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REGULAR RESEARCH ARTICLE

The Pattern Recognition of Small-Scale Privately-Owned Forest in Ciamis Regency, West Java, Indonesia

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ABSTRACT

Small-scale Privately-owned Forest (SSPF) has various patterns identification, based on the stand structure and species composition. The recognition and classification of the SSPF cropping patterns are required for further planning and policy development. Therefore, this study aims to classify the cropping pattern of SSPF in Ciamis Regency, West Java Province, Indonesia. The data were collected by observing the stand structure and species composition of 150 plots of land, encompassing three Sub-districts representing the central, northern, and southern regions of Ciamis Regency. The four categorical variables include tree species composition, age, spatial distribution, and intercropping pattern. While the two continuous variables were stand density and basal area. The patterns obtained were classified based on a Two-Step Cluster algorithm with log-likelihood distance measure, and auto clustering using Schwarz's Bayesian Information Criterion, validated by silhouette index. In addition, a multicollinearity test was conducted to reduce redundancy in using variable sets. The results showed that, the improvement of the cluster quality based on the silhouette index value, was achievable by excluding the tree spatial distribution variable, which exhibits multicollinearity. The cropping patterns were classified into three categories, namely tree crops, mixed-tree lots, and agrisilviculture for group-1, group-2, and group-3, respectively. Group-1 consisted of stands with one or two commercial tree species, and in several cases, were intercropped. Group-2 contained uneven-aged mixed-tree stands without any crops. While Group-3 consisted of an intercropping system of uneven-aged mixed-tree stands and crops. The results suggest further analysis, in order to relate the cropping patterns with the socio-economic characteristics of the landowners, as well as the strategies for the development of a sustainable SSPF.

KEYWORDS
Agrisilviculture; Tree crops; Stand structure; Species composition; Two-step Cluster

1. INTRODUCTION

Small-scale privately-owned forest (SSPF) is a traditional land use system, particularly on Indonesia's Java Island. It is grown on a confined piece of land with a minimum total area of 0.25 ha, and is dominated by tree vegetation covering more than 50% space, for example 500 trees/ha (Puspitojati et al., 2014; Soendjoto et al., 2008). The most recent national SSPF standing stock reported that, forest resources fluctuated between 18.9 and 23 million m^3 between 2015 and 2019 (KLHK, 2019). Based on the 2013 agricultural census, the number of households cultivating forestry crops was 6.4 million, and Java island was home to 72% of the families (Badan Perencanaan Pembangunan Nasional, 2014). Therefore, the total area of the SSPF on Java Island was estimated to be 2.6 million ha, with 0.9 million ha, such as 35% of the portions in West Java Province (Departemen Kehutanan, 2009).

Ciamis Regency is one of the areas in West Java Province with the most significant representation of the SSPF. Based on the land cover analysis and landscaping imagery interpretation, the SSPF in Ciamis Regency in 2006-2008 is estimated to be approximately 20% of the total SSPF in West Java Province (Departemen Kehutanan, 2009). The most recent data showed that the Ciamis SSPF has a total area and a log production of 50,192 ha and 194,395 m^3 in 2019 (Cabang Dinas Kehutanan Wilayah VII Provinsi Jawa Barat, 2019a, 2019b). The presence of SSPF in the Ciamis Regency aided in stimulating local economic activity, as evidenced by the growth of the wood forest product processing industry. This development further extended to 455 units in 2019, employing 6,474 people, and having an investment value of IDR54.1 billion units (Dinas KIKMP, 2020).

The SSPF in Ciamis Regency has evolved in various patterns distinguished by vegetation structure characteristics. The preliminary observations on the SSPF in Ciamis District showed that, stand structure and species composition differed significantly between landowners. This finding was consistent with Awang et al. (2007) observation, where the SSPF is characterized by family-based management and separately developed by each landowner. The SSPF is distributed based on location, land size, and the diversity of cropping patterns in various topography. Previous studies showed that the diversity of stand characteristics in the form of structure and species composition was improved through biophysical and agro-climatic conditions (Abebe et al., 2013), socio-cultures of local communities (Blanco et al., 2019), silvicultural and management regimes practiced by landowners (Shepherd, 1986), as well as the transformation process of their management (Wiehle et al., 2014).

