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Vegetation Structure and Composition of Coffee Agroforestry in Kalibaru Sub-District

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Abstract. *Agroforestry is a form of sustainable agriculture; the present threat of agroforestry is a change in agroforestry landforms that have switched to a less sustainable form. Coffee plays a role in the agroforestry ecosystem, Kalibaru is one of the Banyuwangi District coffee centers managed by the local community. The objective of this study was to determine the vegetation structure and analyze the effect of that on environmental parameters. Data was collected by vegetation analysis and soil parameter analysis with PAST 2020 Software version 4.05. In total, 15 research plots were used, consisting of 5 complex agroforestry, 5 simple agroforestry, and 5 monoculture plots. The results showed 20 species in complex agroforestry, 24 species in simple agroforestry, and 18 species in monoculture were found. The highest important index level in complex agroforestry: Durio zibethinus 63.87% for trees, the Swietenia mahagoni 64.43% for poles, and Coffee canephora 128.87% for shrubs. In simple agroforestry : Cocos nucifera 72.83% for trees, Leucaena leucocephala 80.70% for poles, and the Coffea canephora 137.57% for shrubs. In monoculture agroforestry: Hibiscus similis 82.99% for trees, Leucaena leucocephala 209.22% for poles, and Coffea canephora 130.96% for shrubs. Agroforestry in Kalibaru was categorized in the moderate diversity. The diversity index (H') in complex agroforestry showed H' trees 2.21, pole 2.03 and. shrubs 1.60. Simple agroforestry shows H' tree 2.00, pole 2.49, and shrubs 1.50. Monoculture shows H' tree 1.98, pole 0.64, and shrubs 1.54. Agroforestry a role in maintaining soil moisture and temperature, complex agroforestry: temperature 24 0C, and Moist 5.82, simple: temperature 24.2 0C, Moist 5.42, and Monoculture temperature 26 0C, Moist 4.54.*

Keywords: *agriculture, distribution, diversity, soil parameters, important value indexs*

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INTRODUCTION

Agroforestry could be defined as land use that manages main plant species with mixed crops (Escobar-López et al., 2022) to gain benefit from ecological interactions. The application of agroforestry depends on local people's knowledge, interaction with the environment and socio-economic (Hasannudin et al., 2022), so that agroforestry practices are considered as a form of sustainable agriculture. Agroforestry has the threat of shifting land use that is less sustainable so it impact ecosystem stability (Pearson, 2021).

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Coffee is one of the plantation plants' role in agroforestry (Lisnawati et al., 2017). Kalibaru Sub-District is a coffee center, coffee land use is dominated by community gardens and the rest belongs to private or government plantations (Parmawati et al., 2022). Coffee is one of the leading commodities in Kalibaru which has encouraged various research related to coffee, such as the management of smallholder coffee farming (Pusfitasari et al, 2018), coffee processing (Lusi et al, 2020), and coffee productivity based on geography (Sari et al., 2015). Coffee agroforestry is important for the intensification of agricultural ecology (Lisnawati et al., 2017). Coffee agroforestry is managed as an agricultural system with layered, multi-species (complex), moderately shaded, and no shade (monoculture) (Hakim, 2021; Latue et al., 2019). Shade trees in coffee agroforestry would function as light filtration for coffee plants, to enhance the productivity of coffee agroecosystem and reduce soil evaporation (Piato et al., 2022).

Kalibaru people's coffee agroforestry is in the community field which borders the production forest area. However, there is no research related to the Kalibaru people's coffee agroforestry, so there is a need for scientific studies related to coffee agroforestry. This study provides structure of agroforestry plants diversity and soil parameters, we also analyzed the stratification in each agroforestry profile, this data can be used as basic information for further research on the preservation of sustainable agriculture in Kalibaru Sub-District.

MATERIALS AND METHODS

Study Area

The coffee agroforestry survey was conducted from March to May 2022 in Kalibaru Subdistrict, Banyuwangi District. Kalibaru has anarea of 40,676 Ha with a coffee plantation area of 3,827 Ha in 2021. Kalibaru has an altitude of 1.312 - 2.624 ft with an average rainfall intensity of 2.478 mm/year. The locations for agroforestry data collection were carried out in 4 villages, Kalibaru manis, Kalibaru wetan, Banyuanyar, and Kajarharjo (Figure 1). Observation of vegetation is carried out by making observation plots in agroforestry coffee plantations owned by the Kalibaru people.

