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The Role of Understory Plants in Microclimate in Coconut-Based Agroforestry.

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Abstract. The use of land with a coconut-based agroforestry system is currently widely practiced in the South Minahasa region. In this agroforestry system, coconut trees are planted together with other plants on a single plot of land. The diversity of underplanting also plays a role in modifying the microclimate around the coconut trees, which in turn can affect the growth and productivity of the plants. Microclimate is the climatic conditions that occur around plants and is greatly influenced by various factors, including plant diversity. Coconut trees in coconut-based agroforestry systems bring about changes in the microclimate under the canopy and can lower air temperature, reduce radiation, and decrease wind speed under the canopy. This study aims to determine the effect of various types of vegetation on the microclimate in coconut-based agroforestry. The research was conducted in Ongkaw Village using a survey method. Microclimate measurements included solar radiation transmission, air temperature, air humidity, and wind speed at each observation plot. Data on underplant vegetation was observed using a purposive sampling plot method on coconut agroforestry land with different vegetation structures.

The results showed that, compared to monoculture areas, the presence of understory plants significantly reduced air temperature, increased relative humidity, slowed wind speed, and reduced the intensity of light reaching the ground. Compared to other types of plants, plots with multi-strata fruit plants had the best microclimate conditions; shrub plots showed a moderate effect on microclimate moderation, while more open plots tended to have higher temperatures and lower humidity.

The conclusion of this study is that the selection of understory plants in coconut agroforestry systems greatly influences microclimate conditions. Multi-strata fruit trees have been proven to be the most effective in creating a cooler and more humid microclimate, which can contribute to improved soil health and reduced stress on the main crop.

Keywords: coconut agroforestry; microclimate; understory plants

INTRODUCTION

Land management using agroforestry systems has long been practiced by communities. Community knowledge in implementing agroforestry systems is usually obtained from experience or taught by elders and farmers who manage agroforestry land (Toding et al., 2022; Gusti et al., 2022). The agroforestry systems implemented in various regions may differ in pattern due to the influence of socio-cultural and biophysical conditions of the land (Toding et al., 2022; Titdoy et al., 2014; Ibrahim et al., 2021).

The implementation of agroforestry systems in a region has good prospects, where agroforestry, as a system that combines various types of crops in one area, will enable an increase in the productivity of each crop's harvest. The implementation of agroforestry systems is not without advantages and disadvantages that are felt by farmers in the application of various patterns. On the one hand, farmers' income can increase due to increased crop yields, but on the other hand, income can also decrease due to pest attacks, the need for more labor, and farmers experiencing difficulties in planting and maintenance (Toding et al., 2021; Laratmase et al., 2022; Oping et al., 2023).

Coconut-based agroforestry is a developing agroforestry model in South Minahasa. This land management system combines coconut trees with agricultural crops or other trees. In this system, coconut trees are planted alongside other crops to achieve optimal economic and ecological outcomes.

Microclimate is the climatic conditions that occur around plants and is greatly influenced by various factors, including plant diversity. Coconut trees in coconut-based agroforestry systems bring about changes in the microclimate under the canopy and can affect the temperature, humidity, and wind patterns around coconut trees, lowering soil and air temperatures, and reducing radiation and wind speed under the canopy. These changes will have a direct effect on soil water evaporation and humidity, which in turn can significantly affect plant growth, reduce water availability to plants and soil evaporation, which is very important during the growth and development period of plants in an agroforestry system (Rao et al., 1997). Because of the above, it is important to understand the relationship between plant diversity and microclimate in order to optimize the application of coconut-based agroforestry. The purpose of this study is to determine the effect of various types of vegetation on the microclimate in coconut-based agroforestry.

RESEARCH METHODOLOGY

The research was conducted in Ongkaw Village, Sinonsayang District, South Minahasa Regency, in July-August 2025, which included determining respondents, conducting interviews, collecting data, and analyzing data. This research used a survey method. The collected data were analyzed using descriptive and comparative analysis and presented in the form of descriptions, tables, and figures. Field research included observations to obtain microclimate measurements under coconut tree canopies. The variables observed in this study were radiation outside and under coconut tree canopies, air temperature outside and under coconut tree canopies, air humidity outside and under coconut tree canopies, and wind speed outside and under coconut tree canopies. Measurements were taken 0,5 meter above the ground at 9:00 a.m., 1:00 p.m., and 5:00 p.m. during a week of sunny days.

