Crop Pattern Suitability Based on Water Availability in Dry-Land Agriculture Nawungan, Selopamioro, Imogiri, Bantul

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Abstract. Climate change has changed the rainfall pattern. It causes a shifting in the beginning of the rainy and dry seasons as well as the planting season. This will affect changes in the calculation of the potential availability of agricultural water due to the distribution of water that is not in accordance with needs. Strategies and adaptation technology so that the agricultural sector is resilient to climate change are urgently needed. Crop patterns setting is considered an alternative to adapt to the limited water availability in Nawungan. The purpose of this research is to evaluate the suitability of cropping patterns in Nawungan agricultural land to find out whether the cropping patterns that have been or are being implemented are still appropriate or not with climate change. The research methods included interviews, surveys and field measurements, as well as laboratory analysis. Interviews were conducted with 30 respondents to collect information regarding variations in crop patterns applied. Field surveys were carried out to determine the zoning of crop patterns based on interview data. Field measurements were made of landscape analysis. Laboratory analysis was carried out on the measurement of soil parameters. The results showed that crop pattern that is suitable with the water availability at the research location is P3 (paddy-secondary crop-bero) zoning. Cropping period that has sufficient water availability is MT-2.

1. Introduction

In the past, farmers used pranoto mongso as a benchmark in farming, such as determining the start of the rice planting season. Farmers' understanding in reading phenomena or natural phenomena that are happening at this time tends to be difficult due to uncertain climate change [1]. As a result of climate change, the rainfall pattern has also changed, causing a shift in the beginning of the rainy and dry seasons as well as the planting season. This will affect changes in the calculation of the potential availability of agricultural water due to the distribution of water that is not in accordance with needs [2].

Changes in rain patterns due to climate change affect the amount of water availability. According to Ayu et al. [3], mastery of rainfall variations throughout the season can be used as an estimate of the amount of groundwater available in a rain-fed area for a certain period of time. Rainfall is one of the climatic factors that affect the success of plant productivity.

The impact of climate change, especially the agricultural sector, is feared to bring problems to the sustainability of agricultural production. For example, research by Runtunuwu and Syahbudin [4] states that there has been a shift in the beginning of the season and planting period as a result of a decrease in the amount of rainfall and changes in rain patterns in 1879 – 2006 in the Tasikmalaya area, West Java, thus reducing the potential for one rice planting period. . Another example of a plant that is vulnerable to changes in rainfall patterns is shallots. If the rainfall is high, the shallots will be more susceptible to fungal attack until they rot and if the drought conditions will cause the plants to dry [5].

Strategies and adaptation technology so that the agricultural sector is resilient to climate change are urgently needed. Adaptation technology related to excess water management during the rainy season by making ponds can be used to irrigate crops during the dry season where water availability is limited [6]. Apart from that, research by Banjarnahor and Simanjuntak [7] in Central Sumba regarding the regulation of plant types as well as research by Rusastra et. al. [8] who apply land use for lowland rice-rice-soybean crops can be used as a form of limited water management during the dry season so that production can be maintained.

Rainfall in the Selopamioro area tends to be low. According to Kurniawan [9] rainfall in the Selopamioro area is 1,564 mm/year with the peak of the rainy season in December, January and February. The amount of rainfall is very important because rainfall is a natural input for agricultural cultivation in Selopamioro. Apart from that, rainfall patterns are important so that planting periods and crops can be determined according to their potential water availability.

Crop patterns setting is considered an adaptation to the limited availability of water for agriculture on Nawungan. The planting pattern applied on Nawungan agricultural land refers to Bantul Regent Decree No. 434 in 2020 is rice-secondary crops-secondary crops based on rainfall which decreased slightly from the previous year. A shift in the planting period causes the cropping pattern to also shift, as a result the second planting season has a risk of crop failure or less than optimal yields due to the approach of the dry season. Therefore, it is necessary to evaluate the suitability of cropping patterns in Nawungan agricultural land to find out whether the cropping patterns that have been or are being implemented are still appropriate or not with climate change.