The large variety of SPFF planting patterns, without classification into simpler groups, cause difficulties in the planning and development for more productive and sustainable resources, by the local government and forest managers at the farmers' level. Several studies were conducted on stand structure and species composition in forests' ecological processes (Chanthorn et al., 2017), mapping and relating to successional age classes (Reyes-Palomeque et al., 2021); bioregions comparing (Bhatta et al., 2021), or changes due to anthropogenic disturbance (Loto and Bravo, 2020) and Templeton et al. (2019). However, studies on identifying and classifying forest cropping patterns based on stand structure and species composition are still limited. Therefore, this study identifies and classifies SSPF planting patterns, based on stand structure and species composition, as well as assists policymakers in planning future development. A clear grouping of cropping patterns is recommended as the basis for determining possible improvements and changes in both management intensity and species composition.

2. MATERIALS AND METHODS

2.1. Research location

The study was conducted in the Ciamis Regency, in West Jawa Province, Indonesia (Figure 1). This regency is located at 108°19′- 108°43′E and 7°40′30″- 7°41′30″S with a total area and distance of 1,536.84 km2 and 124 kilometers from West Java Province's capital city, respectively. The area ranges in altitude from 31 to 842 masl. on average per subdistrict (BPS Kabupaten Ciamis, 2021) in the mountains, at an elevation of 1775 masl. (Pemerintah Kabupaten Ciamis, 2019). Furthermore, Ciamis Regency has three soil types: andisol, inceptisol, and ultisol. The ultisol soil type predominates in the southern and central regions, covering an area of 79,445.67 Ha (49.73 percent), while andisol soil is found in the northern region (Pemerintah Kabupaten Ciamis, 2019). The southern region is a hilly plateau with slopes ranging from 15 to 40%, while the central and southern regions are lowlands with undulating slopes ranging from 0 to 15% (Pemerintah Kabupaten Ciamis, 2012). Additionally, the average monthly temperature ranges from 26.87 to 28.94°C, the humidity ranges from 68.85 to 88.75%, and the average rainfall from 2002 to 2012 is 2,110.16 mm/year. In 2020, the regency had 1,229,070 people, with a density of 799 people per km^2 (BPS Kabupaten Ciamis, 2019, 2021). Therefore, Ciamis Regency is known to be part of West Java Province, with the highest population after DKI Jakarta (BPS, 2019; BPS Provinsi Jawa Barat, 2018).

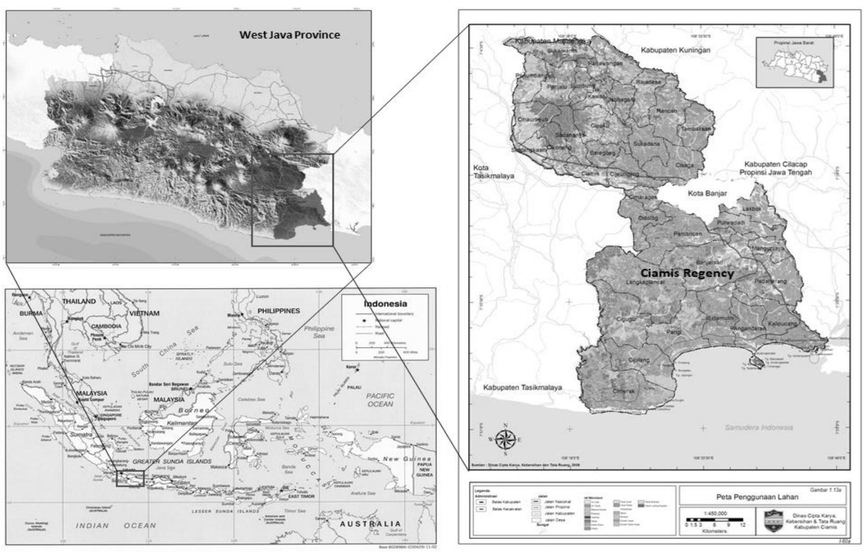

Figure 1. Case study location in Ciamis Regency, in southeastern West Jawa Province, close to the Indian Ocean