RESULT and DISCUSSION

Microclimate is the climatic conditions that occur around plants and are greatly influenced by various factors, including plant diversity. Coconuts in coconut-based agroforestry systems bring about changes in the microclimate under the canopy that can affect the temperature, humidity, and wind patterns around coconut plants, lowering soil and air temperatures and reducing radiation and wind speed under the canopy. These changes will have a direct effect on soil water evaporation and humidity, which in turn can significantly affect plant growth, reduce water availability to plants and soil evaporation, which is very important during the growth and development period of plants in an agroforestry system.

The people of South Minahasa have passed down knowledge about how to manage land sustainably from generation to generation. This local wisdom involves the use of agroforestry patterns as part of a better and more environmentally friendly agricultural system. Some communities utilize various types of plants growing together on a plot of land to create a diversity of plants that support each other. Coconut, as one of the long-established plants, is planted together with other trees or plants to maintain soil fertility and reduce dependence on a single type of plant.

Various types of underplanting in coconut-based agroforestry systems can modify the microclimate on various scales, such as air temperature and humidity, change the characteristics of rainwater runoff, slow down wind speed, and create dynamics in the distribution of sunlight intensity reaching the agroforestry floor.

The characteristics of agroforestry planting patterns in Ongkaw Village depend on the landowner. Several types of vegetation were found on coconut-based agroforestry land in Ongkaw Village. From the various types of vegetation found, three types of vegetation were selected that were considered to represent the role of understory plants in the microclimate of coconut-based agroforestry. Observations were made on three different types of vegetation, namely grass vegetation representing open areas under coconut-based agroforestry floors, shrub vegetation, and fruit tree vegetation representing multi-stratified areas.

Figure 1. Vegetation types under coconut-based agroforestry (a) Grass vegetation type (b), Shrub vegetation type (c) Fruit tree vegetation type.

Research results in Ongkaw Village show that the diversity of understory plants in agroforestry systems creates complex dynamics in the distribution of light intensity reaching the agroforestry floor. Land with different types of vegetation stratification will produce different distributions of light intensity. Coconut agroforestry sites with grass vegetation types provide the most light distribution compared to shrub vegetation types and various fruit crops. This is in line with research by Tanaka et al. (2023), which shows that agroforestry systems with a high percentage of understory vegetation can reduce light intensity by 60–90% compared to areas without understory vegetation. This is thought to be due to stratification in the vegetation canopy layer, where each layer of undergrowth with different leaf characteristics acts as a filter to increase light absorption (Ishida et al., 2022).

Plants growing under agroforestry systems act as light filters, reducing the amount of radiation reaching the ground. This causes a decrease in soil temperature and reduces the likelihood of drought when summer arrives. Lakitan (2002) noted that the size and density of the canopy will determine how much solar radiation energy can be absorbed, which can reach up to 90% of the total received, where the difference in radiation transmitted at each layer at each location is influenced by varying land conditions, canopy density, distance between plants, and planting patterns. This is in line with research by Purba et al. (2019), which shows that the distance between plants greatly affects the fraction of solar radiation; the closer the distance between trees, the less radiation reaches the plants below. In addition, the radiation transmitted in the morning is higher because it comes from the east, which affects the radiation received at each layer in all types of land. Furthermore, sun exposure is also influenced by the duration of sunlight from morning to afternoon (Purba et al., 2019).

The diversity of understory plants also has a different effect on light intensity on the agroforestry floor (Table 1). The results of research by Yamashita et al. (2023) show that daily fluctuations in light intensity on the agroforestry floor in areas with simple understory vegetation experience daily variations in light intensity of 50–70%, while areas with diverse understory vegetation experience more stable variations of only 20–30%. This is due to the stratification of leaves from various types of understory plants that function as an efficient filtering system against extreme light changes during the day, when solar radiation reaches its peak (Saito et al., 2022). Despite large daily fluctuations in solar radiation, agroforestry systems with high understory plant diversity show a better ability to maintain consistent light conditions on the agroforestry floor during the rainy season, when understory vegetation growth peaks.