2. Methodology

This research was carried out in the Nawungan Imogiri River Basin, Bantul. The research location has an area of 551,483 m2. The research stages include interviews, surveys and field measurements, as well as laboratory analysis. Interviews were conducted with 30 respondents to collect information regarding variations in cropping patterns applied. Field surveys were carried out to determine the zoning of planting patterns at the research location based on interview data. Field measurements were made of the slope (using a clinometer) and infiltration rate (using a single ring infiltrometer). Laboratory analysis was carried out on the measurement of soil parameters such as texture (using the pipette method), bulk density (using a pycnometer), bulk volume (using the ring method), organic matter (using the Walkley-Black method), and water retention (using a pF device for pF 0 , 2, 2.54, 4.2). Secondary data collection was also carried out on rainfall data from BMKG for 2013 - 2022 and climatological data from AWS during the research implementation, from January to June 2023.

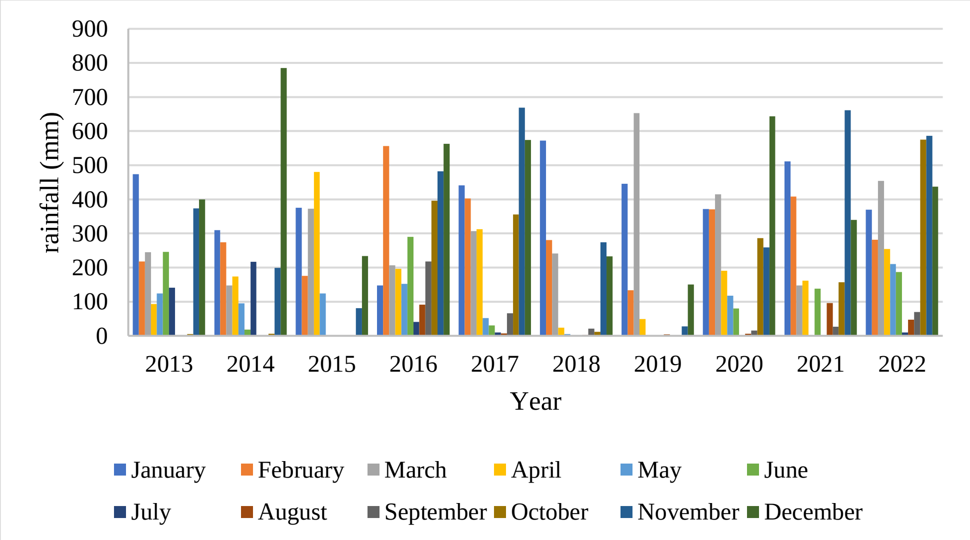

Fig. 1. Rainfall Pattern in Research Area

Data processing techniques are carried out quantitatively for the following parameters:

1. Availability of ground air
   Calculation of groundwater using effective rainfall and availability is directly intended to meet plant water needs for growth [10]. Rainfall data for 10 years is sought for 80% rainfall (R80), namely rainfall probability of 80% occurs or maybe greater than its rainfall.
2. Water requirements for crops
   The calculation of crop water needs uses the actual evapotranspiration calculation which is obtained from the potential evapotranspiration multiplied by the crop coefficient.

   $$Eta = Eto \times KC$$

   Where Eto is resulted from Penman-montheit equation:

$$ETo = \frac{0.408\, x\, \Delta(Rn - G) + \frac{\gamma Cn}{T + 273} u2(es - ea)}{\Delta + \gamma\,(1 + Cd)}$$

3. Evaluation of crop pattern suitability
   Evaluate the suitability of crop patterns using the water balance between soil water availability and plant water needs. Calculation of the water balance to determine the condition of groundwater deficit or surplus, then the calculation of alternative planting arrangements is carried out during the second planting period.

