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Study of Microclimate of Pepper (*Piper nigrum* L.) in various Agroforestry Systems

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ABSTRACT

One of Indonesia's centres of pepper plant yields is Lampung Province. The productivity of the pepper is decreasing. Pepper productivity is declining, so selecting the right crop system, according to the needs of the microclimate of pepper plants, is needed to produce optimal productivity. This research aims to study the microclimate variations of several agroforestry systems, analyze the relationship of microclimate productivity, determine the ideal type, and evaluate the level of pepper productivity in various systems. This research was conducted in Aji Kagungan Village, Abung Kunang District, North Lampung Regency, at 450-1500 meters above sea level in January-April 2019. The research method used was survey purposive sampling, which considered the uniformity of the age of pepper plants and differences in the types of vegetation that make up the system. The data observed were microclimate, land condition, and productivity of pepper plants. Data was collected on five types of systems divided into four zones. Each zone has four observation points, observations were made 8 times with an interval of 10 days. The results showed that the determinants of microclimate diversity of pepper agroforestry systems were canopy area, density, frequency, and vegetation. In contrast, the magnitude of sunlight transmission, temperature, and humidity in pepper agroforestry systems was influenced by vegetation characteristics. The form of relationship formed by the transmission of sunlight and air temperature is positive linear, while the humidity of the air forms a negative linear relationship to the productivity of pepper plants in the agroforestry system tested while of the five types of agroforestry systems tested. Type 5 is the ideal pepper agroforestry system. Where the microclimatic conditions formed by Type 5 can produce the highest pepper productivity among other system types.

Keywords:
Agriculture; characteristic; pepper; production; vegetation.

1. Introduction

Spices play an important role in the history of civilization, exploration, and trade in the world, especially in Indonesia. One of these spice commodities is pepper. Pepper (*Piper nigrum* L.) is one of the leading export spices from the Indonesian plantation sub-sector commodity, which has made a real contribution as a source of non-oil and gas foreign exchange for the country. Pepper plants have long been cultivated in Indonesia and are used as raw materials for medicines, the food industry, perfumes, and vegetable pesticides. The main pepper products traded internationally are white pepper and black pepper. White pepper and black pepper come from the same pepper tree. White pepper is processed from fruit ripened on the tree, harvested, separated from the skin, and dried. Black pepper is produced from pepper pods, harvested before they are ripe and still green in colour. They are dried immediately without exfoliating the skin (Damasus & Effendi, 2019). Pepper is called the king of spices for its flavor, aroma, and medicinal properties. It is valued for its spiciness and flavor, which is associated with the presence of piperine, a bioactive compound (Goswami & Malviya, 2020).

Pepper estate crop exports rank sixth after rubber, oil palm, coffee, cocoa, and coconut. In 2022, the national pepper plantation area reached 193,854 Ha and could export 58,378 tons (Direktorat Jendral Perkebuan, 2022). Pepper plants are widely cultivated and developed in Indonesia, especially in the provinces of Aceh, Bangka, Lampung, West Kalimantan, North Kalimantan, and South Sulawesi, so Indonesia is one of the largest pepper exporting countries in the world.

One of the pepper production centres in Indonesia is Lampung Province, and since the 18th century, Lampung Province has been known as the world's pepper warehouse, Lampung Black Pepper. Many pepper plants in Lampung Province are cultivated and developed in North Lampung, East Lampung, West Lampung, Tanggamus, and Way Kanan regencies with fluctuating pepper production. This can be proven by the decrease in the area of smallholder plantation crops in the sub-district area; in 2020-2021, the area was 10 Ha and decreased to 6 Ha in 2022. In North Lampung in 2017, 3772 tons of pepper were produced. Based on Direktorat Jendral Perkebuan (2022) Lampung black pepper production reached 15,983 tons. The low productivity of pepper plants is indicated to be caused by the agroforestry cropping patterns applied by farmers.

