Vol. 14, No. 2 (2025): 547 - 559 http://dx.doi.org/10.23960/jtep-l.v14i2.547-559

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Water Balance Analysis Using the Thornthwaite-Mather Method as a Basis for Cropping Pattern Development in Dry Land

Sophia Dwiratna[1,✉], Yogina Lestari Ayu[1], Chay Asdak[1], Nabila Aura Pithaloka[1]

[1] Department of Agricultural Engineering, Faculty of Agro-Industrial Technology, Padjadjaran University, Bandung, INDONESIA.

Article History:

Received : 04 October 2024
Revised : 04 November 2024
Accepted : 13 November 2024

Keywords:

Dry land,
Rainwater harvesting,
Thornthwaite-Mather,
Water balance,
Water management.

Corresponding Author:
✉ sophia.dwiratna@unpad.ac.id
(Sophia Dwiratna)

ABSTRACT

Soil water availability is crucial for supporting plant growth, especially in drylands that rely on rainfall as the primary source to meet plant water needs. Rainfall variability complicates the prediction of planting times and the optimization of cropping patterns. This condition negatively impacts productivity and increases the risk of flooding and landslides. This study aims to analyze the land water balance using the Thornthwaite Mather method on nine existing planting patterns and schedules, and to recommend strategies that can be implemented to prevent water deficit conditions. A descriptive method with a quantitative approach was used to analyze agroclimatic data to identify periods of water surplus and deficit. The results of the water balance analysis show that water surplus occurs from November to May, while deficit occurs from June to October. Conservation strategies, such as rainwater harvesting through microcatchment and macrocatchment systems, are proposed as effective approaches to address water deficit. These strategies can increase water availability, reduce the risk of crop failure, and optimize the use of available water resources. This study is expected to serve as a foundation for developing adaptive cropping patterns and enhancing the sustainability of the agricultural sector in the face of climate change.

1. INTRODUCTION

The availability of water in the soil is a crucial factor that directly affects plant growth. Rain is the main source that supports water needs in cultivating plants on dry land. However, rain has a variable pattern in terms of quantity, intensity, and arrival time, making it difficult to predict the right planting time and arrange appropriate planting patterns (Ayu *et al*., 2013). Rainfall has a major influence on the success of agriculture, because its fluctuations will determine the level of water availability throughout the year (Qudriyah *et al*., 2022).

In the dry season, water limitations are often exacerbated by the lack of adequate irrigation infrastructure. This condition can cause prolonged drought and trigger water competition among farmers. As a result, some farmers choose to implement a fallow system to maintain water availability (Djanggola, 2023). Meanwhile, excess water during the rainy season increases the risk of landslides and floods that damage agricultural land and reduce farmer productivity and income (Salampessy *et al*., 2018). This condition emphasizes the need for water management solutions that can overcome the imbalance between water needs and availability to support the sustainability of the agricultural sector.

One approach that can be used to analyze the availability and needs of water in an area is to use the land water balance through the Thornthwaite-Mather method. This method identifies the amount of water entering and leaving an area in a certain period based on rainfall parameters, potential evapotranspiration (ETP), field capacity (FC), and permanent wilting point (PWP) (Maulida *et al*., 2022; Sitanggang *et al*., 2022). Through this approach, it is possible to determine whether an area is experiencing a surplus (excess water) or a deficit (lack of water). The use of the Thornthwaite-Mather method has the advantage of simple parameters, making it easy to apply in areas with limited climate data. Various studies have also proven the accuracy of the estimates produced (Fahmi *et al*., 2019).

Accurate water balance analysis plays an important role in increasing the efficiency of water use and preventing a decrease in crop productivity due to water deficit (Perwitasari & Bafdal, 2016). Water balance-based strategies can also optimize the use of water resources, thereby reducing the risk of crop failure (Dwiratna & Suryadi, 2019). Land water balance is used to assess the suitability of agricultural land for crop water needs, regulate planting and harvesting times, and manage irrigation appropriately, which in turn supports successful crop production despite limited water resources (Sani *et al*., 2024).

Effective water management strategies also involve the application of rainwater harvesting techniques. The two main relevant methods are microcatchment and macrocatchment systems as approaches to optimizing rainwater collection and distribution. Microcatchment systems involve collecting water from a small catchment area around the crop and directly channeling it to the plant roots. Meanwhile, macrocatchment systems involve larger catchment areas, such as dams that direct water from the outer catchment area to the crop fields below (Prinz & Malik, 2002).

This study aims to analyze the land water balance using the Thornthwaite Mather method on various existing cropping patterns. The results of this analysis are expected to be the basis for developing adaptive cropping patterns and improving the sustainability of the agricultural sector in facing climate change.

2. RESEARCH METHODs

2.1. General Conditions of the Research Area

This research was conducted in Samarang District, Garut Regency, West Java. The area of Samarang District covers an area of 3674.20 ha and is located at an altitude of 500-1270 meters above sea level with geographical coordinates ranging from 107.76°-107.87° East Longitude and 7.13°-7.24° South Latitude. This area is dominated by hills (61%) and the rest is lowlands (39%). Samarang District has an agrarian character with various agricultural commodities including rice fields and dry land. Administratively, this district includes 13 villages consisting of 114 RW (Community Units) and 408 RT (Neighborhood Units) (BPP Kecamatan Samarang, 2023).

2.2. Research Tools and Materials

The tools used in this study were Garmin GPS Map 64S, labels, laptops equipped with Cropwat 8.0 and Microsoft Excel software, hammers, knives, stainless steel sample rings with a diameter of 5 cm and a height of 5 cm, blocks, roll meters, shovels, and markers. Meanwhile, the materials used in this study were rainfall data (2013-2022), climatology data (2013-2022), soil type maps, field capacity and permanent wilting point data through soil sampling and testing, and maps of Samarang District. The selection of a ten-year period (2013-2022) is in line with common practices in hydrology and climatology research which often use decadal data to ensure more stable and reliable analysis.

2.3. Research Methods

This study used a descriptive method with a quantitative approach by focusing on presenting phenomena that occur through data supported by literature studies without intending to test a particular hypothesis.

2.4. Data Analysis

Water balance was analyzed according to Thornthwaite-Mather (1957) with the following steps:

Rainfall: The average regional rainfall (R) value is calculated using the Thiessen polygon method. Whit R_1 to R_n are the rainfall at each rainfall station (mm) and A_1 to A_n are the polygon areas of each rainfall station (m^2), the average rainfall was calculated according to Equation (1) (Harto, 1993).

$$R = \frac{R_1A_1 + R_2A_2 + R_3A_3 + \cdots + R_nA_n}{A_1 + A_2 + A_3 + \cdots + A_n} \tag{1}$$

***Potential Evapotranspiration* (*ETP*):** The *ETP* value is calculated based on climatological data (air temperature, humidity, wind speed, and duration of sunlight) using the Penman Monteith method on Cropwat 8.0 software.

***Plant Coefficient* (*Kc*):**

The plant coefficient (*Kc*) value of each plant was determined based on data from FAO.