The data analysis technique was carried out using a descriptive-quantitative method based on the value of groundwater availability and plant water requirements at the study site. Analysis of the water balance, namely using the comparative method, compares the value of water availability with the water needs of plants during the second planting season by adjusting the climate and soil characteristics at the study site. Water balance analysis to determine which planting periods experience water shortages.

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3. Results

3.1 Cropping pattern zone

Based on the interview results, it was found that 3 zoning cropping patterns were applied by farmers at the study site. Planting pattern zone 1 has a plant pattern of rice-shallots-shallots-vegetables (mustard/chilli). Planting pattern zone 2 has a rice-shallot-vegetable (mustard/chilli). And planting pattern zone 3 has a rice-palawija crop pattern (peanuts/cassava).

The existing zoning of planting patterns is spread over land on various slopes. The slope of the slope in each zone includes flat, very gentle, gentle, slightly steep and steep slopes. Each zoning on a particular slope is the basis for determining soil sampling which were about 28 points.

3.2 Climate Characteristic

The climate characteristics at the study site based on the 10-year rainfall trend show a monsoonal pattern characterized by a type of rainfall with one peak rainy season (unimodial). In June, July and August there is a dry season while in December, January and February there is a rainy season.

3.3 Soil Characteristics

The clay content in each slope class and planting pattern zone of soil texture is dominated by the clay fraction. High clay content will cause the soil to be watertight [11].

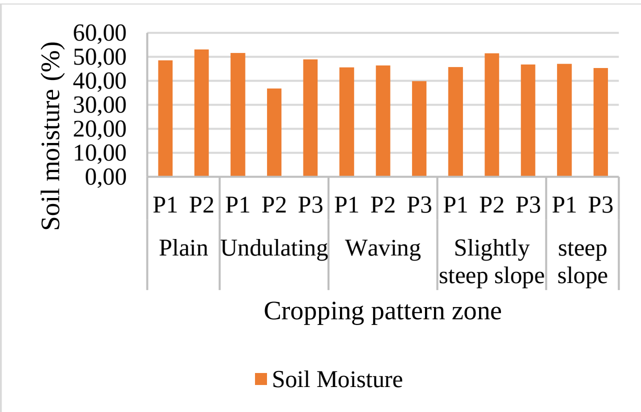

Fig. 2. Soil Moisture

Table 1. Soil Texture

Slope class	Cropping pattern zone	Sand (%)	Silt (%)	Clay (%)	Soil texture
Plain	P1	25	33	42	Clay
	P2	73	9	17	Sandy loam
Undulating	P1	14	16	70	Clay
	P2	20	35	44	Clay
	P3	54	21	24	Sandy clay loam
Waving	P1	18	17	65	Clay
	P2	9	9	82	Clay
	P3	34	31	35	Clay loam
Slightly steep slope	P1	25	23	52	Clay
	P2	26	30	44	Clay
	P3	44	29	27	Loam
Steep slope	P1	38	29	33	Clay loam
	P3	38	20	42	Clay

Moisture levels in each cropping pattern zone and slope class show values that do not vary too much. The moisture content value ranges from 36.87 – 53.63%. The lowest moisture content values are found in planting pattern zone 2 with a very gentle slope class. The low moisture content is caused by the very poor percentage of porosity so that the pores are small and the percentage of micro pores that store water is also small so that the soil's ability to bind water becomes very weak.

Fast drainage pores occupy 55.43% of the total pore space of the soil, while slow drainage pores only occupy 2.69% of the total pore space of the soil. Fast drainage pores are macro pores that will lose water at low matrix suction [12]. The high level of fast drainage pores indicates that the soil in the catchment area of the study allows water to pass through quite easily.

The organic carbon content shows that the soil organic matter content in the research catchment area ranges from 0.00% - 1.7% which is classified as very low to low with an average of 0.81%. Yang et al. [13] stated that the organic matter content of soil in agricultural land systems is influenced by the practice of returning harvest residues to the land. The low organic matter content in the research catchment area can be caused by harvest residues that are not returned to the land.