2.2. Data collection

The study locations were determined through multistage-cluster sampling with two stages. Three sub-districts were selected to represent the Ciamis Regency in the first stage. These sub-districts were Banjaranyar representing the southern region, Ciamis representing the central region, and Sukamantri representing the northern region. In the second stage, 50 plots were made on the SSPF in each sample sub-district, and the process of determining the points was based on a preliminary field survey and discussions with crucial respondents (12 village officials, four forestry extension workers, three farmer group administrators), considering the SSPF spots on the map. The selection of plots in the field follows predetermined criteria. The criteria for choosing the plots are 1) The operational definition of the SSPF, for example a minimum area of 0.25 ha in one stretch and tree vegetation 500/ha, according to the Minister of Environment and Forestry Regulation No. 89 of 2018, Minister of Forestry Regulation No. P. 03 of 2004 and the Decree of the Minister of Forestry Number 49 /

Kpts-II / 1997 (Puspitojati et al., 2014; Soendjoto et al., 2008); 2) There is a confirmed landowner; 3) The distance between points should at least be 200 m to ensure the spread of plots.

The structure and composition of the stands were observed on a 20 m x 20 m plot at each predetermined point. The following variables were assessed: basal area (BA), stand density, tree age (TA), tree species composition (TC), spatial tree distribution (TD), and crop farming under the intercropping system. Furthermore, the variables BA and stand density were measured as parameters to describe the stand structure (Bhatta et al., 2021). Table 1 shows that the remaining variables were divided into several categories. The TA variable is divided into even-aged, uneven-aged, and multi-aged, based on O'Hara (1998) while the TC variable was divided into monoculture and mixed-species categories based on Sardjono et al. (2003). The ecological terms, uniform or regular, random, and clumps refer to the category of TSD variables (Ludwig & Reynolds, 1988). However, these three categories of TSD were not measured using quantitative calculations, such as the Quadrat Variance Method. Instead, they were justified through visual observation of the appearance of the tree distribution in the observation plot, using the criteria described in Table 1. This relies on the fact that the spatial tree distribution is used to describe the spacing arrangement of the farmers on the plot scale instead of the spatial distribution of specific species at the community scale. Meanwhile, intercropping variables were observed in the SSPF stands to describe the presence or absence of understorey cultivation.

Table 1. Proposed variables used in the cluster analysis

Categorical Variables		Description
Tree Age	Even-aged	Stands with trees of the same age
	Uneven-aged	Stands with various ages of trees (O'Hara, 1998)
	Multi-aged	Stands with several age classes (O'Hara, 1998)
Tree Species Composition	Monoculture	Stands with 1 or 2 dominant tree species (Sardjono et al., 2003)
	Mixed-species	Stands consisting of a mixture of various tree species, all of which are considered important (Sardjono et al., 2003)
Tree Spatial Distribution	Regular	Stands with trees distributed regularly with a particular spacing
	Random	Stands with trees distributed randomly without regular spacing
	Clumps	Stands with trees distributed unevenly or in clusters
Intercropping	With Intercropping	Stands with intercropping between trees and understorey cultivation
	Without intercropping	Stands without intercropping between trees and understorey
Continuous variables		**Description**
Standing stock density (tree ha^{-1})		Number of trees per hectare
Basal Area (m^2 ha^{-1})		The base area of the tree trunk that is calculated based on tree diameter at breast height

2.3. Data analysis

Cluster analysis was performed as the primary data analysis method, using IBM SPSS 25 software to group the collected SPFF data plots for pattern recognition. Bhagat et al. (2013) reported that one approach used in pattern recognition is cluster analysis. The use of categorical or discrete data is based on the assumption that they can differentiate observations in objects with similar general characteristics (Watson, 2014). However, cluster analysis of categorical data necessitates a different algorithm distinct from continuous data sources (Bhagat et al., 2013; Řezanková & Everitt, 2009). Furthermore, categorical data also makes it easier to describe and label group characteristics. The variables used to classify cropping patterns were a mix of categorical and continuous data. However, this is true, where an object is frequently defined by a combination of categorical and continuous variables (Dinh et al., 2021).