The application of various cropping systems by farmers formed an agroforestry system with a very high diversity of constituent components in each type of agroecosystem. Several types of pepper-based agroforestry systems applied by farmers are composed of various types of vegetation, such as Gamal trees (*Gliricidia sepium*), Coffee (*Coffea*), Nutmeg (*Myristica fragrans*), Teak (*Tectona grandis*), African (*Maesopsis mini*-Engl), *Archidendron pauciflorum* (local: *Jengkol*), etc. The diversity of types of vegetation that make up this agroforestry system certainly causes a variety of microclimates, including sunlight interception, air temperature, and air humidity, which are created for pepper plants. Various environmental center factors influence the productivity of pepper plants. Elevation above sea level plays an important role in pepper production (Gusta, and Same., 2022). Efforts to deal with this can be made by choosing the type of components that make up the agroforestry system appropriately and by the needs of the microclimate of pepper plants to produce optimal productivity. Therefore, research on the microclimate of pepper plants in several agroforestry systems is necessary.

2. Materials and Methods

The research was conducted in some smallholder plantations in Aji Kagungan Village, Abung Kunang District, North Lampung Regency, at an altitude 450-1500 m above sea level (asl), from January to April 2023. The research method used was a purposive sampling survey that considered the uniformity of the age of the pepper and the different types of vegetation in the components of the system. Data observed were microclimate, land conditions, and productivity of pepper in some types of systems, with an area of each type of 5000 m^2. Data was collected on five types of systems divided into four zones. Each zone has four observation points; observation was made 8 times with an interval of 10 days.

2.2. Statistical data analysis

The results of observations of microclimate elements (sunlight transmission, air temperature, and air humidity) were analyzed. Statistical Analysis using PCA. The spatial distribution of vegetation in each system was analyzed using the multivariate Principal Component Analysis (PCA) approach. This method aims to determine the distribution pattern of the influence of vegetation on climate and productivity. A correlation test was performed to determine the correlation between climate and productivity. If a strong relationship indicated by R-Square ≥ 0.5 was found, a further analysis was carried out using a multiple regression test with climate factors as the independent variable. Land condition data in the form of nutrients N, P, and K, C-Organic, Texture, and pH, along with microclimate, were analyzed using land suitability analysis according to the needs of pepper plants. The software used for analysis is Xlstat 2016.

3. Results and Discussion

3.1 The influence of the characteristics of the system compiler on microclimate

Observation of the planting system indicates that in one pepper plantation area, differences were found in the vegetation compiler system in terms of kind, amount, shade canopy area, density, frequency, and kind of vegetation. If the vegetation is too lush with a high canopy area, it will obstruct the transmission of sunlight to the canopy underneath the plant, this also causes variations in air temperature and humidity. In line with this statement, Dabischa et al. (2021) confirmed that the transmission of sunlight would increase air temperature and decrease humidity levels. This situation occurs because the three elements of the microclimate formed are interconnected, where the high and low transmission of sunlight will affect a system's air temperature and humidity. Solar energy is an energy source that determines the process of photosynthesis and plant respiration, where solar energy is used as the activation energy for surface molecules and is used in the activity of molecules which causes air temperature to rise and humidity to decrease so that the formation of air temperature and humidity is closely related towards sunlight transmission (Maka and Alabid, 2022).

The close relationship between microclimates is inseparable from the role of vegetation variables in the five types of systems, where these variables are related to the productivity of pepper plants observed. To obtain the main components of the system compilers that influence the climate and productivity of each type of pepper agroforestry system, a Principal Component Analysis (PCA) was performed. Through this analysis, important variables can be grouped to estimate vegetation and climate variables closely related to productivity in each type of agroforestry system (Figure 1).

PCA results, presented in Tables 1 and 2, show that the grouping of observation plots based on vegetation characteristics, and four factors strongly influence the emergence of new factors as the main factors. These four factors can be formulated into two main factors that have a reasonably close correlation with the variables analyzed and can be considered to reflect phenomena related to the characteristics of each type of system. Thus, from the four factors filtered on the PCA, only two main factors are used, namely factors 1 and 2. These two factors can account for 95.16% of total diversity. Other factors are not used in the classification because they have a sufficiently low ability to account for total diversity or are lower than the average contribution of each factor to total diversity.