Table 2. Soil Organic Matters

Slope class	cropping pattern zone	C-Organic (%)	SOM (%)	Level
Plain	P1	0.73	1.25	Low
	P2	0.00	0.00	Very low
Undulating	P1	0.82	1.42	Low
	P2	0.98	1.70	Low
	P3	0.05	0.08	Very low
Waving	P1	0.62	1.07	Low
	P2	0.78	1.35	Low
	P3	0.32	0.54	Low
Slightly steep slope	P1	0.63	1.08	Low
	P2	0.37	0.63	Low
	P3	0.22	0.39	Very low
steep slope	P1	0.35	0.61	Low
	P3	0.22	0.39	Very low

The majority of land infiltration rates showed an insignificant decrease, except for land in cropping pattern zone 1 of the steep slope class showing a significant decrease in infiltration rates. Differences in infiltration rates in cropping pattern zone 1 land with steep slope classes are influenced by land processing. Add explanation. Tillage affects the volume of soil [12].

Table 3. Soil Physic Characteristics

Slope class	Copping pattern zone	BD (g/cm^3)	PD (g/cm^3)	Porosity (%)	Fast drainage pores (%)	Slow drainage pores (%)	Soil texture
Plain	P1	0.77	1.85	58	39.00	4.61	Clay
	P2	0.73	1.75	58	35.71	1.98	Sandy loam
Undulating	P1	0.81	1.85	56	35.32	4.94	Clay
	P2	1.07	1.98	46	28.67	2.42	Clay
	P3	0.79	1.82	56	30.10	2.20	Sandy clay loam
Waving	P1	0.86	1.97	56	32.83	5.93	Clay
	P2	0.87	2.04	57	32.41	0.22	Clay
	P3	0.98	1.91	49	36.20	5.60	Clay loam
Slightly steep slope	P1	0.89	1.81	51	32.27	4.46	Clay
	P2	0.79	1.84	57	35.82	2.97	Clay
	P3	0.86	1.88	54	30.31	1.17	Loam
Steep	P1	0.86	1.88	54	31.30	2.91	Clay loam
	P3	0.82	1.70	51	35.48	0.66	Clay

3.4 Water Availability

Based on the table of available water content, it shows that the value of available water content at the research location is quite varied. The highest average available water content was found in cropping pattern zone 3 on land with a rather steep slope. The differences in texture, density, porosity and organic material in each planting pattern zone cause quite significant differences in values. This is in accordance with Ayu et al. [3] stated that there are differences in soil surface conditions, organic matter, texture, structure and vegetation is a factor causing the difference in water holding capacity.

Table 4. Soil Water Availibility

Slope class	cropping pattern zone	Soil Water Availability (%)
Plain	P1	11.04
	P2	7.56
Undulating	P1	8.87
	P2	7.25
	P3	8.27
Waving	P1	5.33
	P2	10.88
	P3	8.40
Slightly steep slope	P1	6.92
	P2	9.56
	P3	13.07
steep slope	P1	10.00
	P3	12.25

3.5 Potential evapotranspiration

Based on the results of the analysis, the average amount of potential evapotranspiration (ETo) ranges from 2.9 – 3.49 mm/day. Based on the modified penman method, the amount of potential evapotranspiration (ETo) is influenced by the reflection coefficient. The reflection coefficient is the ratio of the amplitude of the reflected wave compared to the amplitude of the incoming wave. The reflection coefficient depends on the amount of vegetation distribution with land use.