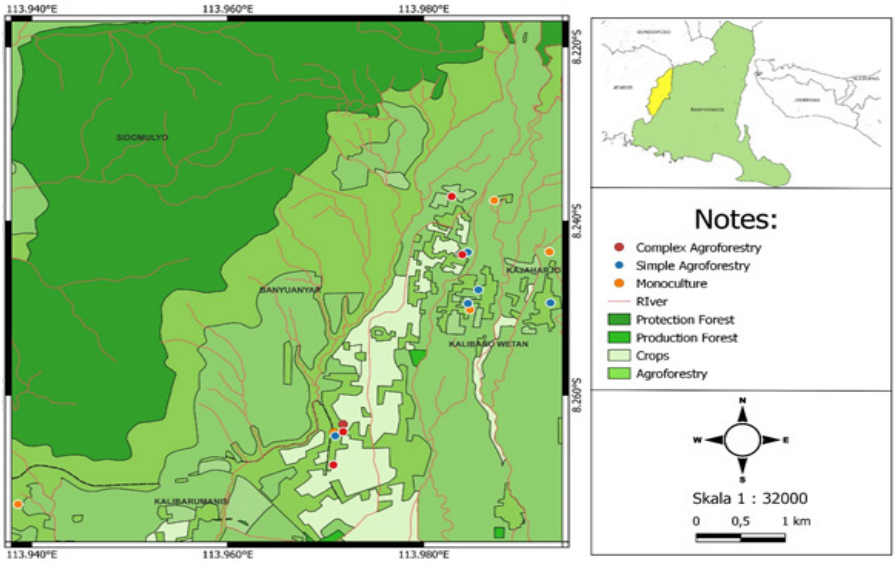

Figure 1. Map of the research in Kalibaru Sub-district, Banyuwangi Regency, East Java Indonesia.

Agroforestry has 3 types of profiles, complex agroforestry, simple agroforestry, and monoculture. Complex agroforestry is the management of planting a combination of forest plants / woody trees plant species with swidden crops to make agroforestry vegetation similar to forests with complex plants layer (Marconi & Armengot, 2020). Simple agroforestry is an intercropping pattern of planting with more than one type of plant species, planted as living fences and random plantings in the field (Latue et al., 2019). Monoculture coffee plantations are land management with full sun and a combination of economic-types plants (Nguyen et al., 2020). In total 15 research plots were analyzed consisting of five complex agroforestry plots, five simple agroforestry plots .and five monoculture plots.

Methods and Data Analysis

This study was conducted to determine the vegetation structure of Kalibaru Subdistrict people's coffee agroforestry by *purposive sampling*. Vegetation data collection was carried out by sampling 25x25 M2 plots to analyze trees, 10x10 M2 plots to analyze poles, and 5x5 M2 plots to analyze shrubs. Vegetation data were collected from 15 sampling points which were divided into 3 agroforestry profiles: complex, simple, and monoculture. The soil parameter data (pH, moist, temperature, light) were measured using a soil detector.

Quantitative analysis of research data, according to research conducted by Le Wang et al, 2022 to determine plant diversity, an analysis of Shannon-Wiener diversity index (H'), Margalef richness index (R), and Evenness index (E) (Wang et al., 2022). Meanwhile, to find out the structure of vegetation, it's analyzed using the important value index (Hidayat, 2018). In the analysis of diversity and structure of vegetation, it was distinguished based on plant habitus trees, poles, and shrubs. To find out the comparison and correlation of soil parameter dependencies using Software of PAST 2020 version 4.05.

RESULTS AND DISCUSSION

Coffee Agroforestry Structure

During observations in people agroforestry, there are differences in the distribution of plant species with various agroforestry profiles, shown in (Figure 2) and (Figure 3). Nearly 70% of the local people of Kalibaru are coffee farmers, with different land management. The results of our sampling in Kalibaru district get 3 profiles of coffee agroforestry systems. Plants species such as mahoni (*Swietenia mahagoni* (L .) Jacq), waru gunung (*Hibiscus similis* Blume), and kelapa (*Cocos nucifera* L.) are used by local people for hedges.