2.3.1 Multicollinearity test

The multicollinearity test ensured that no strong correlation existed between the variables used (Nahdliyah et al., 2019); because redundancy and the presence of multicollinearity can reduce the quality of the expected result (Canali & Lancellotti, 2014). Furthermore, a non-parametric correlation with Spearman's correlation coefficient was used on categorical variables, while Pearson's correlation coefficient was used on continuous variables. The threshold used to test the occurrence of multicollinearity is the correlation coefficient (R) above 0.5 (R> 0.5). This is based on Dormann et al. (2013), who suggested a threshold value in the range of R values of 0.5-0.7 for the collinearity test. Furthermore, simple removal was performed on variables that exhibit multicollinearity to eliminate redundancy (Canali & Lancellotti, 2014).

2.3.2 Two-step cluster analysis

A two-step clustering (TSC) algorithm and a log-likelihood distance measure were used to group data from various cropping patterns. This approach and the log-likelihood distance method can group a mixture of categorical and continuous data (Carbone et al., 2019), (Yozza et al., 2016). Subsequently, this method has been used by several previous studies, including Vavougios et al. (2016), Qin et al. (2019), Long et al. (2020). The advantage of the TSC procedure is the ability to automatically set the number of groups (Carbone et al., 2019) using Schwarz's Bayesian Information Criterion (BIC). The BIC was used because it is a popular and reliable method to automatically determine the number of clusters (Teklehaymanot et al., 2021).

2.3.3 Cluster validation

Validation is required to assess the accuracy of the analysis results and the silhouette index is one of the clustering validation formulas (Nahdliyah et al., 2019). After multicollinearity analysis, the value is used to evaluate the clustering quality and determine the best set for reduced variables. Meanwhile, the best grouping is determined by the highest silhouette index value closest to 1 (Anaraki et al., 2021). The result of the pattern recognition performed by the best-validated cluster number was then profiled by describing the stand structure and species composition in each obtained cluster. This description was summarized based on the critical variables of the group.

3. RESULTS

3.1 Correlation-based multicollinearity test

The multicollinearity test conducted through non-parametric correlation analysis showed that the TC and TSD variables had a correlation coefficient (R) above 0.5 (Table 2) since the two variables have a close relationship, and multicollinearity occurs. Therefore, the clustering analysis can use other variables since the R values are below the threshold. Furthermore, the Pearson correlation on continuous variables (Table 3) also shows no strong relationship; these two variables can be used together in grouping analysis.

Table 2. Correlation matrix among categorical variables

			TA	TC	TSD	Intercropping
Spearman's rho	Tree Age (TA)	Correlation Coefficient	1.000	0.445	0.223	0.106
		Sig. (2-tailed)		0.000	0.006	0.198
	Tree Species Composition (TC)	Correlation Coefficient	0.445	1.000	**0.542**	0.202
		Sig. (2-tailed)	0.000		0.000	0.013
	Tree Spatial Distribution (TSD)	Correlation Coefficient	0.223	**0.542**	1.000	0.305
		Sig. (2-tailed)	0.006	0.000		0.000
	Intercropping	Correlation Coefficient	0.106	0.202	0.305	1.000
		Sig. (2-tailed)	0.198	0.013	0.000	

Table 3. Correlation matrix between continuous variables

		Stand Density	Basal Area
Stand Density	Pearson Correlation	1	0.201
	Sig. (2-tailed)		0.014
Basal Area	Pearson Correlation	0.201	1
	Sig. (2-tailed)	0.014	

The existence of multicollinearity in the TC and TSD variables requires further justification to determine which variables will be excluded. Therefore, grouping and validation were further carried out with the treatment of six and five variables by simply removing the TC or TSD.

3.2 Obtained groups description

The results of auto clustering analysis using the BIC value approach resulted in three groups in three treatments of variable set. First, the BIC value was continually decreased until 5 clusters increased when the number was more than 5 (Figure 2). Conceptually, the number of clusters was determined based on the smallest BIC value. However, considering that the BIC value often decreases with the increase in clusters, the determination can be made by considering the most significant value in the ratio of changes in the BIC value (Yozza et al., 2016). As presented in Figure 2, the largest changes were in the 3 and 4 cluster numbers. Furthermore, the TSC algorithm with the BIC approach and the Log-likelihood distance determined that the number of clusters automatically formed is three groups for all variable sets.