***Plant Evapotranspiration* (*ETC*):** The *ETC* value is determined using Equation (2) (Allen *et al*., 1998).

$$ETC = Kc \times ETP \tag{2}$$

The calculated *ETC* was used to determine its difference from rainfall according to (*R* – *ETC*).

***Accumulation of Potential Water Loss* (*APWL*):** The *APWL* value was determined by summing the negative (R – ETP) values sequentially month by month.

***Soil Water Content* (*KAT*):** The *KAT* value was determined according to the *APWL* value, if the *APWL* value is 0 then the *KAT* value meets the field capacity (*KL*), while if the *APWL* value is not 0 it was calculated as the following.

$$KAT = TLP + AT \times \left(1{,}00412351 - \frac{1{,}073807306}{AT}\right)^{|APWL|} \tag{3}$$

where *TLP* is permanent wilting point (mm), *AT* is available water (*KL* – *TLP*) (mm), *KL* is field capacity (mm), and |*APWL*| is the absolute value of accumulated potential water loss (mm).

***Changes in Soil Water Content* (*dKAT*):** The *dKAT* value (mm) was determined by subtracting the *KAT* value of that month from the *KAT* value of the previous month.

***Actual Evapotranspiration* (*ETA*):** The *ETA* value was determined based on the *CH* and *ETC* values, if the *CH* > *ETC*, then the *ETA* value is the same as *ETC*, while if the *CH* < *ETC* then it is calculated using Equation 4.

$$ETA = CH + |dKAT| \tag{4}$$

***Deficit* (*D*) and *Surplus* (*S*):** The deficit value was obtained only in conditions of *CH* < *ETP*, and was calculated using Equation (5). The surplus value (*S*) is obtained only in conditions CH > ETP, and is calculated using Equation (6).

$$D = ETC - ETA \tag{5}$$

$$S = CH - ETC - dKAT \tag{6}$$

The final analysis in the form of recommendations prepared as a follow-up to the land water balance analysis, aims to propose implementative strategies to prevent water deficits and ensure optimal water availability.

3. RESULTS AND DISCUSSION

3.1. The Existing Planting Patterns and Schedules

Information on existing planting patterns and schedules was obtained through interviews with farmers in Samarang District. The analysis only focused on the most popular crops, namely corn, chili, tomato, cabbage, mustard greens, shallots, eggplant, vetiver, oranges, and coffee. The assessment criteria include an analysis of the extent to which planting patterns depend on certain seasons, especially to reduce the risk of crop failure. This also aims to ensure that the planting patterns applied can be adjusted to market needs, so that agricultural products continue to have stable demand and benefit farmers. Based on the interview, the planting patterns and schedules are listed in Table 1.

3.2. Rainfall Analysis

Rainfall analysis in Samarang District was conducted using the Thiessen polygon method. Data were obtained from four rainfall stations around the research location, namely Paseh, Cisanti, Leuwigoong, and Pangauban Stations. Figure 1 displays a polygon map formed from the four stations. Based on the analysis results, the percentage of each station to form this polygon is as follows, (1) Paseh Station is 17.73% or 100.54 ha; (2) Cisanti Station is 1.45% or 8.22 ha; (3) Leuwigoong Station is 48.15% or 273.11 ha; and (4) Pangauban Station 32.67% or 185.28 ha.

Table 1. Existing planting patterns and schedules in Samarang District

No	MT I	MT II	MT III
I	Chili (Nov I – Apr III)	Tomatoes (May I – Jul III)	Cabbage (Aug I – Oct III)
II	Chili (Nov I – Apr III) Tomatoes (Nov I – Jan III)	Cabbage (May I – Jul III)	Mustard greens (Aug I – Sep I)
III	Chili (Nov I – Apr III) Tomatoes (Nov I – Jan III)	Corn (May I – Jul III) Cabbage (May I – Jul III)	Corn (Aug I – Oct III)
IV	Chili (Nov I – Apr III) Tomatoes (Nov I – Jan III)	Corn (May I – Jul III) Mustard greens (May I – Jun I)	Shallot (Aug I – Sep III)
V		Patchouli (Nov I – Okt III)	
VI		Orange (Nov I – Okt III)	
	Chili (Nov I – Apr III)		
VII		Orange (Nov I – Okt III)	
		Corn (May I – Jul III)	
VIII		Coffee (Nov I – Okt III)	
	Eggplant (Nov I – Feb III)	Corn (May I – Jul III)	

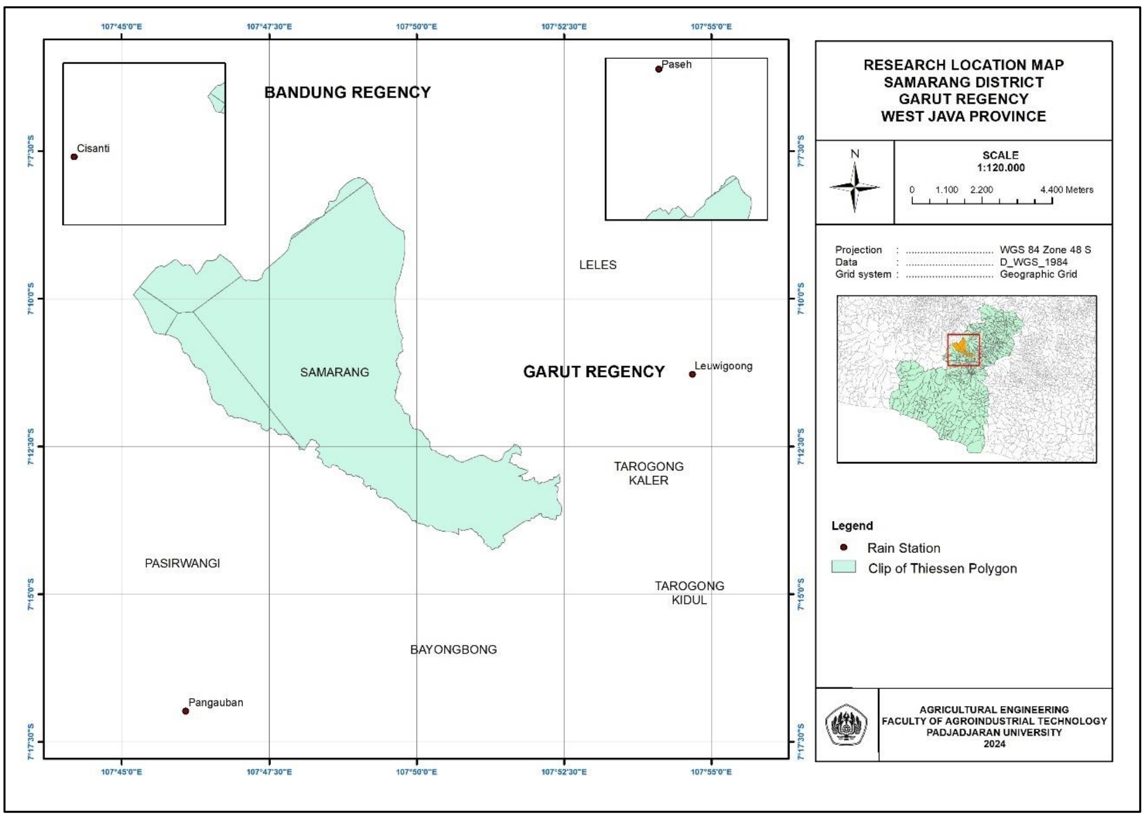
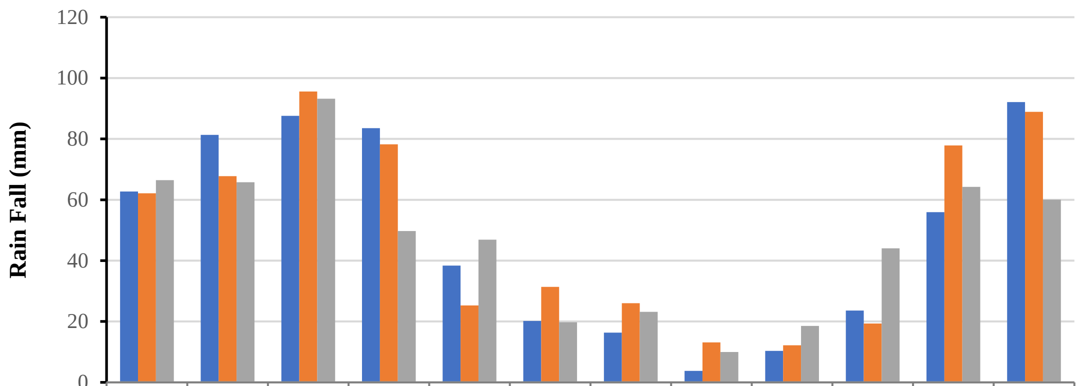