In the middle area of coffee agroforestry there are differences in land management and distribution of plant species. Management is natural and has a dense spacing between plants, making the complex system look like a forest with various types of plants. The types of coffee shade plants in complex systems are mindi (*Melia azedarach* L.), jabon (*Neolamarckia cadamba* (Roxb), Miq), sono (*Dalbergia latifolia* Roxb.), nongko (*Artocarpus heterophyllus* Lam.), kayu kembang (*Ptecarpus indicus*) and other woody plants species. Meanwhile, the management of a simple agroforestry system with more regular planting and determination of plants species based on the interests of each farmer, can be seen in (Figure 2b) in contrast to (Figure 2a) of the complex agroforestry system. Semi-open management with tree species in the middle area such as durian (*Durio zibethinus* L.), langsep (*Lansium domesticum* Correa),

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and alpukat (*Persea americana* Mill.).

Management of monoculture system is different from complex agroforestry systems and simple agroforestry. In the middle of the land, the monoculture only integrates types of plants that have economic value as coffee shade plants, and no tree plants species. The most of local people that manage coffee agroforestry with a monoculture system of the types of plants used are, pepaya (*Carica papaya* L.), pisang (*Musa paradisiaca* L.), and jambu (*Psidium guajava*).

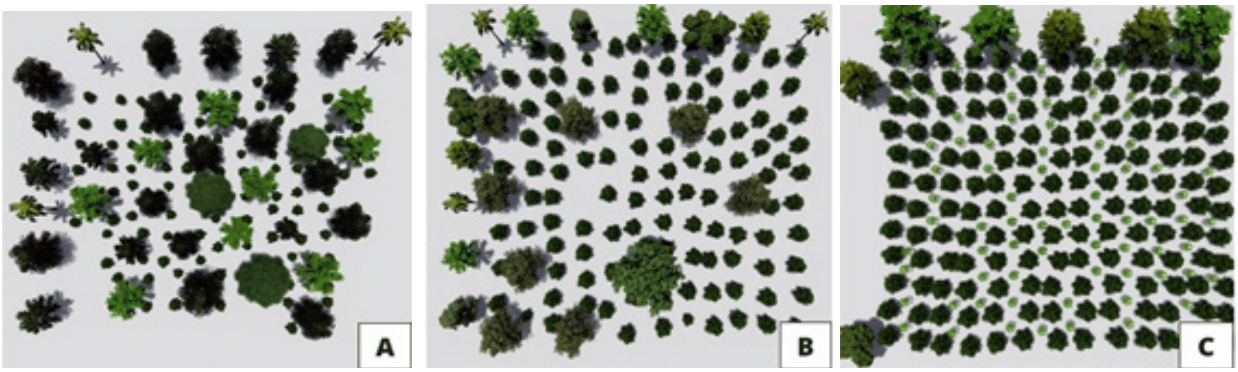

Figure 2. Distribution of coffee agroforestry plants (A: complex agroforestry,B: simple agroforestry, and C: monoculture)