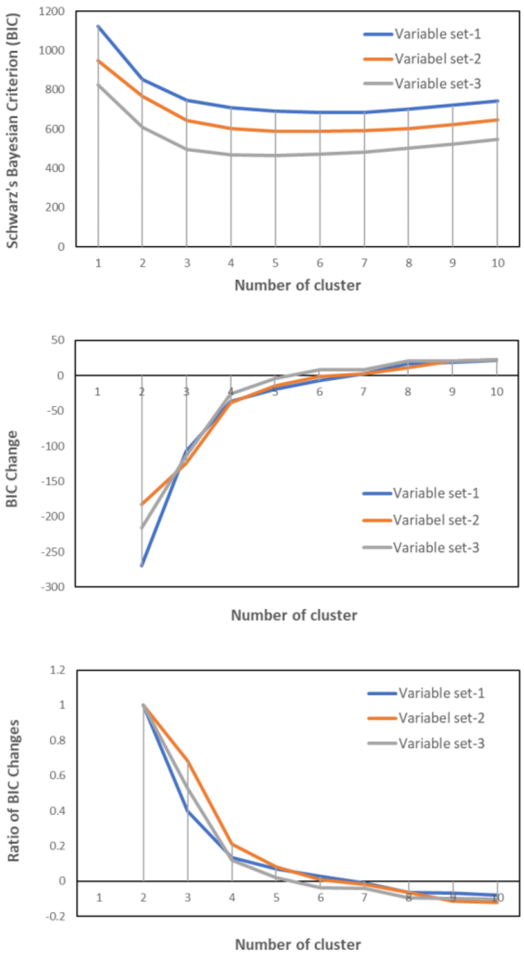

Figure 2. Comparison of Bayesian Information Criterion (BIC) value, BIC Change and Ratio of BIC Change among six variable clusterings (Variable set-1), five variable by excluding tree species composition (Variable set-2) and spatial tree distribution (Variable set-3)

The three treatments of the predictor variable set showed different trends in terms of the group member. Using six and five variables by excluding TSD indicated a similar trend, where the highest member was group-2. The other variable set, excluding the TC variable, showed a different trend where the highest member was group-3. However, the number of clusters formed in all treatments was distributed evenly in the predictor variable set used. This can be seen in the ratio of the largest and lowest groups, which only ranged from 1 – 1.6 (Table 4).

Table 4. Cluster distribution among various variable input

Cluster	Number of input					
	6 variables		5 variables (excluding TC)		5 variables (excluding TSD)	
	N	% of Total	N	% of Total	N	% of Total
1	38	25.3%	50	33.3%	44	29.3%
2	60	40.0%	43	28.7%	64	42.7%
3	52	34.7%	57	38.0%	42	28.0%
The ratio of size: most significant to smallest cluster	1.58		1.33		1.52	

Remarks: N = number of cluster member; TC = Tree species composition; TSD = Tree spatial distribution

3.3 Validation of the obtained groups

The use of predictor variables in grouping has a significant value of 0 to 1 as the least important to the most important. The importance of each predictor variable was from TC, TSD, TA, intercropping, stand density, and BA (Table 5). These essential values were changed using five predictors by eliminating the TC or TSD. The two continuous variables stand density and BA, were consistently at the bottom of the list. Therefore, these two variables did not determine the grouping through this TSC algorithm but remain necessary in characterizing the formed groups.

Table 5. Predictor importance among clusters based on various variable inputs

Nodes	Importance		
	6 variables	5 variables (excluding TC)	5 variables (excluding TSD)
Tree species composition (TC)	1	-	0.9716
Tree spatial distribution (TSD)	0.7341	1	-
Tree age	0.5750	0.8780	0.7803
Intercropping	0.4592	0.5778	1
Stand desity	0.1668	0.2127	0.0961
Basal area	0.0977	0.0902	0.1125

Silhouette index describes the quality of clusters formed based on the TSC algorithm. The use of all six variables and the simple removal of the TC all resulted in a silhouette fair value. Removing the TSD variable can improve the quality of silhouette value, reaching more than 0.5. The silhouette value in the grouping using all six variables resulted in 0.45 (Figure 3. A). Excluding the TC variable slightly decreased the silhouette index value to 0.43 (Figure 3. B). In contrast, excluding the TSD variable resulted in a higher silhouette index value of 0.57 or classified as a good value (Figure 3. C). Therefore, using five variables of TSC, intercropping, TA, BA, and stand density can produce the best silhouette value among the three treatments. Therefore, the subsequent discussion on group characteristics is based on grouping using these five variables.