Figure 1. Thiessen polygon map of rainfall in Samarang District

3.3. Rainfall Analysis

Rainfall analysis in Samarang District was conducted using the Thiessen polygon method. Data were obtained from four rainfall stations around the research location, namely Paseh, Cisanti, Leuwigoong, and Pangauban Stations. Figure 1 displays a polygon map formed from the four stations. Based on the analysis results, the percentage of each station to form this polygon is as follows, (1) Paseh Station is 17.73% or 10,054,279.83 m^2; (2) Cisanti Station is 1.45% or 821,931.44 m^2; (3) Leuwigoong Station is 48.15% or 27,310,770.40 m^2; and (4) Pangauban Station 32.67% or 18,528,365.52 m^2.



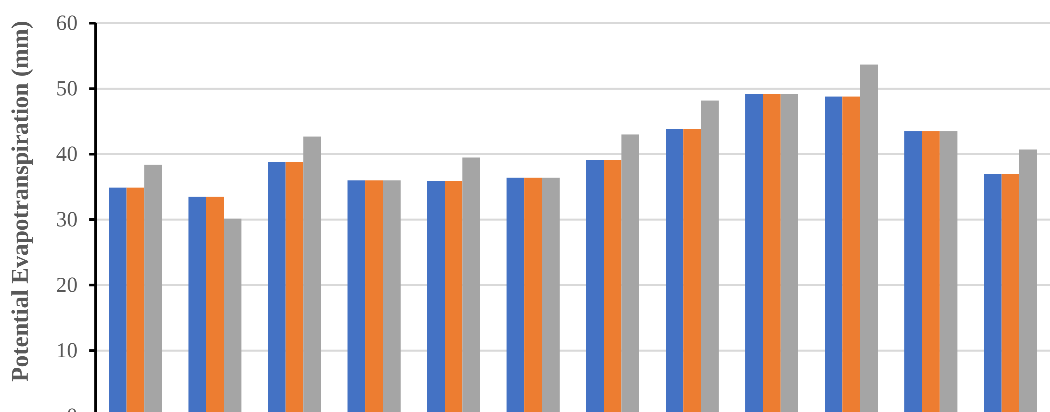
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RF I	62.74	81.31	87.57	83.54	38.36	20.16	16.36	3.77	10.37	23.62	55.93	92.12
RF II	62.12	67.79	95.58	78.21	25.29	31.37	26.01	13.13	12.18	19.36	77.87	88.92
RF III	66.43	65.78	93.22	49.73	46.88	19.74	23.19	10.00	18.54	44.04	64.24	60.06

Figure 2. Average rainfall (10-day period) in the area of Samarang District

Figure 2 shows the 10-day average rainfall data for area at the study location. Overall, the three dasarian areas show the same pattern, where the highest rainfall occurs in March and the lowest in August. The period with low rainfall occurs between May - August, reflecting the dry season. Conversely, the highest rainfall was recorded in November - April, indicating the rainy season with abundant water supply.

3.4. Potential Evapotranspiration Analysis

Potential evapotranspiration (*ETP*) in this study was calculated using the Penman-Monteith method through Cropwat 8.0 software. This method is recommended by FAO as the best approach for estimating evapotranspiration and allows for accurate water balance analysis (Perwitasari & Bafdal, 2016). The input parameters include temperature, humidity, wind speed, and duration of sunlight. The results are graphed as in Figure 3. The *ETP* values were then multiplied with plant coefficients (*Kc*) to get actual values of plant evapotranspiration (*ETC*) for each cropping pattern.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ETP I	34.9	33.5	38.8	36	35.9	36.4	39.1	43.8	49.2	48.8	43.5	37
ETP II	34.9	33.5	38.8	36	35.9	36.4	39.1	43.8	49.2	48.8	43.5	37
ETP III	38.39	30.15	42.68	36	39.49	36.4	43.01	48.18	49.2	53.68	43.5	40.7

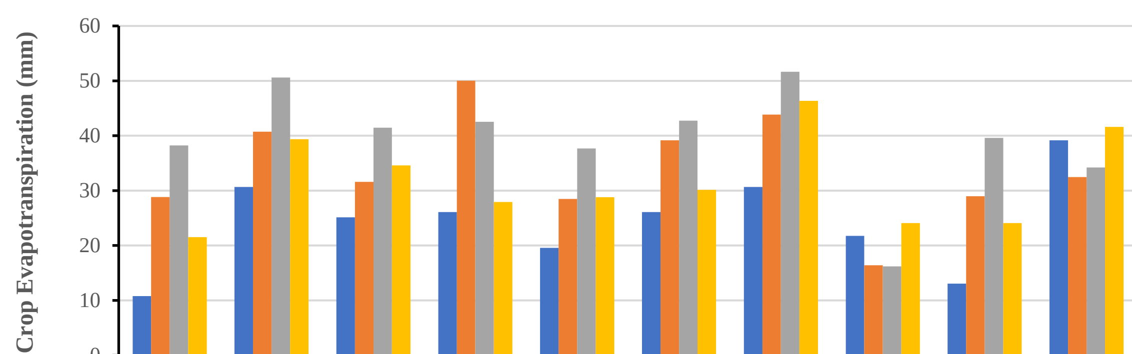
Figure 3. Potential evapotranspiration (*ETP*) based on 10-daily period.