According to Nakamura et al. (2023), the diversity of understory plant species will produce a different light spectrum on the agroforestry floor. High understory plant diversity can alter the composition of transmitted light, with a decrease in blue (400-500 nm) and red (600-700 nm) wavelengths that are important for photosynthesis. This is due to the absorption of certain pigments in the leaves of various plant species, which causes a light environment that is qualitatively different from direct sunlight (Kawamura et al., 2022). The interaction between the level of understory plant diversity and these light characteristics will further affect the biogeochemical processes occurring in the agroforestry canopy. The results of a study by Kobayashi et al. (2023) show that the decrease in light intensity due to interaction with understory plants creates microclimatic conditions that are ideal for litter decomposition, with decomposition rates 20-25% higher than in areas with full sunlight. These modified light conditions support more diverse decomposer community activity, reduce direct evaporation from the soil surface, and can disrupt the decomposition process (Endo et al., 2022).

Table 1. Average Sunlight Intensity in Coconut-Based Agroforestry in Ongkaw Village, Sinonsayang District

No	Treatment	Average Solar Radiation Intensity (lux)		
		9 a.m	1 p.m	5 p.m
1	Under the grass vegetation header	9592,5	281475,5	1880
2	Under the canopy of shrub vegetation	5271	5530,5	696
3	Under the canopy of fruit tree vegetation	996,5	1254,5	477,5
4	Outside the canopy	19170	41385	35215

Table 2. Average Wind Speed in Coconut-Based Agroforestry in Ongkaw Village, Sinonsayang District

No	Treatment	Average Wind Speed ($m.s^{-1}$)		
		9 a.m	1 p.m	5 p.m
1	Under the grass vegetation header	0,36	0,67	0,42
2	Under the canopy of shrub vegetation	0,28	0,56	0,31
3	Under the canopy of fruit tree vegetation	0,16	0,28	0,25
4	Outside the canopy	0,62	1,10	0,83

Based on observations, the maximum wind speed under the canopy of coconut trees is 0.67 m/s, while the minimum is 0.12 m/s. On the other hand, wind speed reaches 1,10 m/s in open areas outside the canopy (Table 2). Wind speeds of 0.1 to 0.25 m/s affect transpiration and evaporation processes, as well as carbon dioxide concentrations in the air. However, wind is also a source of carbon dioxide, which is essential for plant growth, and it also affects temperature and humidity (Karyati, 2019). This factor also affects soil quality (Meylan et al., 2017) and facilitates the humane eradication of plant pests and diseases (Avelino et al., 2023).

Table 3. Average Temperature in Coconut-Based Agroforestry in Ongkaw Village, Sinonsayang District

No	Treatment	Average Temperature (°C)		
		9 a.m	1 p.m	5 p.m
1	Under the grass vegetation header	31,0	38,0	34,15
2	Under the canopy of shrub vegetation	30,25	37,0	32,2
3	Under the canopy of fruit tree vegetation	28,2	35,65	30,75
4	Outside the canopy	31,75	38,85	35,6

Research conducted in Ongkaw Village shows that areas with high species diversity of understory plants have lower temperatures than more open areas (Table 3). Agroforestry systems with high species diversity of understory plants have proven to be more resistant to temperature variations and drought than monoculture systems or those with minimal understory cover. This is because understory vegetation has the ability to alter the microclimate through shading, transpiration, and soil structure improvement. Shading from understory plants reduces direct solar radiation to the soil surface, thereby reducing evaporation and maintaining soil moisture for longer (Hairiah et al., 2020).

Locations with high density and diversity of undergrowth tend to have lower air temperatures 2–3°C lower than areas without undergrowth. This is due to evapotranspiration and shade, which reduce heat absorption by the soil. Locations with tall coconut trees have higher temperatures than locations with dwarf coconut trees. In addition, locations with denser coconut stands have lower temperatures than locations with sparser stands.