A B C

Figure 3. Comparison of cluster quality of six variables (B) and five variables by excluding tree species composition (B) and spatial tree distribution (C)

3.4 Characteristics of determined Groups

The group formed based on the TSC analysis with five predictor variables resulted in three groups with their respective characteristics. The stand density and BA value of group-3 were to the left of the centroid (Figure 4) below the average value of all objects, which was 1639.7 tree ha^{-1} and 24.4 m^{2} ha^{-1}, respectively (Table 6). Conversely, group-2 was to the centroid's right or had a higher value than the average, and group-1 was close to the average stand density and BA value.

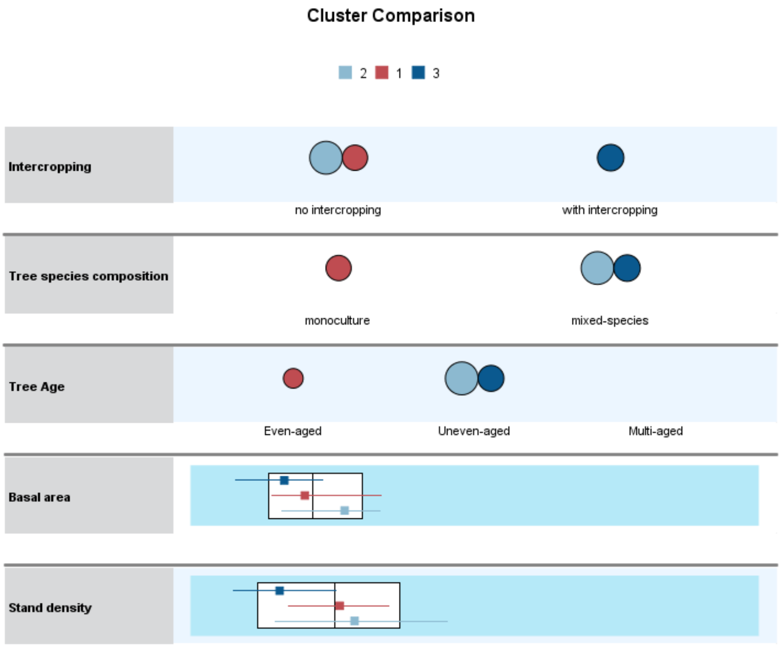

Figure 4. Cluster comparison based on predictor variables

Group-1 members were typically a monoculture system with even-aged trees, consisting of one or two tree species cultivated as the primary commodity. They were mostly not intercropped with any crops. However, farmers combine their tree stand with crops in some cases. Group-2 consisted of uneven-aged multispecies stands without intercropping with crops. Finally, group-3 consisted of an intercropping system of uneven-aged multispecies of trees with crops. Based on the characteristics, group-1 can be labeled as a "tree crops" pattern, group-2 as a "mixed-tree lots" pattern, and group-3 as an "agrisilviculture" pattern (Table 7).

Table 6. Group statistics of three determined clusters

Variables			Cluster 1	Cluster 2	Cluster 3	Combined
Stand Density (tree ha^{-1})		Mean	1800.57	1802.34	1223.21	1639.67
		Std. Deviation	1047.46	911.86	663.63	925.90
Basal Area (m^2 ha^{-1})		Mean	25.40	27.41	18.68	24.37
		Std. Deviation	13.15	12.12	8.56	12.06
Tree age	Even-aged	Frequency	23	0	0	23
		Percent	100.0%	0.0%	0.0%	100.0%
	Uneven-aged	Frequency	8	64	40	112
		Percent	7.1%	57.1%	35.7%	100.0%
	Multi-aged	Frequency	13	0	2	15
		Percent	86.7%	0.0%	13.3%	100.0%
Intercropping	no intercropping	Frequency	38	64	0	102
		Percent	37.3%	62.7%	0.0%	100.0%
	with intercropping	Frequency	6	0	42	48
		Percent	12.5%	0.0%	87.5%	100.0%
Tree species composition	monoculture	Frequency	38	0	0	38
		Percent	100.0%	0.0%	0.0%	100.0%
	mixed-species	Frequency	6	64	42	112
		Percent	5.4%	57.1%	37.5%	100.0%