3.5. Plant Coefficients

The plant coefficient is needed to calculate plant evapotranspiration (*ETC*). Each phase of plant growth has different coefficient values and ages, as listed in Table 2. The coefficient value of plants based on three classifications (secondary crops, vegetables, and plantation) of commodities planted in the study location based on four growth phases. Through the data, vegetable plants generally have a relatively higher coefficient value compared to secondary crops and plantations.

Table 2. Plant coefficients based on growth phase for different crop commodities

Crop Class	Commodity	Age	Growth Phase			
			Initial	Development	Mid season	Late season
Secondary (Palawija)	Corn (*Zea mays*)	3 month	0.30	0.73	1.05	0.55
Vegetables	Shallot (*Allium cepa* var. *aggregatum*)	2 month	0.70	0.93	1.05	0.80
	Sawi (*Brassica rapa*)	40 day	0.70	0.88	1.05	0.95
	Tomatoes (*Solanum lycopersicum*)	3 month	0.60	1.15	1.15	0.80
	Chili (*Capsicum annuum*)	6 month	0.45	0.92	1.08	0.80
	Eggplant (*Solanum melongena*)	4 month	0.60	0.90	1.05	0.90
	Cabage (*Brassica oleracea* var. *capitata*)	3 month	0.70	0.91	1.05	0.95
Plantation	Orange (*Citrus sp.*)	1 year	0.50	0.47	0.45	0.55
	Patchouli (*Chrysopogon zizanioides*)	1 year	0.30	0.83	1.10	0.55
	Coffee (*Coffea sp.*)	3 year	0.90	0.93	0.95	0.95



	Corn	Onion	Mustard Green	Tomato	Chili	Eggplant	Cabbage	Orange	Patchouli	Coffee
ETC Ini	10.77	30.66	25.13	26.1	19.58	26.1	30.66	21.75	13.05	39.15
ETC Dev	28.83	40.73	31.59	50.03	28.49	39.15	43.84	16.403	28.967	32.457
Etc Mid	38.22	50.59	41.46	42.55	37.69	42.735	51.66	16.2	39.6	34.2
ETC Late	21.51	39.36	34.58	27.92	28.8	30.15	46.36	24.09	24.09	41.61

Figure 4. Average of actual plant evapotranspiration (*ETC*)

3.6. Actual Evapotranspiration (*ETC*)

Plant evapotranspiration is calculated by multiplying the *ETP* value by *Kc* of each plant growth phase. The average value of plant evapotranspiration (*ETC*) for each growth phase is presented in Figure 4. The average value of plant evapotranspiration (*ETC*) for various types of commodities at four growth phases. The numbers in this table describe the water requirements for plants to go through the evaporation and transpiration processes at each phase. In general, plants require more water during the mid-season phase due to the intensive plant formation process (Adiningrum, 2015).

3.7. Soil Moisture Content

The results of water content testing at field capacity (KL) and permanent wilting point (TLP) conditions are shown in Table 3. Based on the results of soil sample testing, latosol soil samples have higher field capacity and permanent wilting point values than podsol soil samples. This shows that latosol soil types provide better conditions to support plant growth and development because they have a higher water storage capacity and availability than podsol soil types (Sari *et al*., 2020). Therefore, water conservation strategies must be adjusted to soil characteristics to increase the efficiency of water use and prevent soil damage (Auliyani, 2020).

Table 3. Field capacity (KL) and permanent wilting point (TLP) values

Soil type	Average KL (%)	Average TLP (%)
Podsol	34.02	18.84
Latosol	37.05	20.15

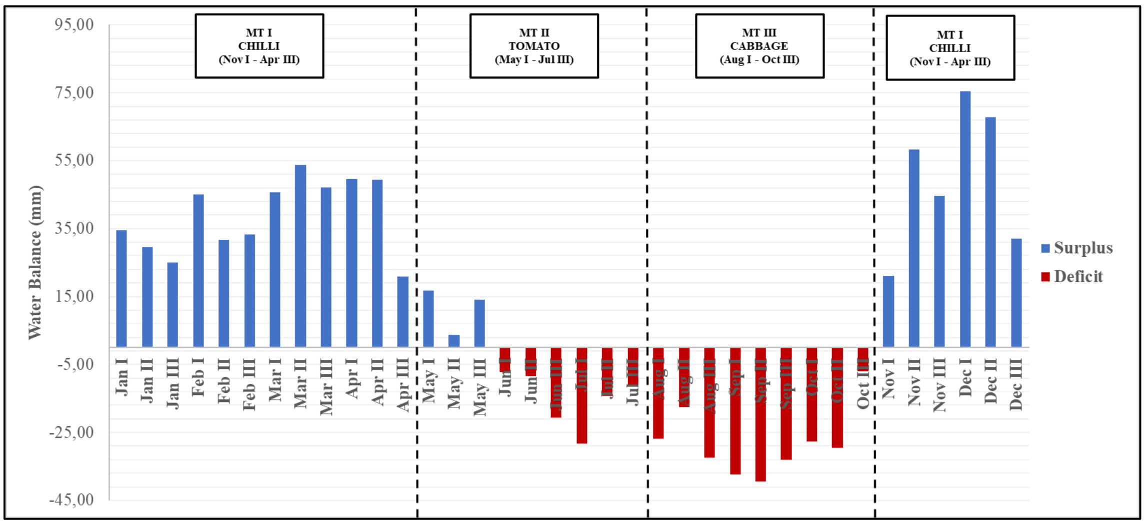


Figure 5. Cropping pattern and planting schedule for (Chili – Tomatoes – Cabbage)

3.8. Water Balance Analysis

The results of the water balance analysis for the existing planting pattern and schedule are shown in Figures 5-12. Figure 5 shows that water deficits occur in MT II for tomatoes (June I - July III) and MT III for cabbage (August I - October III). Chilies in MT I have quite good tolerance to drought, so they can still survive even though rainfall decreases. Tomatoes and cabbage require a consistent water supply, especially during the vegetative growth phase. Water shortages in MT II and MT III can reduce crop yields, especially if there is no additional water supply.

Figure 6 shows that water deficits occur in MT II for cabbage (June I - July III) and MT III for mustard greens (August I - September I). The intercropping of chilies and tomatoes in MT I allows for optimal land use without interfering water and nutrient needs for each other. However, cabbage and mustard greens only depend on soil moisture.

Figure 7 shows that water deficits occur in MT II for intercropping between cabbage and corn (June I - July III) and MT III for corn (August I - October III). Chili and tomatoes in MT I can take advantage of higher rainfall at the beginning of the rainy season, but corn requires a lot of water in the seed filling phase (late season). Water shortages in MT II and MT III can increase the risk of crop failure, especially for corn which has high water needs.

Figure 8 shows that water deficit occurs in MT II for tumpeng sari between corn and mustard greens (June I - July III) and MT III for shallots (August I - September III). Chilies and tomatoes in MT I can survive with the rainfall that occurs, but the water shortage that occurs in MT II and MT III is very critical for corn, mustard greens, and shallots that require a higher water supply. Without additional water supply, the risk of crop failure is very high.