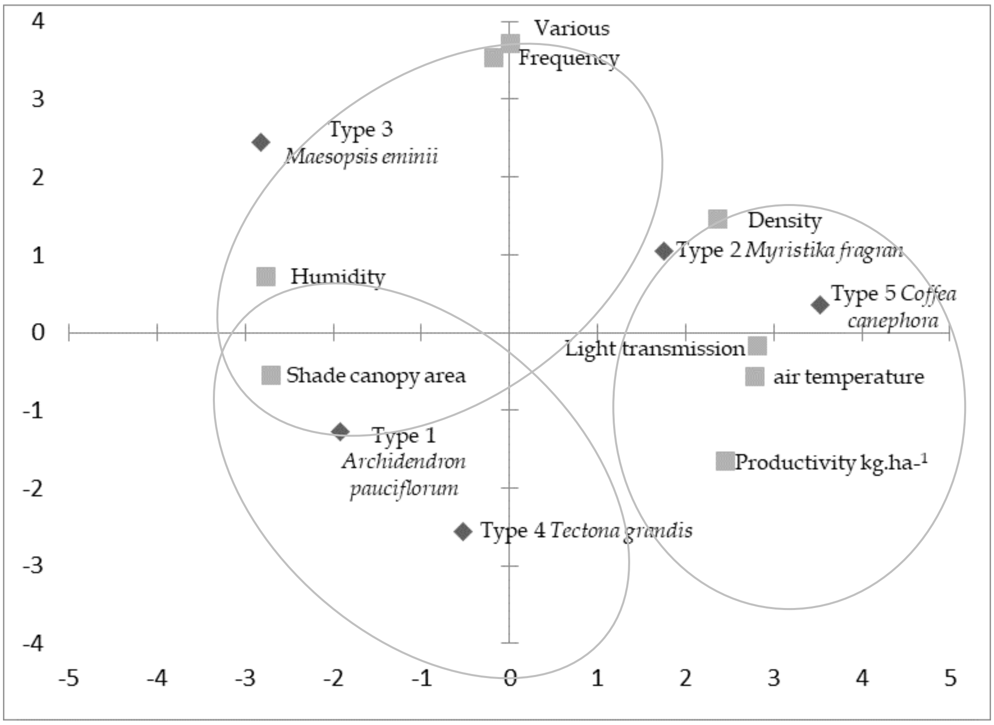

Figure 1. Distribution diagram and the close relationship between vegetation characteristics, microclimate elements, and the five types of pepper agroforestry systems.

Information:

Type of agroforestry system

Microclimate and characteristics of the vegetation system

The eigenvalues table and factor loadings table show that the main factor 1 (F1) represents about 60.86% of the diversity of data, with its main characteristic variable being the headline area (factor loadings value of -0.962) and density (factor loadings value of 0.836). This means that the canopy width and vegetation density variables determine the diversity in the five agroforestry systems of 60.86% pepper plants. Main factor 2 (F2) represents about 34.29% of the diversity of data, with its main identifying variable being the type of vegetation (factor loadings value of 0.988) and frequency (factor loadings value of 0.939). This means that the diversity in the five pepper agroforestry systems is 34 29% and is determined by the variable type and frequency of vegetation.

The canopy width and density variables influence 60.86% of microclimate and productivity, where these two factors determine the diversity of microclimate and dominant productivity. The analysis showed that the broad canopy tends to negatively correlate with the density of vegetation, where the increase in the canopy area tends to be followed by low vegetation density. As explained by Latuamury et al. (2012), the density of plant canopy in the field is inversely proportional to plant density, meaning that at locations where high canopy densities are found, the vegetation density varies from sparse to moderate and vice versa if it is found that the density of sparse plant canopy is rare when there is high vegetation density. This is in line with the statement of Mestre et al. (2017), which states that the higher the plant canopy area, the decrease in species diversity and density. Thus, the structure of the growth of vegetation that makes up the system with a large canopy area will affect the microclimate formed, especially with the presence of a high canopy area, which will obstruct the transmission of sunlight to the pepper plants in a type of agroforestry system.

Table 1. The eigenvalues factor of PCA results in vegetation, climate, and productivity variables for each type of Agroforestry system

Variable	F1	F2	F3	F4
Eigenvalue	5,478	3,087	0,309	0,127
Variability (%)	60,86	34,29	3,433	1,407
Cumulative %	60,86	95,16	98,59	100,0

After observing the vegetation and microclimate variables, it turns out that the productivity of pepper plants in system types 2 and 5 is closely related to the transmission of sunlight and air temperature. Transmission of sunlight and air temperature close to optimum increases productivity in this type of system. This means that to improve the productivity of pepper plants, it is necessary to reduce the shade of the canopy plant area to increase the transmission of sunlight, increase air temperature, and reduce air humidity around pepper plants.