Table 7. Summary of group characteristics

Cluster	Characteristics	Label
Group-1	Trees planted with regular spacing, consisting of an even-aged and one tree species two commercial tree species, mostly without intercropping of understorey plants, some of them combining with seasonal crops, commonly reflect intensive management practices, with an average stand density of 1800.6 trees ha^{-1} and BA 25.4 m^2 ha^{-1}	Tree crops
Group-2	Stands consisting of uneven-aged and multispecies, without any intercropping of undergrowth, reflecting conventional management practices, with an average stand density of 1802.3 trees ha^{-1} and BA 27.4 m^2 ha^{-1}.	Mixed-tree lots
Group-3	Stands consisting of uneven-aged and multispecies of trees, with intercropping of understorey plants, reflecting semi-intensive management practices, with an average stand density of 1223.2 trees ha^{-1} and BA 18.7 m^2 ha^{-1}	Agrisilviculture

4. DISCUSSION

This study depicts the current condition of the SSPF patterns in the Ciamis Regency by grouping using the TSC algorithm. Cluster analysis based on the stand structure and species composition resulted in three groups of cropping patterns. These are group-1 or tree crops pattern, group-2 or mixed-tree lots cropping pattern, and group-3 or agrisilviculture pattern (see some examples in Figure 5). In addition, they confirmed the classification of the SSPF planting pattern in West Java Province conducted by IPB (1983). These include pure pattern of one tree species, a mixed-tree pattern of different trees species, and agroforestry patterns of tree and understorey intercropping. The study showed that these cropping classifications are still valid in the Ciamis Regency. However, more detailed observations on the various cropping patterns can update the dynamic of SSPP's management practices.

The mixed-tree lots cropping pattern (group-2) had the most members, consisting of 42.7% of the observed cropping patterns. It illustrates the traditional management of the SPFF, which had not been focusing on a specific tree species but consisted of a variety of mixed species. The primary tree species were mahogany (*Swietenia macrophylla* King), tisuk (*Hibiscus macrophyllus* Roxb. ex Hornem.), sengon (*Paraserianthes falcataria* (L.) I.C.Nielsen), durian (*Durio zibethinus* L.), duku (*Lansium domesticum* var. duku) in Ciamis Sub-district; teak (*Tectona grandis* L.f.), mahogany, sengon, tisuk, coconut (*Cocos nucifera* L.) in Banjaranyar Sub-district; afrika (*Maesopsis eminii* Engl.), ganitri (*Elaeocarpus ganitrus* Roxb. ex G.Don), puspa (*Schima wallichii* Choisy), mahogany, and sengon in Sukamantri Sub-district. This pattern reflects a traditional management practice where low-capital inputs are applied. However, this pattern may have a higher biodiversity value since farmers did not select a specific species as their primary commodities. Several lesser known species were also found in this pattern. These include kihuut (*Aporosa fructescens* Blume), kiciat (*Ficus septica* Burm.f.), sampang (*Melicope denhamii* (Seem.) T.G.Hartley), huru kacang (*Neolitsea triplinervia* Merr.), kanyere (*Bridelia stipularis* (L.) Blume), kiteja (*Daphiniphylum glaucescens* Blume). Landowners did not cultivate understorey in this pattern. A previous study by Siarudin et al. (2021) in several areas of West Java Province indicated that landowners who apply mixed-tree lots patterns were generally constrained by limited time and financial capital. Therefore, they do not prioritize their resource to cultivate understorey plants that require intensive maintenance. In addition, some of the stands did not have much space and sufficient light to cultivate lower plants. As presented in Table 6, group-2 had the highest stand density and basal area values of 1,802.3 tree ha^{-1} and 27.4 m^2 ha^{-1}, respectively.