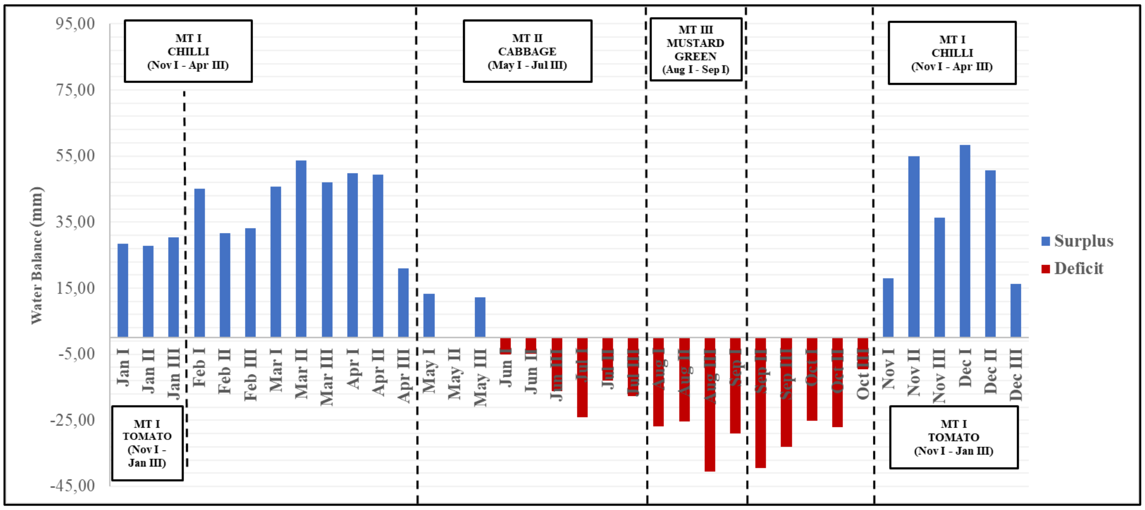


Figure 6. Cropping pattern and planting schedule for (Chili//Tomatoes – Cabbage – Mustard)

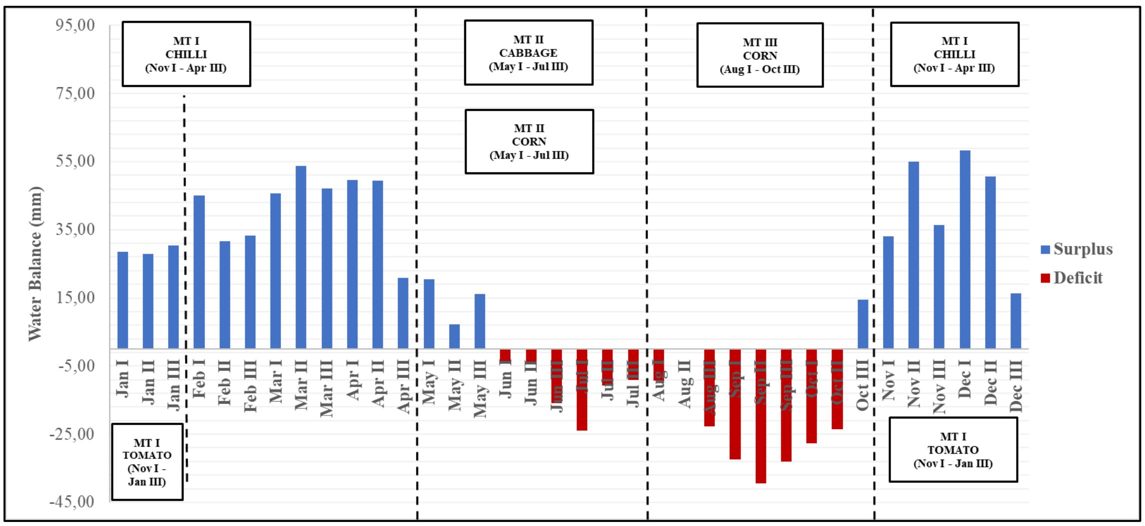


Figure 7. Cropping pattern and planting schedule for (Chili//Tomatoes – Cabbage//Corn – Corn)

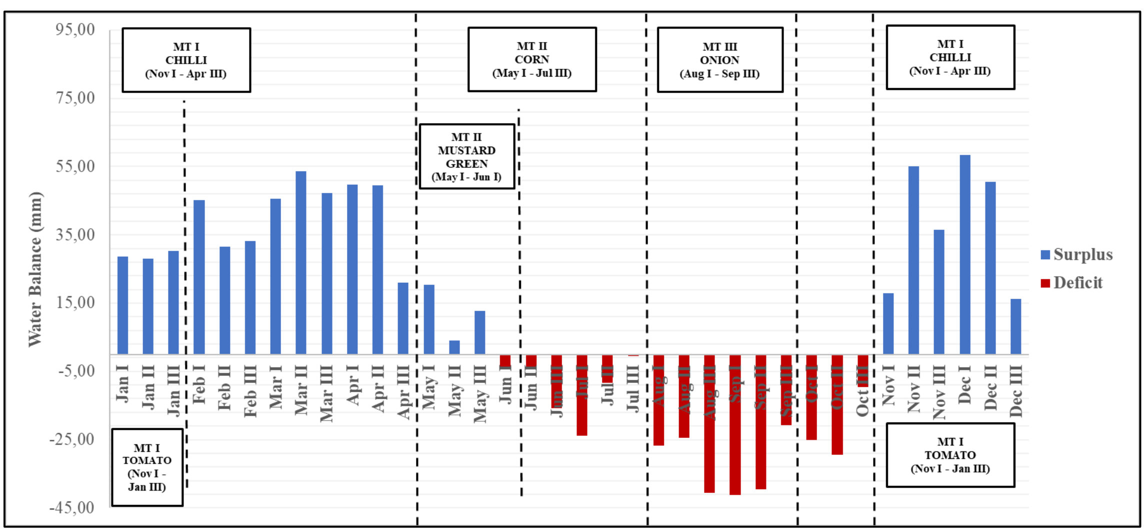


Figure 8. Cropping pattern and planting schedule for (Chili//Tomatoes – Corn//Mustard – Shallot)