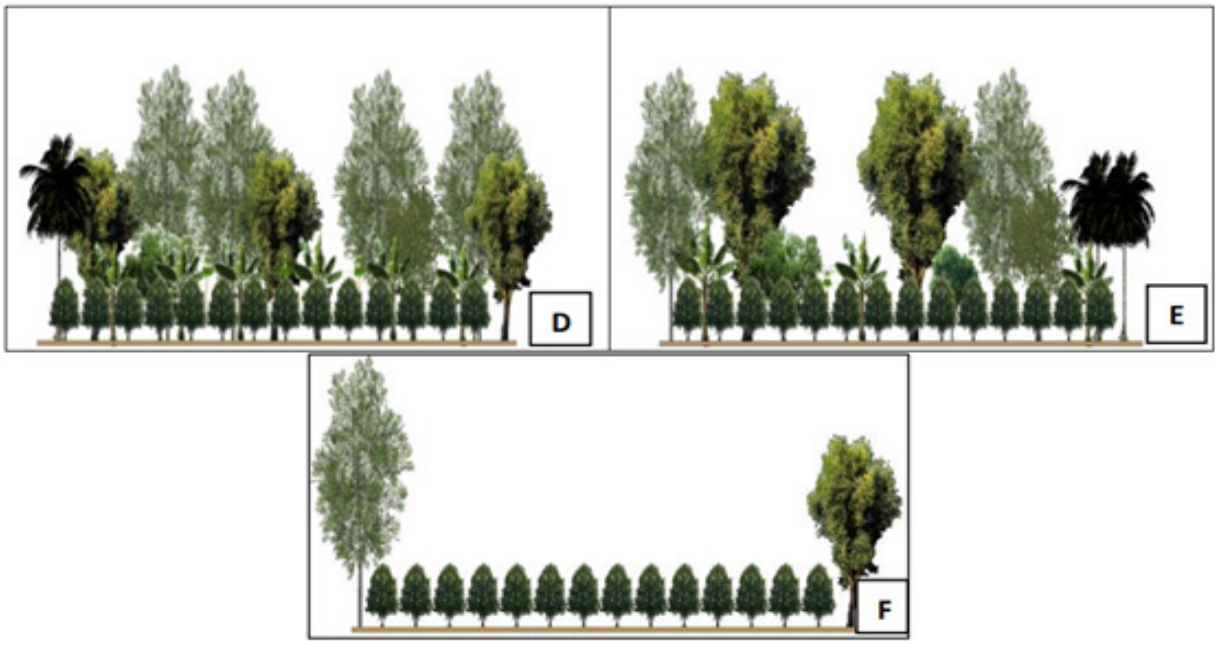

Figure 3. Coffee agroforestry profiles (D: complex agroforestry, E: simple agroforestry, and F: monoculture)

The diversity of coffee agroforestry patterns in local people is influenced by community interests and considers environmental conditions (Hakim, 2021). Such as planting mahoni (*S. mahagoni* (L.) Jacq), waru gunung (*H. similis* Blume) and kelapa (*C. nucifera* L.) on the edge of the land with the aim of reducing soil erosion. In addition, reducing erosion by planting woody trees in community coffee agroforestry aims to meet the demand for wood and protect forests from illegal logging. Local people from each agroforestry land management have their own perceptions. Differences in perception are due to old local

knowledge and modern knowledge, old local knowledge in the community is the perception that coffee agroforestry management with various types of plants can meet personal needs, as well as livestock needs. On the other hand, modern knowledge enters society, due to people's interest in a commodity with high selling value and a faster harvest period.

Vegetation Diversity and Coffee Agroforestry Important Value Index

Vegetation Diversity

In this study, 31 species with 20 families were found at 15 sampling sites in people's coffee agroforestry. The coffee agroforestry system in Kalibaru has a vegetation composition and structure containing many types of trees, some are wood-producing trees, seasonal fruit trees, and shrubs for fodder. Table 1 shows agroforestry in Kalibaru is in the category of moderate diversity (1<H'<3), and the monoculture stake diversity index is categorized as low (H'≤1).

Based on the analysis profile of coffee agroforestry in Kalibaru, the diversity index (H') in complex agroforestry shows H' trees of 2.21, poles 2.03, and shrubs 1.60. Simple agroforestry shows H' trees 2.00, pole 2.16, and shrubs 1.50. Monoculture shows H' trees of 1.98, poles 0.64, shrubs 1.54 (Table 1). Complex agroforestry coffee of management naturally affects species diversity in vegetation relatively high (Table 1). Complex agroforestry with natural management can support species diversity in society. Another study confirmed agroforestry's role in the diversity and evenness of species (Molla et al., 2023).

The species richness index (R) of the agroforestry complex shows that trees R: 3.19, poles 2.89, shrubs 1.92. Simple agroforestry shows trees R: 2.49, poles 3.17, and shrubs 2.53. Monoculture trees R: 2.76, poles 0.91, and shrubs 2.15 (Table 1). Species richness in agroforestry is influenced by land use of diverse interests, complex agroforestry that integrates diverse crops and dense planting density makes the species richness value high. Simple agroforestry that integrates seasonal fruit plants with semi-structured utilization marked in a moderate richness value. Monoculture with single-commodity land use and lack of shade plants makes in low species richness value.