Table 2. Factor loading of each observation variable

Variable	F1	F2	F3	F4
Various	0,002	0,988	-0,030	-0,149
Shade canopy area	-0,962	-0,145	0,231	-0,024
Density	0,836	0,387	0,367	0,131
Frequency	-0,062	0,939	-0,281	0,186
Light transmission of the Sun	0,998	-0,045	0,013	0,036
Air temperature	0,988	-0,149	-0,002	0,037
Humidity	-0,981	0,191	0,026	-0,005
Productivity kg ha^{-1}	0,869	-0,442	-0,158	-0,156

3.1.1. Sun Sunlight transmission

Pepper plants need sunlight to carry out the process of photosynthesis, in which growth depends on the amount of radiation received, assuming other environmental parameters are considered constant. Transmission of sunlight by pepper plants in each type of agroforestry system shows that the diversity of vegetation compiler the system will affect the transmission of sunlight received by pepper plants under the auspices of the system composing vegetation.

Based on the presentation of statistical descriptive analysis data shows that there are fluctuating differences in each observation caused by differences in weather when observations are at the same time. However, overall, the five types show different differences in the transmission of sunlight by the crown of pepper plants. Among the five types of components compiler of the pepper crop agroforestry system, the differences in each type of system are seen in Table 3. Each type shows differences. This difference is due to the characteristics of the system components that exist in each system, where the transmission of type 5 sunshine is higher than the other four types and type 3 is lower than the other four types of systems.

In this research, each type of system has different components. The existence of these differences affects the transmission of sunlight to the canopy of pepper plants, this is certainly related to the type, amount, crown area, dominance, frequency, and density of each vegetation compiler in the system. This can be seen in the INP and SDR in each type of component compiler in the pepper crop agroforestry system. The more lush and expansive vegetation canopy will reduce the transmission of sunlight received by pepper plants; this is related to the density of protective plants that will block the radiation from the sun falling on pepper plants. The less radiation that can penetrate the surface of the pepper plant, the lower the air temperature and the higher the humidity, which will reduce the productivity of pepper plants. Hanafi (2005) states that the more plants per unit area, the higher the leaf area index, so the percentage of sunlight transmission received by the lower plant parts becomes less due to the light barrier by the leaves above it.

The difference in INP is due to the three components that affect the important value index of the five types of components compiler the agroforestry system Relative Density (KR), Relative Frequency (FR), and Relative Dominance (DR). Ismail et al. (2017) state that if the INP of a high-value type of vegetation, then that species greatly affects the stability of an ecosystem. This is in line with several researchers' statements that canopy closure influences the amount of sunlight transmission. The amount of transmission is caused by the percentage of canopy closure (Gao et al., 2022). Another opinion also expressed by Prakoswo et al. (2018) revealed that the percentage of sunlight entering an area is influenced by regional differences and land use. This is also confirmed by Mortensen (2014) statement that regional differences will affect the PAR value that will be generated.

Table 3. Light Transmission ratio (%) in the canopy of pepper plants in some types of systems

Agroforestry	The amount of data	Lowest average	Highest average	Average
Type 1	8	48,40	63,40	54,90±4,37
Type 2	8	58,40	71,80	64,79±4,97
Type 3	8	47,20	59,30	51,15±3.94
Type 4	8	51,70	66,90	58,71±3.29
Type 5	8	65,70	79,50	70,81±4,76

From the explanation above, the differences in the components of the system in each type affect the transmission of sunlight received by the crown of the pepper plant, the higher the level of shade above the canopy of the pepper plant, the more sunlight transmission will be low and vice versa, if the sun cover is low the transmission of sunlight by the canopy pepper, will be higher.