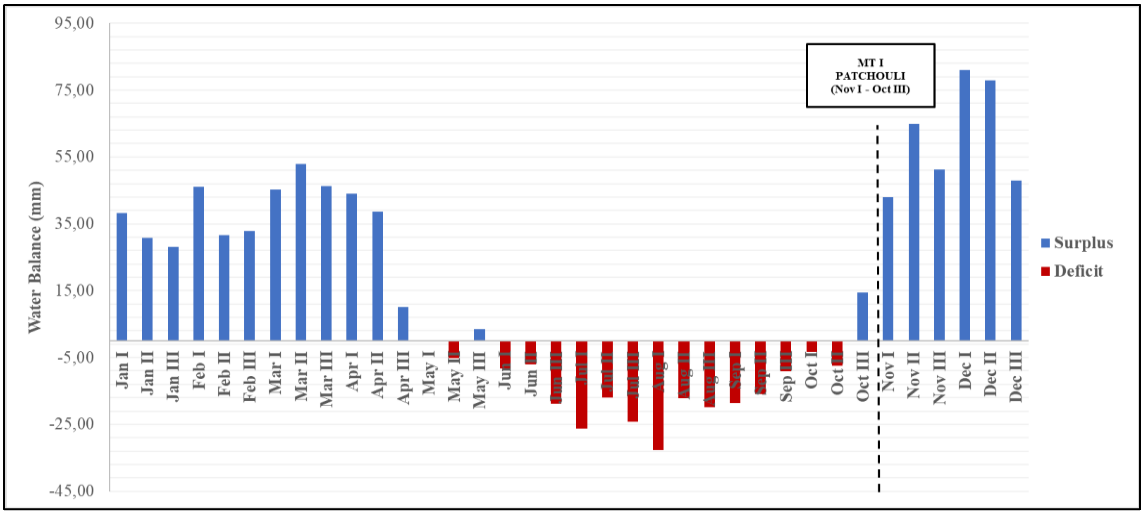


Figure 9. Cropping pattern and planting schedule for Patchouli (Akarwangi)

Figure 9 shows that vetiver planted throughout the year since November has a water surplus. On the other hand, the deficit condition in this planting pattern lasts almost half a year, namely from May to October. This indicates that the availability of water in the land is no longer sufficient for the needs of vetiver plants. However, in deficit conditions, vetiver can still survive well thanks to its deep and strong roots.

Figure 10 shows that water deficit occurs in MT I for oranges (August I - October II). Chilies in MT I can take advantage of the fairly high rainfall at the beginning of the rainy season, but oranges require a stable water supply throughout the year. Water shortages in MT I can cause a decrease in the quality and quantity of orange yields.

Figure 11 shows that water deficits occur in MT I for oranges (August I - October II) and MT II for corn (June III - October II). Oranges require a stable water supply throughout the year, so water shortages in MT I greatly affect their yields. Corn in MT II can take advantage of rainfall at the end of the dry season, but water shortages in MT II can still affect their growth, especially in the seed formation phase.

Figure 12 shows that water deficit occurs in MT I for coffee (August I - October II) and MT II for corn (June I - October III). Coffee as an annual plant is resistant to drought. However, eggplant and corn require a fairly high water supply during the critical phase of their growth.