Kalibaru coffee agroforestry has a high evenness index. Complex agroforestry shows trees' evenness index of 0.70, poles 0.70, and shrubs 0.45. Simple agroforestry shows trees' evenness index of 0.73, poles 0.72, shrubs 0.31. Monoculture shows trees' evenness index of 0.72, poles 0.54, shrubs 0.38 (Table 1). Low evenness of pole in monoculture was due to the presence of plants lamtoro (*Leucaena leucocephala* (Lam.) de Witt) and jambu (*Psidium guajava* L) in high abundance (Table 2). The dominance of coffee on shrubs affects the overall low-equipped agroforestry evenness (Table 2). High evenness species in agroforestry, indicate that agroforestry has efforts to maintain biodiversity, as explained by Lestari et al. (2021) that evenness shows balance of species in the community.

Table 1. Parameter index ofAgroforestry Diversity

Category	Tree			Pole			Shrubs		
	H'	E	Richness	H'	E	Richness	H'	E	Richness
Complex agroforestry	2.21	0.70	3.19	2.03	0.70	2.89	1.60	0.45	1.92
Simple agroforestry	2.00	0.73	2.49	2.16	0.72	3.17	1.50	0.31	2.53
Monoculture	1.98	0.72	2.76	0.64	0.54	0.91	1.54	0.38	2.15

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The species' highest important value in coffee agroforestry showed the results as follows: In complex agroforestry, trees with the highest important value belong to durian (*D. zibethinus* L.) (63.87%), pole: mahoni (*S. mahagoni* (L.) Jacq) (64.43%), shrubs: robusta coffee (*Coffea canephora Pierre* ex *A. Froehmera*) (128.87%). In simple agroforestry, trees with the highest important value is trees (*C. nucifera* L.) (72.83%), pole: strata lamtoro (*Leucaena leucocephala* (Lam.) de Witt) (80.70%), shrubs: robusta coffee (*C. canephora* Pierrre ex *A. Froehmer*) (137.57%). In monoculture the highest important value of tree strata is waru gunung (*H. similis Blume*) (82.99%), pole strata: lamtoro (*L. leucocephala* (Lam.) Jacq) (209.22%), and shrubs strata: robusta coffee (*C. canephora* Pierre ex *A. Froehner*) (130.96%).

Table 2. Species High important value

Species	Important Value Index (%)		
	CA	SA	MNC
Tree			
Durio zibethinus L.	63.87	57.94	17.12
Cocos nucifera L.	61.47	72.83	39.90
Swietenia mahagoni (L.) Jacq.	47.76	30.72	25.55
Hibiscus similis Blume	19.41	12.12	82.99
Pygeum parviflorum Teijsm. & Binn.	26.01	12.21	45.98
Parkia speciosa Hassk	10.03	13.06	13.50
Pole			
Swietenia mahagoni (L.) Jacq.	64.43	-	-
Hibiscus similis Blume	60.83	-	-
Leucaena leucocephala (Lam.) de Wit	-	80.70	209.22
Durio zibethinus L.	45.10	54.10	-
Psidium guajava L.	-	-	90.78
Albizia chinensis (Osbeck) Merr.	9.97	15.92	-
Neolamarckia cadamba (Roxb.) Miq.	39.14	-	-
Shurbs			
Coffea canephora Pierre ex A.Froehner	128.87	137.57	130.96
Musa paradisiaca L.	46.47	54.21	60.44
Gliricidia sepium (Jacq.) Walp	21.95	31.11	37.15
Leucaena leucocephala (Lam.) de Wit	8.70	30.52	25.37
Albizia chinensis (Osbeck) Merr.	35.14	9.34	5.08

Note: CA: complex agroforestry, AS: simple agroforestry and MNC: Monoculture

The canopy layer in the coffee field which consist of 3 layers of strata including trees, pole, and shrubs play an important role in the ecology of coffee agroforestry. Several plant species of tree that have an important role in coffee agroforestry are kelapa (*C. nucifera* L.), mahoni (*S. mahagoni* L. Jacq), and durian (*D. zibethinus* L.). Kelapa (*C. Nucifera* L.) in coffee agroforestry can increase carbon stocks, and part of plants such as fruits, stems and leaves can be used to increase local people's incomes (Lewerissa et al., 2020). Local people often use seasonal fruit plants in coffee agroforestry, durian (*D. zibethinus* L.), because it has a distinctive taste (Arsa et al., 2021) and high local market demand, this makes durian (*D. zibethinus* L.) often encountered in coffee agroforestry.