3.1.2. Air temperature

The results of observations and statistical descriptive analyses that have been carried out on each type of component compiler in the pepper crop agroforestry system indicate that the differences in the types of system constituent components will affect the air temperature created in an area. This difference is caused by the presence of 3 components that affect the important value index of the five types of components compiler the agroforestry system, such as relative density, relative frequency, and relative dominance. Ismail et al. (2017) state that if the INP of a type of vegetation is of high value, then that species greatly influences the stability of an ecosystem. In line with the statement of Prakoswo (2018), states that changes in land use will affect the resulting microclimate.

Differences in the components of an agroforestry system certainly create a diversity of canopy cover, if the canopy cover is relatively high, the intensity of sunlight is relatively low, whereas when the canopy cover is low, the intensity of sunlight tends to be higher. The results showed that the vegetation in each pepper agroforestry system influences the temperature of the air formed. Thus, the mechanism of vegetation in the formation of air temperatures can be interpreted as follows:

1. Vegetation positively affects air temperature based on the canopy effect, where the tree covers the area under direct sunlight so it does not become hot and affects the air.
2. Vegetation positively affects the cooling process (decrease in evening air temperature) based on the evapotranspiration mechanism, where water from the leaf surface in the afternoon cools the leaf surface and affects the surrounding air temperature.
3. Vegetation harms the heating process (rising morning temperatures) based on the 'blanket' mechanism, where the canopy prevents heat exchange from the surrounding area so that the environment underneath quickly becomes hot. This is supported by the statement of Bhatta and Vetaas (2016), which states that the closing of the canopy of a tree will affect the high and low temperatures in an environment. In line with the statement of Rahimi and Nobar (2023), which states that trees, as one of the elements of vegetation, play a role in controlling the thermal environment because they have an umbrella mechanism (canopy effect) and evaporative cooling (evapotranspiration). Mortensen (2014) also revealed that the higher the intensity of sunlight, the higher the air temperature in an area. Reinforced by Jia et al. (2022), different land uses will affect the climate produced.

Based on the presentation of statistical descriptive analysis data Table 6. This shows differences in air temperature in each type of system, and differences in the composition of the vegetation compiler system cause this. With the different compositions, the temperature of air formed will be different, too, overall, and there will be a difference in air temperature by the crown of pepper plants in each type of system. Among the five types of pepper agroforestry systems, the differences between each type of system are seen in Table 6, where the average air temperature of type 5 is higher than the other four types, and type 3 is lower than the other four types of system.

3.1.3. Humidity

The results of observations and descriptive statistical analysis on each type of component compiler in the agroforestry system indicate that the system will form air humidity around different pepper plants with different types of components and compilers. This difference is caused by the presence of 3 components that affect the important value index of the five types of system components such as relative density, relative frequency, and relative dominance. Ismail et al. (2017) state that if the INP of a high-value type of vegetation, then that species greatly affects the stability of an ecosystem. In line with the statement of Prakoswo et al. (2018), it states that changes in land use will affect the resulting microclimate.

The difference in humidity in the air formed was identified due to differences in the types of components compiler of the agroforestry system, as in the discussion of sunlight transmission and previous air temperatures. This difference creates a diversity of canopy cover, if the canopy cover is relatively high, the intensity of sunlight reaching the canopy surface of the pepper plant is relatively low, whereas when the canopy cover is low, the intensity of the sunlight reaching the canopy cover tends to be higher.

Table 4. Average Air Humidity (RH %) in Several Types of Agroforestry Systems

Agroforestry	The amount of data	Lowest average (RH %)	Highest average (RH %)	Average (RH %)
Type 1	8	85,00	90,90	87,89±1,84
Type 2	8	83,40	89,30	86,01±1,78
Type 3	8	86,50	92,10	89,10±1,82
Type 4	8	84,40	90,30	86,95±1,82
Type 5	8	81,80	88,20	84,87±1,88

The intensity of solar radiation is relatively large and will cause air and soil temperatures to rise. To release water particles due to condensation in the air or on the surface of the ground more quickly, so that the water vapor pressure in the air is not saturated, consequently, the air humidity will decrease. The density of vegetation influences the high or low intensity of sunlight that reaches the environment around pepper plants. High density will produce high air humidity, conversely, if vegetation density is relatively low then air humidity will tend to be lower (Prakoswo et al., 2018) supported by the statement of Jia et al. (2022), different land uses will affect the climate produced.