3.6 Crop Water Needed

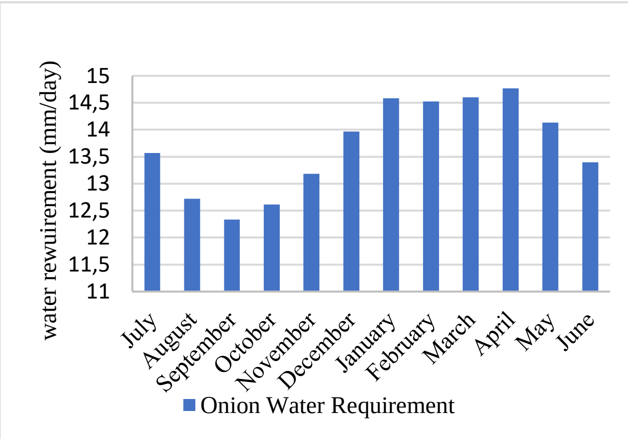

Fig. 3. Onion Water Requirement

The value of plant water needs was obtained in the range of 12.8 – 14.8 mm/day. The water requirement for shallots is lowest when planted in September and highest in April. The water needs of shallot plants depend on several factors, for example the age of the plant, temperature and humidity, rainfall.

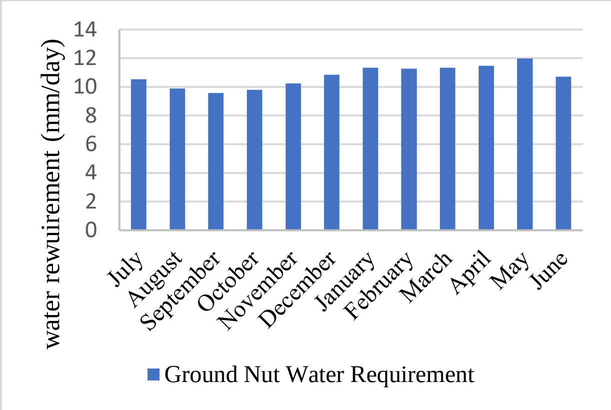

Fig. 4. Ground Nut Water Requirement

The value of water requirements for peanut plants obtained as shown in the picture below ranges from 8.8 – 12 mm/day. The water requirement value for peanuts is lowest if planted in September and highest in April.

3.7 Evaluation of Crop Pattern Suitability

Evaluation of the suitability of planting patterns is seen based on the balance of soil water availability and plant water needs. Groundwater availability is calculated from effective rainfall. Effective rainfall is rainfall that is effectively and directly used to meet plant water needs for growth [10].

Table 5. Crop Pattern

Slope Class	Crop Pattern Zone	Crop Pattern Term			
		I (Dec - Mar)	II (Apr - June)	III (July - Sep)	IV (Oct - Nov)
Plain	P1	Paddy	Onion	Onion	Caism
	P2	Paddy	Onion	Chilli	
Undulating	P1	Paddy	Onion	Onion	Chilli
	P2	Paddy	Onion	Chilli	
	P3	Paddy	Cabai		
Waving	P1	Paddy	Onion	Onion	Caism
	P2	Paddy	Onion	Chilli	
	P3	Paddy	Cassava		
Slightly steep slope	P1	Paddy	Onion	Onion	Chilli
	P2	Paddy	Onion	Chilli	
	P3	Paddy	Groundnut		
Steep slope	P1	Paddy	Onion	Onion	Caism
	P3	Paddy	Cassava		

Based on the figure below, through the calculation of an effective rainfall of 80% and surface runoff considered zero, it was found that each zoning pattern experienced a water deficit during the second planting season in May and June. During these months the availability of ground water is between 5 – 7 mm/day, while the water needs of shallots and peanuts are more than 7 mm/day and even reach 14 mm/day for shallots.