In addition to plants species that have economic value, the woody plants such as mahoni (*S. mahagoni* (L.) Jacq), waru gunung (*H. simillis* Blume), nyampuh tree (*P. parviflorum* Teijsm & Binn.), sengon (*Albiizia chinensis* (Osbeck) Merr) and jabon (*Neolamarckia cadamba* (Roxb) Miq) in coffee agroforestry ecosystem also play important role. Mahoni (*S. mahagoni* (L.) Jacq) is a woody plant species that is very tolerant of various environmental conditions (Budianto et al., 2014). Mahoni (*S. mahagoni* (L.) Jacq) is often encountered in coffee agroforestry due to its important role in reducing erosion (Mashudi & Susanto, 2016). Waru gunung (*H. simillis* Blume) and nyampuh (*P. parviflorum* Teijsm & Binn) are woody plants that is used as building material and firewood by the local people. As human population continues to increase in demand for wood for plywood and furniture (Rizky et al., 2022), the people of Kalibaru plant fast-growing species of wood such as sengon (*A. chinensis* (Osbeck) Merr) and jabon (*N. cadamba* (Roxb) Miq.) to meet the demand for wood raw materials and increase income. Jabon (*N. cadamba* (Roxb) Miq) has broad leaf characteristics and hardwood properties, often used for pulp, plywood, and furniture needs. Sengon (*A. chinensis* (Osbeck) Merr) is a woody plant that is tolerant of environmental conditions and can increase soil organic elements such as N, pH, and C-organic (Khalif & Utami, 2014). The fast-growing nature of sengon (*A. chinensis* (Osbeck) Merr) and jabon (*N. cadamba* (Roxb) Miq) results in a high need for water and plant nutrients (Ninilouw & Linda, 2015). This has a negative impact on the growth of plants underneath such as coffee.

In the shrubs strata coffee shade plants that are often found in coffee agroforestry are lamtoro (*L. leucocephala* (Lam) de Witt) and klirisidi (*G. sepium* (Jacq) Walp.). Local people utilize plants klirisidi (*G. sepium* (Jacq) Walp) to meet animal feed needs, due to its tolerance to all environmental conditions and also increases organic matter C and N by around 37% and 82% respectively (Camelo et al., 2021). Local people's perception of a good shade plant for coffee is lamtoro (*L. leucocephala* (Lam) de Witt), a small leaf morphology that filters light in coffee agroforestry without inhibiting the growth of coffee plants. This is in line with the research of Campa et al (2017) which explains that the influence of light absorption on coffee leaves significantly affects coffee productivity (Campa et al., 2017).

Pisang (*M. paradisiaca* L.) is an important plant in coffee agroforestry, the high benefit value of pisang (*M. paradisiaca* L.) in local people, namely: its leaves are used as a traditional food wrapper, the heart of pisang (*M. paradisiaca* L.) as vegetables and fruits as Table food, traditional processed and offerings of local cultural activities (Mukhoyyaroh & Hakim, 2020). The once-grown pisang (*M. paradisiaca* L.) can be used as a natural fertil-

izer and increase the organic content in coffee agroforestry.

Coffee Agroforestry Soil Quality

Intensive land use has been recorded as environmental and climate problem, including soil ecosystem services (Bārdulis et al., 2022). Coffee agroforestry can overcome environmental problems that occur, based on the PCA analysis shown in (Figure 4), (Table 3 and Table 4), multicultural and simple culture agroforestry systems have high humidity, while in monocultures that manage open and intensive land have high soil temperatures.

Table 3. Coffee agroforestry average soil quality

	pH	Temperature (^{0}C)	Humidity(%)	Light(l/m^2)
Complex Agroforestry	7.3	23.4 ^{0}C	7.02 %	256 l/m^2
Simple Agroforestry	7.5	24.4 ^{0}C	6.08 %	450 l/m^2
Monoculture	7.6	26.4 ^{0}C	4.68 %	636 l/m^2

The quality of soil parameters is influenced by agroforestry vegetation, complex agroforestry integrating land patterns similar to forests can increase soil moisture, reduce light penetration in the undercover, and lower soil temperature. Soil quality in simple agroforestry with low light intensity on the undercover and moderate soil moisture is influenced by structured of agroforestry patterns as well as non-complex planting distances compared to complex agroforestry.