As seen between type 3 and type 5, air humidity is inversely proportional to the data transmission of sunlight and air temperature. Previously, type 5 was higher than type 3, but the humidity of type 3 air was higher. This is because a decrease will follow the higher transmission of sunlight and temperature in air humidity. In addition, the amount of sunlight transmitted causes the water content to decrease due to evaporation, which results in smaller vapor pressure and lower humidity. In addition, increasing the intensity of sunlight will also increase the temperature of the leaves, which causes water to evaporate faster. Rising temperatures allow the air to carry more moisture. The wind carries much CO_2 and expels water vapor. This causes reduced air humidity.

3.1.4. Microclimate Correlation to Pepper Plant Productivity

The productivity of pepper plants in each type of system is presented in Table 5. This difference was caused by the number of pepper plant populations and the diversity of vegetation types compiler the pepper plant agroforestry system. The magnitude of this effect can be seen in the correlation matrix between microclimate and pepper plant productivity Table 5.

Table 5. Productivity of pepper plants

Agroforestry	Planting Distance (cm)	Population (ha^{-1})	Average panicle plants^{-1}	Average panicle Grains^{-1}	Average Dry Weight Grain (g^{-1})	Yields (kg ha^{-1})
Type 1	2,4 X 2,4	1702	386	37	0,022	535
Type 2	2,0 X 2,0	2215	306	55	0,021	783
Type 3	2,4 X 2,4	1530	181	46	0,024	305
Type 4	1,8 X 1,8	2777	239	42	0,027	751
Type 5	1,7 X 1,7	2814	295	43	0,023	821

Source: Primary Data Processing, 2023.

The observation productivity of pepper reaches 535 kg ha^{-1} (type 1), 783 kg ha^{-1} (type 2), 305 kg ha^{-1} (type 3), 751 kg ha^{-1} (type 4), and 821 kg ha^{-1} (type 5). The observations of the five types of components compiler the pepper agroforestry system show that the productivity of type 5 was the highest and type 3 was the lowest. Nevertheless, this production yield was still far from the potential productivity of pepper plants, which could reach 2500 kg ha^{-1} (Ministry of Agriculture, 2013). This showed that the diversity of microclimates created could affect the pepper plants' productivity. A microclimate influences the production of plant biomass. The climate was also one factor influencing plant growth and productivity. Some climatic factors that significantly affect plant growth are the Light transmission of the Sun, air temperature, and humidity (Chiang et al., 2020). The microclimate plays a very important role in the growth and development of plants in certain regions because plants need microclimate elements in optimal conditions to grow and develop well (Dahlberg., 2016).

Table 6. Correlation Matrix Between Micro Climates and Pepper Plant Productivity

Variable	Sunlight Transmission	Air temperature	Humidity	Yields
Sunlight Transmission	1,0			
Air temperature	0,99	1,0		
Humidity	-0,93	-0,95	1,0	
Yields	0,84	0,91	-0,93	1,0

Source: Primary Data Processing, 2023.

The correlation test showed that the productivity of pepper was strongly influenced by the microclimate created in each system type. Table 6 interprets the close relationship between microclimate and pepper crop productivity; the relationship shows a positive relationship between sunlight transmission and air temperature on the productivity of pepper, while the humidity of the air gives a negative relationship. According to the statement of Al-Bakri et al. (2013), if the intensity of sunlight were higher, it would be followed by an increase in air temperature and a decrease in air humidity. It showed the closeness of the relationship shown by the magnitude of the correlation value microclimate, the correlation value of sunlight transmission to air temperature $r = 0.99$, the humidity was r = -0.93 and air temperature to humidity was r = -0.95 while the correlation value of sunlight transmission to productivity was r = 0.84, air temperature to the productivity of r = 0.91 and air humidity to the productivity of R^2 = -0.93. According to Rachman et al. (2024), the correlation between the microclimate and productivity of pepper plants in different agroforestry system components is strong, with a correlation coefficient of ≥0.5. and different is, with a coefficient of ≥0.5.

