7	July	160.45	14	11.46
8	August	68.24	8	8.53
9	September	48.72	7	6.96
10	October	52.97	6	8.83
11	November	102.52	8	12.82
12	December	187.84	17	11.05
Annual Average		1652.66	1553	116.91
Monthly Average		139.02	13	9.74

Source: BMKG Namlea Station, 2020

Table 2. Climatology data in Namlea district (2010 – 2019)

No	Month	Irradiation Sun (%)	Air humidity (%)	Air pressure (mb)	Wind Speed (knots)
1	January	48.25	87.73	1008.4	5
2	February	51.97	87.52	1009.2	5
3	March	57.23	86.69	1009.4	5
4	April	69.25	86.47	1009.7	5
5	May	72.17	85.54	1009.5	5
6	June	51.37	77.21	1010.2	6
7	July	55.65	83.83	1010.6	6
8	August	65.74	79.93	1010.4	7
9	September	60.22	77.46	1010.7	6
10	October	77.05	78.30	1009.1	5
11	November	84.11	79.58	1007.5	5
12	December	61.55	84.17	1008.0	4
Annual Average		754.57	994.45	12112.8	60
Monthly Average		62.88	82.87	1009.4	5

Table 3. Average temperature and evapotranspiration data in Namlea district (2010 – 2019)

No	Month	Average Temperature $T^{0}C$	Heat Index (i)	ETP (cm)	F	Corrected ETP(mm)
1	January	26.88	12.76	13.84	1.05	145.3
2	February	26.90	12.78	13.86	0.94	130.3
3	March	26.77	12.68	13.74	1.04	142.9
4	April	26.91	12.78	13.87	1.01	140.1
5	May	27.24	13.02	14.16	1.04	147.2
6	June	23.82	10.63	8.84	1.01	89.3
7	July	25.97	12.11	12.28	1.04	127.7
8	August	26.27	12.33	12.83	1.04	133.5
9	September	26.87	12.75	13.83	1.01	139.7
10	October	27.88	13.49	14.69	1.04	152.8
11	November	27.88	13.49	14.69	1.02	149.9
12	December	27.51	13.22	14.39	1.05	151.1
Jumlah		3209.07	152.04			
Rataan Suhu Tahunan		267.42				
Rataan Suhu Bulanan		26.74				

The water content or soil reserve (ST) in Namlea Subdistrict is equal to its field capacity of 184 mm which is obtained based on the multiplication results between the porsentation of land use area, available water, and root zone depth, as shown in Table 5. ST (Land Lengas Reserve) = 17,476.7/99.2 = 176.2 or rounded 176.

According to Table 5, it is explained that there was a water deviate on land in Namlea District in May of 141.30 mm and then continued in August to November with a total amount of 475.45 mm. With a breakdown of 190. 26 water deviation occurred in August, 121.98 mm of water became deviate in September, 112.83 mm of water occurred in October and 50.38 mm occurred land water deviation in November.

In these months, farmers or residents must be able to properly store/collect rainwater for later use again in the surplus months. In addition, this month there is a lot of rainfall so that lands need to be conserved in order to overcome the danger of flooding or excess water and become disease outbreaks for humans and other creatures, as shown in Figs. 1-3.

Table 4. Water Potential Area Accumulation Value (APWL)

No	Bulan	CH (mm)	ETP (mm)	CH-ETP (mm)	APWL
1	January	214.49	145.3	69.19	
2	February	185.14	130.3	54.84	
3	March	199.90	142.9	57.00	
4	April	161.32	140.1	21.22	
5	May	111.90	147.2	-35.30	-35.30
6	June	174.70	89.3	85.40	
7	July	160.45	127.7	32.75	
8	August	68.24	133.5	-65.26	-65.26
9	September	48.72	139.7	-90.98	-156.24
10	October	52.97	152.8	-99.83	-256.07
11	November	102.52	149.9	-47.38	-303.45
12	December	187.84	151.1	36.74	
Sum		3209.07			