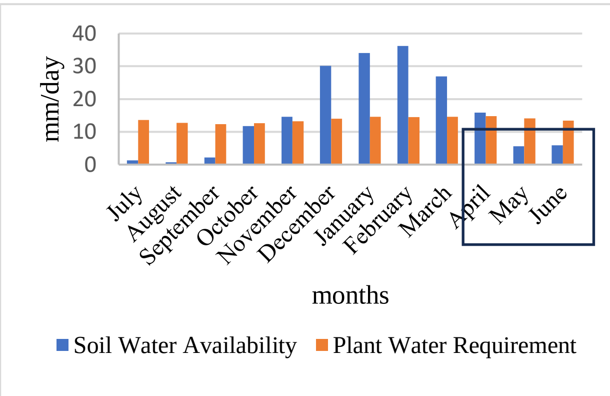

Fig. 5. Water Balance Cropping Pattern Zone 1 Plain Slope

The maximum deficit in Nawungan agricultural land during the second planting season occurred in zones 1 and 2 on cropping pattern zones 1 and 2 on flat to gentle slopes of 9 mm/day with shallots planted. The maximum surplus occurred during the second growing season in zone 3 of cropping pattern on land with rather steep and steep slopes of 5 mm/day with peanuts being planted. While the minimum deficit occurs in cropping pattern zone 3 of 3 mm/day and the minimum surplus occurs in cropping pattern zones 1 and 2 on a flat to gentle slope of 0.5 mm/day..

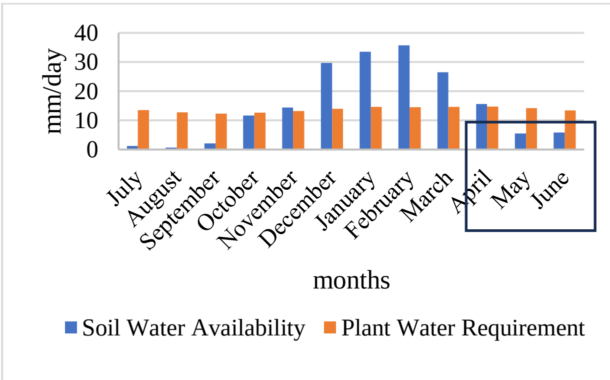

Fig. 6. Water Balance Cropping Pattern Zone 2 Waving Slope

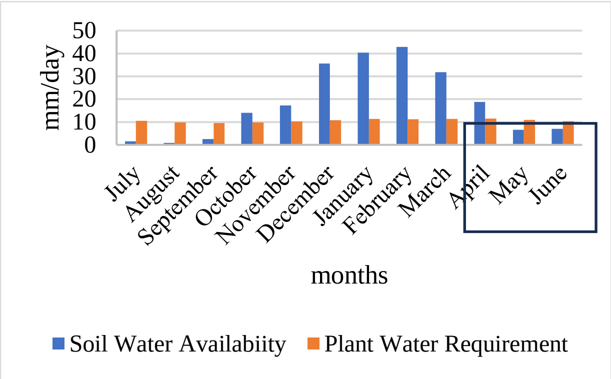

Fig. 7. Water Balance Cropping Pattern Zone 3 Slightly Steep Slope

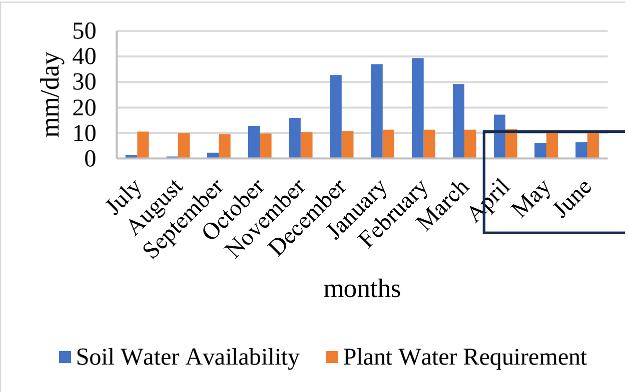

Fig. 8. Water Balance Cropping Pattern Zone 3 Steep Slope

4. Conclusion

1. The climate characteristics at the research location reflect low rainfall which also influences low water availability
2. Soil characteristics at the research location are dominated by fast drainage pores
3. The cropping pattern that is in accordance with water availability at the research location is P3 (paddy-palawija) zoning
4. Cropping period that has sufficient water availability is MT-2.

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