Agroforestry	**Form of Multiple Regression Equations**	**R^2**	**Significant**

The light transmission of the sun causes the temperature of the air to rise so that water particles run faster in the condensation process in the air or on the surface of the ground so that the water vapour pressure in the air is not saturated, consequently the air humidity would decrease. The results above showed that environmental factors affect not only the physical process and diffusion but also the opening and closing of stomata on the leaf's surface through which water and CO_2 are transferred. This is related to the process of photosynthesis; the greater the light transmission of the Sun received by pepper plants, the more the photosynthesis process would increase, and it affects the process of photosynthesis in producing assimilates. The assimilation results could be shown in the productivity of pepper plants. The relationship is interpreted that an increase in sunlight transmission and air temperature would increase the productivity of pepper plants, while if the humidity increases, productivity would decrease.

This was closely related to the process of photosynthesis because, in that process, solar energy is used to generate metabolic energy, namely ATP (Adenosine triphosphate) and NADPH (Nicotinamide adenine dinucleotide phosphate expelled) to reduce CO_2 to carbohydrates, resulting in the assimilation that could be the fruit. Paradiso and Pascale (2014) supported this statement, stating that plants need sunlight for photosynthesis to grow, develop, and produce optimal results. This study's highest productivity of pepper plants was a system Type 5. In this case, it was confirmed that the presence of sunlight transmission, high air temperatures, and low humidity would increase the productivity of pepper plants in line with the statement of Pal et al. (2013), which revealed that plants that get high-sunlight intensity tend to produce plants and relatively better productivity compared to plants with lower sunlight intensity.

The Type 5 system has a diversity of vegetation types that compose an agroforestry system with vegetation cover that was the lowest. Vegetation cover in a system influences the light transmission of the Sun received by pepper plants because, with a low vegetation canopy area in an agroforestry system, it turns out that sunlight transmission reaches the pepper plants greater so that the pepper plants can make photosynthesis better than pepper plants in the type of system with a high shade of canopy vegetation. The average Light transmission of the Sun received by pepper plants in the fifth type of system is 70.79%. Apart from the microclimate element, other factors influence pepper plants' high and low productivity, namely nutrients. The following statement expressed by Khadka et al. (2016) explained that soil fertility is vital for plants because it is a media provider of nutrients for plants. After conducting soil testing, it turns out that type 5 has the highest levels of nutrients among the four other types of systems, so productivity was the highest.

Type 1	**Y**= 182.5 + 8.3**X1** + 2.4**X2** – 1.9**X3**	0.90	0.02
Type 2	**Y**= 812.9 + 1.5**X1** + 6.1**X2** – 2.5**X3**	0.96	0.00
Type 3	**Y**= 163.9 + 2.1**X1** + 8.8**X2** - 2.2**X3**	0.93	0.01
Type 4	**Y**= 470.0 + 0.9**X1** + 12.6**X2** – 1.7**X3**	0.88	0.03
Type 5	**Y**= 1039 + 1.5**X1** + 9.3**X2** – 4.3**X3**	0.94	0.06

Table 7. Analysis of Multiple Regression
Source: Primary Data Processing, 2023

From the results of the regression analysis of productivity on the microclimate (sunlight transmission, air temperature, and humidity) as independent variables, the equation of each type of system was obtained in Table 6. The overall regression coefficient value ≥0.88 shows that ≥88% of the equation is affected by three independent variables, while the rest is influenced by other variables not included in the research model. Of the three independent variables, it turns out that air temperature was a parameter that greatly affects the level of productivity of the pepper plants produced, this can be seen in the form of the equation presented.

3.1.5. Land Suitability of Pepper Plant Needs

Many things must be considered when applying agroforestry planting systems. One aspect that must be considered is the environmental aspect because the agroforestry system was very closely related to the change and diversity of the microclimate created in the environment that implements it. The diversity of the microclimate could have a positive or negative impact depending on the purpose and type of plant being cultivated because each type of plant has its tolerance value to the microclimate that affects it. If the microclimate is created according to and within the tolerance limits of a type of plant, it produces optimal productivity, which would have a positive effect, and vice versa. In determining the use of agroforestry systems, of course, one must attend to the suitability of land for a type of plant so that the productivity plants cultivated, especially pepper, can grow and produce optimal productivity despite the diversity of vegetation types of high or low in forming a pepper agroforestry system.