Table 5. Land use of Namlea district

No	Land Use	Broad (%)	Root Zone	Water Available (mm/m)	Lengas reserves of land (ST)
1	Primary Forest	40.91	1.20	200	9,818.4
2	Manggrofe Forest	0.66	2.00	150	198.0
3	Shrubs	41.82	1.00	150	6,273.0
4	Open Land	15.83	0.50	150	1,187.3
5	Settlement	0.78	0.00	150	0.00
Sum		100.00			17,476.7

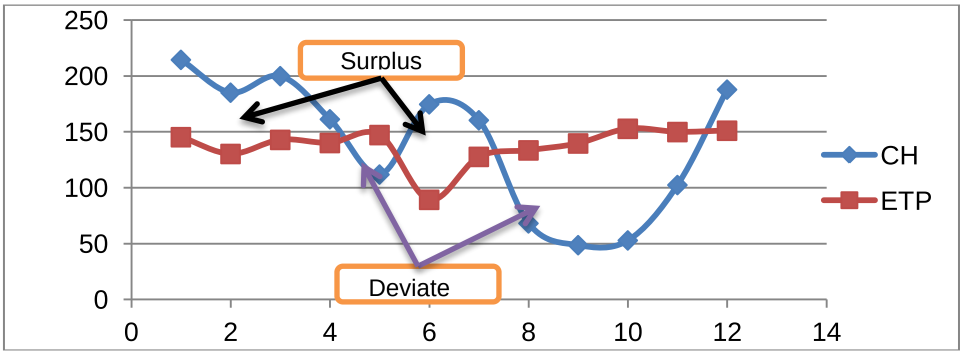

Fig. 1. Graph of accumulated deviation and surplus

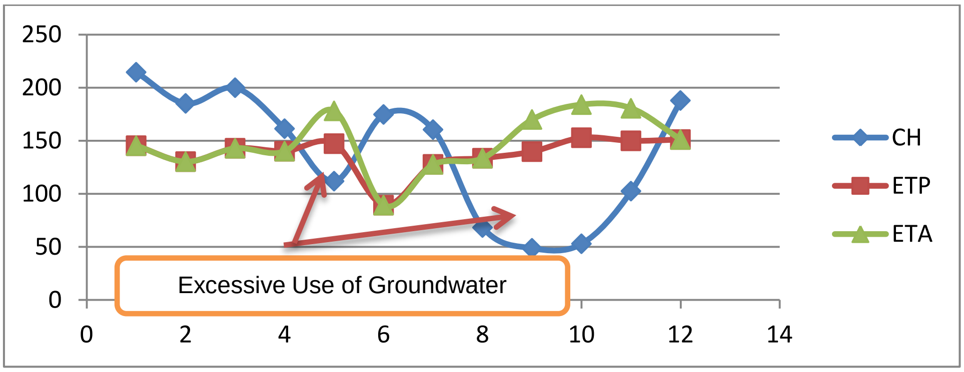

Fig. 2. Groundwater usage chart

Table 6. Table of values of accumulated deviate and surplus

No	Bulan	CH (mm)	ETP (mm)	CH-ETP (mm)	APWL	KAT	Δ KAT	ETA	D	S
1	January	214.49	145.30	69.19		176	0	145.30	0	69.19
2	February	185.14	130.30	54.84		176	0	130.30	0	54.84
3	March	199.90	142.90	57.00		176	0	142.90	0	57.00
4	April	161.32	140.10	21.22		176	0	140.10	0	21.22
5	May	111.90	147.20	-35.30	-35.30	70	-106	-2.10	141.30	0
6	June	174.70	89.30	85.40		176	106	89.30	0	85.40
7	July	160.45	127.70	32.75		176	0	127.70	0	32.75
8	August	68.24	133.50	-65.26	-65.26	51	-125	-64.76	190.26	0
9	September	48.72	139.70	-90.98	-156.24	20	-31	17.72	121.98	0
10	October	52.97	152.80	-99.83	-256.07	7	-13	39.97	112.83	0
11	November	102.52	149.90	-47.38	-303.45	4	-3	99.52	50.38	0
12	Desember	187.84	151.10	36.74		176	180	151.10	0	36.74
	Sum	3209.07								