Agroforestry systems with diverse understory plant compositions are crucial for air temperature mitigation through various complex biophysical mechanisms. This is in line with the findings of Zhou et al. (2023), who discovered that these systems can reduce average daily air temperatures by 1.5-3°C compared to areas without understory vegetation. One of the main reasons for this cooling is the more intensive evapotranspiration of various understory plant species, each with its unique physiological characteristics. Each plant species releases water into the local environment through its unique transpiration capacity, which in turn creates a very significant total effect in the form of a decrease in microair temperature (Ellison et al., 2022). In addition, research by Rahman et al. (2023) shows that at a height of 0.5 meters above the ground, i.e., the breathing zone, the air temperature in areas rich in understory plant diversity can be 2–4°C cooler than in areas with homogeneous understory vegetation. According to Lin et al. (2022), this is because the layered canopy of ground-level plants acts as an effective filter for solar radiation, so that only a small portion of the energy reaches the ground surface and the surrounding air.

The results of the study on air humidity parameters show that the lowest air humidity was found in agroforestry with fruit tree vegetation under coconut trees, while the lowest humidity was found in areas with grass vegetation (Table 4).

The presence of undergrowth increases relative humidity (RH) due to transpiration and reduced evaporation from the soil. Data shows that agroforestry areas with dense undergrowth cover have 5–10% higher relative humidity than areas with minimal vegetation. Average relative humidity reaches 73,3.5% at its highest and 60,2% at its lowest. Meanwhile, factors that affect relative humidity include soil conditions and the duration of radiation dispersion. Relative humidity decreases during the day.

Table 4. Average Air Humidity in Coconut-Based Agroforestry in Ongkaw Village, Sinonsayang District

No	Treatment	Average Air Humidity (%)		
		9 a.m	1 p.m	5 p.m
1	Under the grass vegetation header	63,35	63,4	67,3
2	Under the canopy of shrub vegetation	67,3	63,9	69,35
3	Under the canopy of fruit tree vegetation	73,35	68,1	70,45
4	Outside the canopy	60,2	61,5	66,2

Putri, et al. (2018) argue that the main factors affecting air humidity are sunlight intensity and water content. Thus, accumulated water vapor increases relative humidity. On the other hand, in open areas, water vapor easily disperses from evaporating surfaces. Compared to open areas, relative humidity values are about 3-21% higher at 9:00 a.m. and 3-12% higher during 1:00 p.m. Singh et al. (2002) observed similar differences in relative humidity values between shade trees and open conditions. Significant variations between periods were observed because atmospheric evaporation requirements change sharply with the seasons. There were no significant RH variations between different shade tree species, regardless of the time of observation.

The diversity of understory plants in agroforestry systems has a significant impact on air humidity dynamics through a series of interrelated biophysical mechanisms. Recent research by Zhang et al. (2023) reveals that agroforestry systems with diverse understory vegetation compositions can increase average daily relative air humidity by 10-15% compared to areas without understory vegetation. This phenomenon is primarily due to the collective transpiration capacity of various understory plant species with different physiological characteristics, where each species contributes to the local water cycle through unique transpiration patterns (Sterck, 2022; Meijers et. al., 2025). Canopy cover at the crown-scale best predicts spatial heterogeneity of soil moisture within a temperate Atlantic forest. *Agricultural and Forest Meteorology*, *363*, 110431.). This process creates a cumulative effect that increases the water vapor content in the microclimate around the understory canopy. Research by Chen et al. (2023) shows that at a height of 0-2 meters above ground level, relative humidity in areas with high understory plant diversity can be 8-12% higher than in areas with homogeneous understory vegetation. According to Kumari et al. (2022), this mechanism works through the formation of a stable micro-air layer, where variations in the shape and size of leaves from various understory plant species create a wider evaporative surface, thereby increasing the efficiency of water vapor release into the micro-atmosphere.

CONCLUSION

Agroforestry systems with high species diversity of understory plants have been shown to be more resistant to temperature variations and drought than monoculture systems or those with minimal understory cover. This is because understory vegetation has the ability to alter the microclimate through shading, transpiration, and soil structure improvement. Shade from understory plants reduces direct solar radiation to the soil surface, thereby reducing evaporation and maintaining soil moisture for longer periods.

The selection of understory plants in coconut agroforestry systems greatly influences microclimate conditions. Layered fruit trees have been shown to be most effective in creating a cooler, more humid microclimate, which can contribute to improved soil health and reduced stress on the main crop.

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