A study of the land suitability of pepper could reduce the negative impact caused by the diversity of environmental conditions due to a combination of various vegetation in each type of system. The land suitability of pepper plants for each type of system is presented in Table 7. According to Rachmawati et al. (2020), the land suitability analysis results performed on each type of system included some of the systems as being very appropriate and marginal. It is of course, important to know that corrective actions can be taken immediately, from the several land suitability assessment units above, sunlight transmission was significant to be improved because observations show that the type of system has a diversity of sunshine transmission percentages. The difference was due to the type of vegetation and different levels of vegetation. The pepper requires the intensity of sunlight in the range of 50%-75% so that if the plants get the Light transmission of the Sun around 75%, then the resulting productivity could be optimal, but vice versa, if <75%> then the productivity could be much lower (Issukindarsyah et al., 2020).

Table 8. Land suitability of each type of system for the needs of pepper plants

Terms of use	**System Type**				
land characteristics	**1**	**2**	**3**	**4**	**5**

Micro-climate					
Sunlight Transmission (%)	54,9 ± 4,38	64,8 ± 4,98	51,2 ± 3,95	58,7 ± 5,29	70,8 ± 4,74
Air temperature (°C)	26,9±0,60 S1	28,4±0,42 S1	26,0±0,68 S1	27,6±0,47 S1	29,3±0,37 S1
Humidity (%)	87,9±1,83 S1	86,0±1,78 S1	89,1±1,82 S1	86,9±1,81 S1	84,8±1,90 S1
Root Media					
Texture	Clay	Clay	Dusty clay	Dusty clay	Dusty clay
pH H_2O	5 S2	5 S2	5 S2	4 S2	5 S2
C-organic (%)	1.810 S1	2,480 S1	3,250 S1	3,280 S1	2,940 S1
Nutrients Available					
N total (%)	0,082 S3	0,073 S3	0,081 S3	0,107 S2	0,112 S2
P_2O_5 (ppm)	12,56 S1	11,62 S1	16,32 S1	15,21 S1	22,16 S1
K_2O (me / 100 g)	22,53 S1	21,27 S1	32,19 S1	31,54 S1	32,77 S1
Yields (kg ha^{-1})	535	783	305	751	821

Information: Environmental variables followed by letters indicate the level of suitability based on land suitability criteria for pepper plants according to the Indonesian Ministry of Agriculture: S1; Very Appropriate, S2: Sufficiently Appropriate, S3: Marginal Appropriate.

Land suitability assessments are carried out based on microclimate data, soil conditions, and pepper crop productivity in each type of agroforestry system component. Based on observations and evaluations of the characteristics of each type of agroforestry system implemented by pepper farmers in North Lampung Regency, of the five types of systems, the 5 type is the type of system that has the best land suitability because, based on the appraisal suitability of pepper Mugiyo et al. (2021) for types 4 and 5 generally included in the S1-S2 category, this means that the types of systems 4 and 5 correspond to the characteristics of the needs of pepper plants, but if showed from productivity produced then type 5 gives the best results among the four other types.

For types 1, 2, and 3, there are limiting factors in nitrogen levels in the soil. This can be seen in Table 8. By giving this S3 code, if the land was still used as a location for pepper cultivation, it was necessary to increase nitrogen levels to produce optimal production. The observations show that although nutrients in the soil are available and meet the needs of plants, if the microclimate elements above are not optimal, they would affect the productivity produced and vice versa. Khadka et al. (2016) expressed that soil fertility is very important for plants because it is a nutrient for developing agricultural commodities. They are also supported by the statement of Olaniyi et al. (2015), which states that the right and appropriate land use would produce good crops and high production.

4. Conclusion

Based on the research data obtained and the testing described in the previous chapter, the determinants of microclimate diversity of pepper agroforestry systems were canopy area, density, frequency, and kind of vegetation. The magnitude of sunlight transmission, temperature, and humidity in pepper agroforestry systems was influenced by vegetation characteristics. The relationship formed by the transmission of sunlight and air temperature is positive linear, while the humidity of the air forms a negative linear relationship to the productivity of pepper plants in the agroforestry system tested. Type 5 is the ideal agroforestry system for pepper plants. Where the microclimatic conditions formed by type 5 can produce the highest pepper productivity among other system types.

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