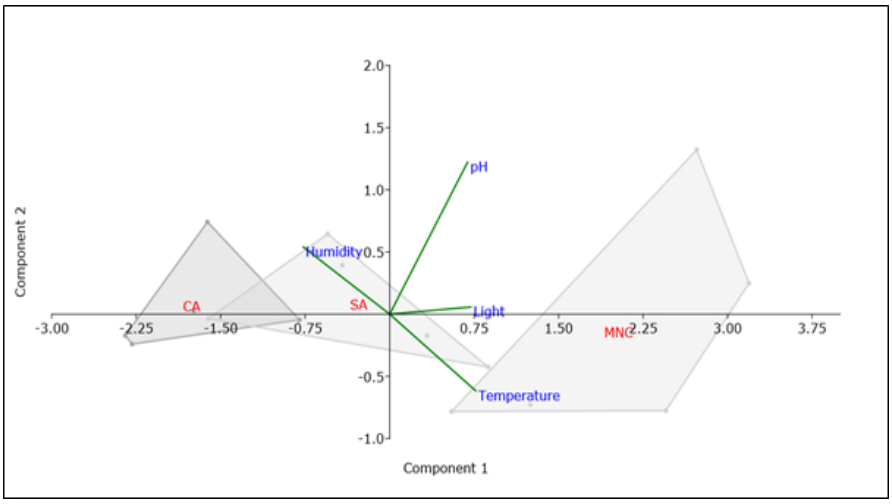
Table 4. Correlation of dependence on soil quality agroforestry coffee

	Temperature ^{0}C	Humidity (%)	Light (l/m^2)	pH
Temperature ^{0}C		0.20	0.25	0.01
Humidity (%)	-0.34		0.32	0.44
Light (l/m^2)	0.31	-0.27		0.19
pH	0.61	-0.21	0.35	

PCA analysis aims to determine differences in soil quality based on coffee agroforestry management systems. Results of the PCA analysis in Figure 4 show that high-temperature correlates with increased pH, on the other hand, if the temperature is high, the humidity is low. The soil quality of Coffee agroforestry varied . In monoculture the pH quality 7.6, the humidity 4.68%, and soil temperature 26.4 ^{0}C. In the agroforestry complex, the pH 7.3, Humidity 7.02 %, and soil temperature 23.4 ^{0}C. Whereas in Simple agroforestry complex, the pH 7.5, Humidity 6.08 %, and soil temperature 24 ^{0}C (Table 3).

Soil pH quality is affected by moisture and nutrients contained. Lack of nutrients results in alkaline soil (Beheiry et al, 2023). The soil content of Aluminum (AI), Iron (Fe), and manganese (Mn) affects the pH quality of the soil (Saplings et al., 2022). According soil quality, complex agroforestry and simple agroforestry with species richness and diver-

sity (Table 1) can maintain relatively high soil moisture (Table 4). Studies confirmed soil moisture is affected the vegetation on it, complex vegetation has high soil moisturewhile open field has low soil moisture (Sánchez et al., 2021), shade plants affects soil evaporation and make soil moisture quality in shaded areas stable (Lin, 2010).



Note: CA: complex agroforestry, SA: simple agroforestry, dan MNC: monoculture
Figure 4. PCA Analysis of Agroforestry Soil Quality

CONCLUSION

In this study, agroforestry was influenced by the interests of local people, three agroforestry systems were analyzed including complex agroforestry, simple agroforestry, and monoculture. Management of complex agroforestry and simple agroforestry with high diversity can play an important role in maintaining biodiversity in Kalibaru District and can improve soil quality in agroforestry. The monoculture systems' absence of filtration of shade has relatively low diversity and species evenness, soil quality increasing at temperature and pH soil. This research can be used as a reference for policy and further research related to the Kalibaru area as a buffer for production forests.

AUTHOR CONTRIBUTION

T.A.P collected, analyzed data, and write manuscripts, L.H and M.A supervised all processes, field studies, and manuscript writing.

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CONFLICT OF INTEREST

There is no conflict of interest during the research work.

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