Table 7. Table of accumulated deviate and surplus values

Moon	1	2	3	4	5	6	7	8	9	10	11	12	Sum
Surplus	69.19	54.84	57.00	21.22	0.00	85.40	32.75	0.00	0.00	0.00	0.00	36.94	
50%	34.60	27.42	28.50	10.61	0	42.70	16.38	0	0	0	0	18.47	
		34.60	27.42	28.50	10.61	0	42.70	16.38	0	0	0	0	
			17.30	13.71	14.25	5.31	0	21.35	8.19	0	0	0	
				8.65	6.86	7.13	2.66	0	10.68	4.10	0	0	
					4.33	3.43	3.57	1.33	0	5.34	2.05	0	
						2.17	1.72	1.79	0.67	0	2.67	1.03	
							1.09	0.86	0.90	0.34	0	1.34	
								0.55	0.43	0.45	0.17	0	
									0.28	0.22	0.23	0.09	
										0.14	0.11	0.12	
											0.07	0.06	
												0.04	
	103.79	116.86	130.22	82.69	36.05	146.14	100.87	42.26	21.15	10.59	5.30	58.09	854.01

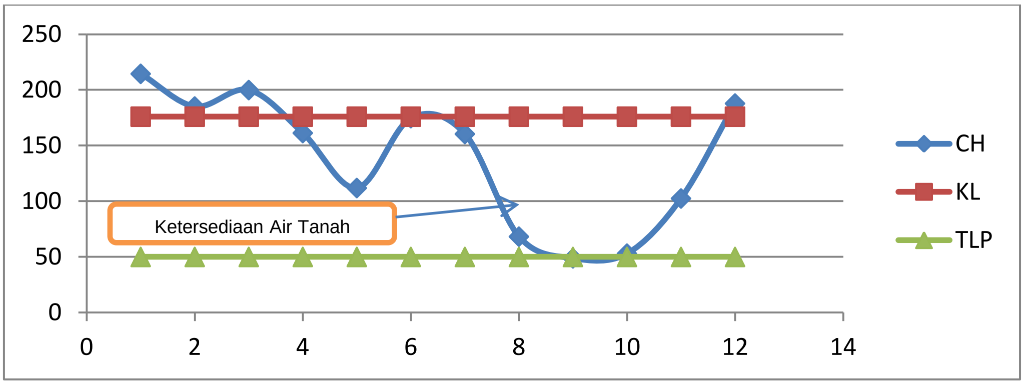

Fig. 3. Groundwater usage graph

According to the results of the runoff calculation in namlea district as also shown in Table 7, that the annual runoff amount is 854.01 mm. With the biggest run off in june at 146.14 mm and the lowest occurring in November at 5.30 mm.

4. CONCLUSION

The difference between rainfall and evapotranspiration in Namlea District was highest in June at 85.40 mm, and lowest in October at -99.83 mm. A negative value indicates that the evapotranspiration value is greater than the monthly average rainfall value during the period 2010 – 2019 in Namlea Village. Namlea Subdistrict experienced potential water loss for evaporation (APWL) in May of 35.30 mm, in August to November of August of 65.26 mm, in September of 156.24 mm, in October of 256.07 mm and in November of 303.45 mm. Neraca air lahan di Kecamatan Namlea yaitu devisit air hujan terjadi pada bulan Mei, then from August to November, while the surplus water occurs in December to July, and continues in June and July. Namlea district annual runoff is 854.01 mm. This research recommends the government to make policies that support irrigation development by paying attention to each weakness in each food crop sub-sector. Then, there needs to be further research related to superior commodities by combining several in-depth analyses regarding technological developments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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