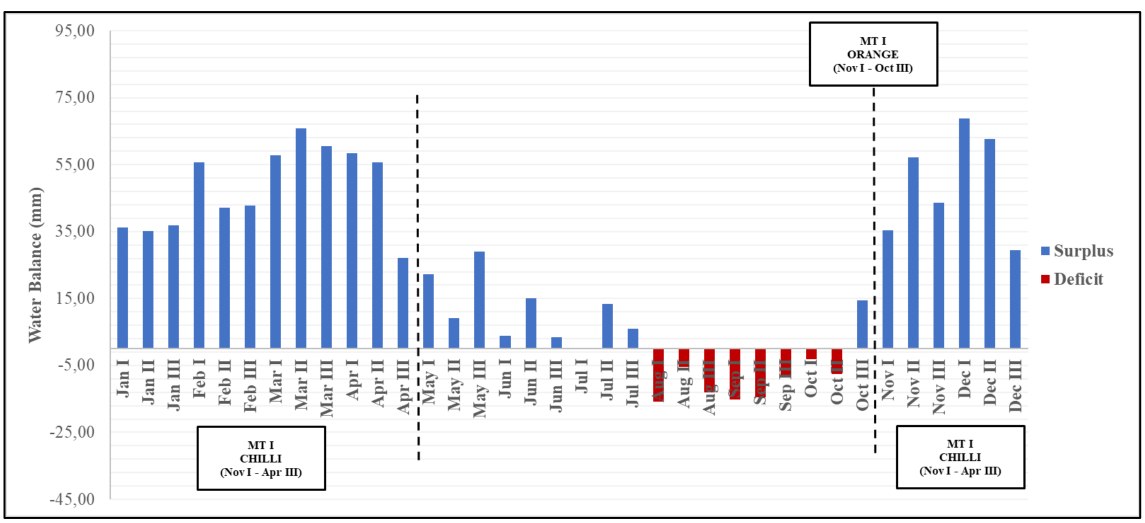


Figure 10. Cropping pattern and planting schedule for Orange//Chili

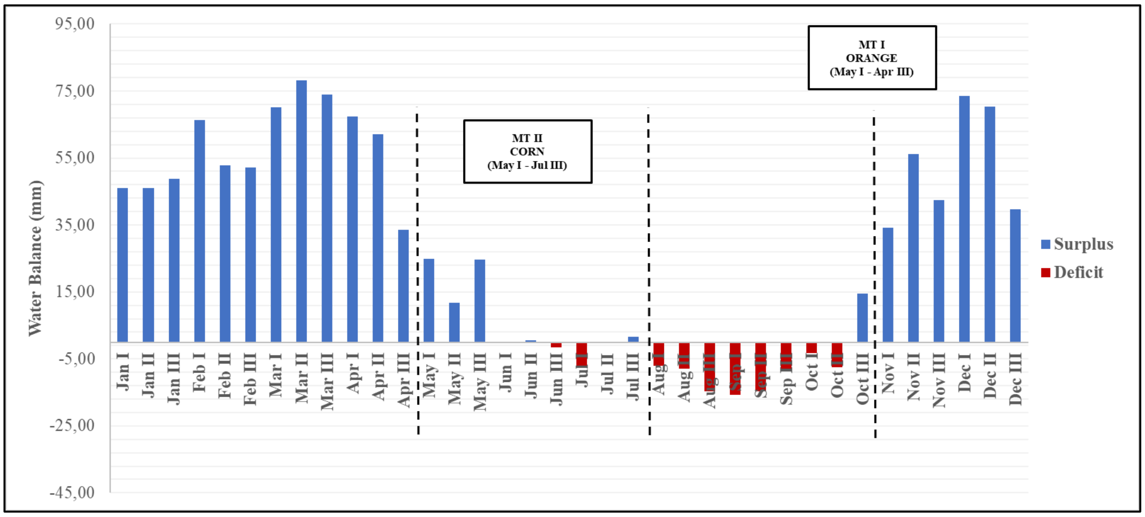


Figure 11. Cropping pattern and planting schedule for Orange//Corn

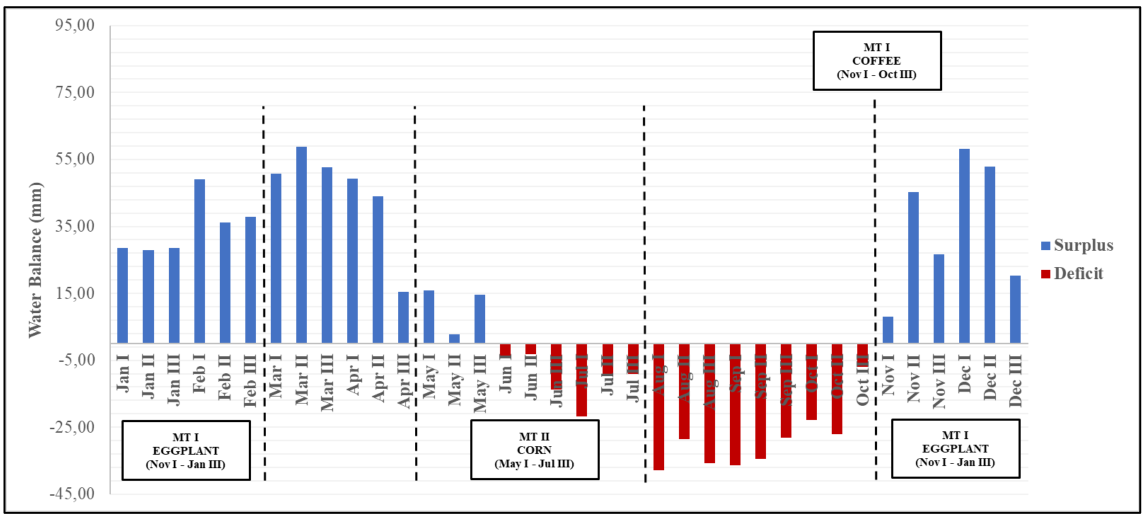


Figure 12. Cropping pattern and planting schedule for Coffee//Eggplant – Corn

Overall, the success or failure of each cropping pattern is greatly influenced by the specific water requirements of the crop, the planting time adjusted to the rainfall pattern, and the use of appropriate water management strategies, such as irrigation, soil moisture conservation, and selection of drought-resistant varieties. The water deficit period for each cropping pattern is presented in detail in Table 4.

Table 4. Water balance analysis for the existing cropping patterns

No	Cropping Pattern	Water Balance
I	Chili–Tomato–Cabbage	Deficit on MT II tomatoes (Jun I – Jul III) & MT III cabbage (Aug I – Oct III)
II	Chili//Tomato–Cabbage–Mustard	Deficit on MT II cabbage (Jun I – Jul III) & MT III mustard (Aug I – Sep I)
III	Chili//Tomato–Cabbage//Mize–Corn	Deficit on MT II cabbage//corn (Jun I – Jul III) & MT III corn (Aug I – Oct II)
IV	Chili//Tomato–Corn//Mustard–Shallot	Deficit on MT II corn//mustard (Jun I – Jul III) & MT III shallot (Aug I – Sep III)
V	Patchouli (Akarwangi)	Deficit on May II – Oct III
VI	Orange//Chili	Deficit on MT I orange (Aug I – Oct II)
VII	Orange//Corn	Deficit on MT I orange and MT II corn (Jun III – Oct II)
VIII	Coffee//Eggplant – Corn	Deficit on MT I orange and MT II corn (Jun I – Oct III)

// = intercropping

3.9. Strategy

Effective water resource management is needed to respond to the results of the water balance analysis on existing planting patterns and schedules in Samarang District. Although farmers' interest in rainwater harvesting is high, its application is still limited, thus opening up great opportunities for wider implementation. Prinz & Malik (2002) explained that rainwater harvesting techniques are divided into microcatchment and macrocatchment, which can be adjusted to local topography. Examples of microcatchment and macrocatchment techniques that can be used according to conditions and problems at the study location are listed in Tables 5 and 6 (Critchley & Siegert, 1991).

Table 5. Model for rain harvesting through microcatchment

No	Technique	Description	Application site	Advantages	Disadvantages
1	Contour Bunds	Soil beds parallel to contour	Land with slopes 8-25%	Reduce erosion risk and increase infiltration	Not suitable for soil that prone to erode
3	Negarin	Diamond-shaped basin with infiltration holes	Dry lands	Increase soil water reserves	Require regular maintenance to prevent holes from clogging
4	Pitting	Making small holes to catch rainwater	Land with slopes 5-15%	Effective in areas with irregular rainfall	Less effective on soils with low permeability
5	Eyebrow Technique	Semicircular mounds around plants	Small moors or perennial crops	Effective for perennials (trees)	Less efficient for large areas
6	Vallerani Type	Small ditches to hold rainwater	Dry land	Allows large-scale rainwater harvesting	Requires expensive special equipment

Table 6. Model for rain harvesting through macrocatchment

No	Technique	Description	Application site	Advantages	Disadvantages
1	Hillside Conduit Systems	Channels on mountain slopes for runoff	Mountains with steep slopes	Reduces erosion risk and increases water infiltration	Not suitable for easily eroded soil
2	Cultivated Reservoir	Artificial reservoirs to store rainwater	Areas with seasonal rainfall	Effective in storing large amounts of water	High construction costs
3	Stone Dams	Stone dams on small rivers	Small rivers or streams	Prevents riverbank erosion	Need many laborers
4	Liman Terraces	Terraces to hold back water runoff	Flat to gently sloping lands	Suitable for agricultural land	Increases erosion risk
5	Jessour Macro-catchments	Combination of small dams and terraces	Valleys or land prone to erosion	Reduces water flow	Complicated construction

The choice of conservation method is highly dependent on geographical conditions, soil type, land slope, and the specific needs of farmers. It is important for local communities to understand and adopt these techniques, so that the benefits can be directly felt in increasing the productivity and sustainability of dryland agriculture. The application of rainwater harvesting techniques has been proven effective in addressing water in areas with climates similar to the study location. For example, in Palangkaraya, where infiltration wells are used to increase the absorption of rainwater into the soil to help reduce puddles and increase groundwater availability (Emilda *et al*., 2017).

Setiawan (2018) also noted that rainwater harvesting techniques can increase water availability in agricultural land by up to 40% during the dry season, while reducing the risk of crop failure due to water shortages. Research by Heryani (2021) discusses the development of rainwater harvesting technology to meet domestic needs in Indonesia. Although the main focus is on household needs, the techniques discussed can be adapted for agricultural purposes. This is especially true in terms of storing and distributing rainwater which is useful for reducing the risk of flooding and drought. In addition, Dwiratna & Suryadi (2019) showed that the water needs of plants during one growing season can be met by the volume of water contained in the runoff water harvesting pond. Through this technique, collected rainwater can be used for crop irrigation, without relying on external water sources which are often limited. The proper application of rainwater harvesting allows farmers to optimize the use of available water resources, thus supporting the success of agriculture even though they only rely on harvested rainwater.

4. CONCLUSION

The condition of the land water balance in Samarang District on Podsol soil experienced a surplus from November to May, so that this period is the right time to plant crops with high water needs. Meanwhile, the deficit occurred from June to October, so planting should be avoided because the availability of water will not be sufficient for plant needs. The results of the water balance analysis indicate the need for conservation through rainwater harvesting with a microcatchment system (water collection in small catchment areas) and macrocatchment (water collection in large catchment areas). Further research is needed to evaluate the effectiveness of this technique in preventing water deficits, including examining the success and challenges of its implementation in the field in terms of technical, cost, and farmer participation. The government needs to be involved in providing technical and financial support, as well as educating farmers so that they can actively participate in the application of rainwater harvesting technology.

REFERENCES

Adiningrum, C. (2015). Analisis perhitungan evapotranspirasi aktual terhadap perkiraan debit kontinyu dengan metode Mock. *Jurnal Teknik Sipil*, ***13***(2), 158-172. https://doi.org/10.24002/jts.v13i2.649

Auliyani, D. (2020). Upaya konservasi tanah dan air pada daerah pertanian dataran tinggi di Sub-Daerah Aliran Sungai Gandul. *Jurnal Ilmu Pertanian Indonesia*, ***25***(3), 382-387. https://doi.org/10.18343/jipi.25.3.381

Ayu, I. W., Prijono, S., & Soemarno. (2013). Evaluasi ketersediaan air tanah lahan kering di Kecamatan Unter Iwes, Sumbawa Besar. *Jurnal Pembangunan dan Alam Lestari*, ***4***(1), 18-25.

Allen, R.G., Pereira, L.S., Raes, D., & Smith, M. (1998). *FAO Irrigation and Drainage Paper No.56: Crop Evapotranspiration* (*Guidelines for Computing Crop Water Requirements*). Food and Agriculture Organization (FAO), Rome.

BPP (Balai Penyuluhan Pertanian) Kecamatan Samarang. (2023). *Laporan Pertanian Kecamatan Samarang Tahun 2022*. Balai Penyuluhan Pertanian, Samarang.

Critchley, W. & Siegert, K. (1991). *A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production*. Food and Agriculture Organization (FAO), Roma.

Dinas Pertanian Kabupaten Garut. (2023). *Laporan Tahunan 2023.* Dinas Pertanian Kabupaten Garut.

Djanggola, A.R. (2023). *Membedah Kemiskinan Petani (Studi Kasus di Daerah Kabupaten Banggai)*. Syakir Media Press, Makassar.

Dwiratna, S. & Suryadi, E. (2019). Penjadwalan irigasi menggunakan neraca air harian pada budidaya ubi jalar (*Ipomea batatas* L.) varietas Rancing. *Jurnal Agrotek Indonesia*, ***4***(1), 8-14. https://journal.unsika.ac.id/agrotek/article/view/1857

Emilda, A., Tray, C.S., Sugiatmo, S., Aminah, A., & Haska, H. (2017). *Buku Praktis Proklim*. Direktorat Jenderal Pengendalian Perubahan Iklim Kementrian Lingkungan Hidup dan Kehutanan, Jakarta.

Fahmi, L.A., Nurdiyanti, A., Dewi, J.C., & Carolin, A. (2019). Analisis kebutuhan air padi sawah dalam menentukan jadwal irigasi dan skema irigasi di Kecamatan Trucuk Kabupaten Klaten berbasis software Cropwat 8.0. *Prosiding Seminar Nasional Geografi Universitas Muhammadiyah Surakarta 2019*: 234-243.

Harto, S. (1993). *Analisis Hidrologi*. PT Gramedia Pustaka Utama, Jakarta.

Hatta, H.R., Maharani, S., Arifin, Z., Annisa, M., Khairina, D. M., & Ramadiani. (2018). *Sistem Pakar Pemilihan Tanaman Pertanian untuk Lahan Kering*. Mulawarman University Press, Samarinda.

Maulida, Y. N., Anisarida, A. A., & Hafudiansyah, E. (2022). Kajian neraca air Daerah Irigasi Ciherang Kabupaten Bandung Provinsi Jawa Barat. *Jurnal Teknik Sipil Cendekia*, ***3***(1), 1-13. https://doi.org/10.51988/jtsc.v3i1.47

Oldeman, L.R., & Frère, M. (1982). *Technical Report on a Study of the Agroclimatology of the Humid Tropics of Southeats Asia*. Food and Agriculture Organization of the United Nations.

Perwitasari, S.D.N. & Bafdal, N. (2016). Penjadwalan irigasi berbasis neraca air pada sistem pemanenan air limpasan permukaan untuk pertanian lahan kering. *Jurnal Ketenikan Pertanian*, ***4***(2), 219-226. https://doi.org/10.19028/jtep.04.2.219-226

Prinz, D. & Malik, A.H. (2002). *Runoff Farming*. Institute of Water Resources Management, Hydraulic and Rural Engineering, Germany.

Qudriyah, R. A., Prasetyo, R., & Yusuf, M. A. (2022). Analisis pengaruh curah hujan terhadap estimasi produktivitas padi berbasis pemrosesan citra Sentinel 2A pada Subround I dan II Tahun 2018-2021 (Studi kasus: Kecamatan Winong, Kabupaten Pati). *Jurnal Geodesi Geomatika*, ***5***(1), 16-23. https://doi.org/10.14710/elipsoida.2022.16859

Saidah, H., Sulistyono, H., & Budianto, M. B. (2020). Kalibrasi persamaan Thornthwaite dan evaporasi panci untuk memprediksi evapotranspirasi potensial pada daerah dengan data cuaca terbatas. *Jurnal Sains Teknologi & Lingkungan*, ***6***(1), 72-84.

Salampessy, Y.L.A., Lubis, D.P., Amien, I., & Suhardjito, D. (2018). Menakar kapasitas adaptasi perubahan iklim petani padi sawah (Kasus Kabupaten Pasuruan Jawa Timur). *Jurnal Ilmu Lingkungan*, ***16***(1), 25-34. https://doi:10.14710/jil.16.1.25-34

Sani, N. F., Darwis, D., Alam, S., Rustam, R., Leomo, S., & Erawan, D. (2024). Analisis neraca air lahan untuk perencanaan tanaman padi gogo dan jagung pada Sub DAS Wolasi. *Jurnal Agroteknologi*, 3(1), 38-48.

Sari, M.A., Nugroho, H.A., & Sari, D.F. (2020). Kapasitas penyimpanan dan ketersediaan air tanah pada jenis tanah Latosol dan Podsol di wilayah pertanian. *Jurnal Tanah dan Lingkungan*, ***22***(1), 27-37. https://doi.org/10.21082/jtl.v22n1

Setiawan, I. (2018). Pemanenan air hujan sebagai solusi defisit air di lahan pertanian kering. *Jurnal Sumber Daya Alam*, ***7***(2), 123-135.

Sitanggang, W.R., Amaru, K., Sampurno, R.M., & Situmorang, Y.L.A. (2022). Analisis neraca air metode Thornthwaite-Mather pada budidaya tanaman jagung manis menggunakan sistem irigasi dan mulsa. *Seminar Nasional Penelitian dan Pengabdian kepada Masyarakat Universitas Muhammadiyah Metro Tahun 2022*, ***4***(1), 84-96.

Swardana, A. (2020). Pemanfaatan data SIG untuk analisis perubahan penggunaan lahan sawah di Kabupaten Garut (2009-2018). *Conference on Innovation and Application of Science and Technology 2020*. Universitas Widyagama, Malang.

Thornthwaite, C.W. & Matter, J.P. (1957). *Instruction and Tables for Computing Potential Evapotranspiration and The Water Balance*. Drexel Institute of Climatology, New Jersey: 254 pp.