The tree crops pattern (group-1) ranked second-most, which was 29.3% of the observed sample. Among three major species of each region were mahogany, sengon, and teak in Ciamis Sub-district; teak, sengon and mahogany in Banjaranyar Sub-district; ganitri, africa and manglid (*Magnolia champaca* (L.) Baill. ex Pierre) in Sukamantri Sub-district. Furthermore, most of these patterns were strictly tree monocultures with no agricultural crop intercropping. In several cases, landowners combined two commercial tree species such as ganitri and afrika found in Sukamantri Sub-district; teak + mahogany or teak + sengon in Ciamis and Banjaranyar Sub-district. However, in some other cases (12.5%), tree monoculture stands were intercropped with crops to form a simple agroforestry system. The combinations of tree species and crops were teak and cardamom (*Amomum compactum*), sengon + cardamom in Ciamis Sub-district; sengon and cardamom, sengon and banana (*Musa* spp.) in Banjaranyar Sub-district; ganitri, afrika and coffee (*Coffea canephora* Pierre ex A.Froehner), sengon, afrika and talas (*Colocasia esculenta* (L.) Schott) in Sukamantri Sub-district. Unlike group-2, these tree crop patterns indicated intensive management practices where landowners allocate their resources to cultivate one or two commercial trees. Some farmers even combined the trees with some crops that require intensive maintenance.

Figure 5. Some cropping pattern examples of small-scale privately-owned forest in Ciamis Regency: (A) tree lots of one or two commercial tree species, sometimes with crops, in group-1 (B) Intercropping of mixed-tree species + crops in group-2 (C) Uneven-aged multispecies stand in group-3

The agrisilvicultural pattern (group-3) was applied to 28% of the surveyed samples. This pattern was characterized by tree stands consisting of mixed-tree species intercropped with one or more crops. The species widely cultivated were cardamom, banana, cassava (*Manihot esculenta* Crantz), talas, salak (*Salacca acehensis* Mogea), and temukunci (*Boesenbergia pandurate* (Roxb.) Schlecht). Furthermore, the difference between this pattern and the simple agroforestry of group-1 was in the tree species composition. Group-1 members consisted of even-aged with one or two commercial tree species, while these group members consisted of uneven-aged multispecies of trees. Landowners intentionally allocated the clumped distribution of trees to provide space for understorey plant cultivation that requires enough light, such as bananas and cassava. The low value of stand density in group-2 (Table 6) was related to the clumped distribution of trees and the existence of free space to cultivate seasonal crops in an intercropping system.

The selection of cropping pattern was presumably related to the perception of the optimal benefit for each landowner. According to Liu et al. (2018), the tree crops pattern with a monoculture system has several advantages, including easier management due to species uniformity, higher yields, and more efficient harvesting. In contrast, the mixed-tree lots pattern is also superior in biodiversity and resistance to various disturbances. The agrisilviculture pattern with intercropping allows landowners to get multi-products that provide short-term and long-term cash income.

The formation of current cropping patterns is not static but dynamic. The appearance of stand structure and composition observed only reflect the latest condition over a series of cropping practices. The transition indicates the landowners' management transformation (Wiehle et al., 2014). For example, based on field observations, the mixed-species patterns in some cases were initially a tree monoculture system with regular spacing. Landowners harvest large trees using a selective harvesting system. Therefore, the trees left behind have small diameters with irregular spacing. The opening of post-harvesting growth space causes the growth of natural seedlings of various tree species from the surrounding parent. Some farmers also embroider tree species different from the previous species, resulting in an uneven-aged multispecies forest (group-2). In other cases, the tree monoculture systems or mixed-tree lots were formerly an agroforestry system in the early stage of tree growth. Tree growers cultivated crops between the young tree rows for one or two years after tree plantation. This intercropping pattern cannot be continued when the tree canopy covers are tight and unable to plant understorey. According to Suryanto et al. (2014), this change is a transition from initial to advanced agroforestry. The classification of initial, intermediate, and advanced agroforestry is characterized by decreasing crop area.

Shepherd (1986) stated that several biophysical and agro-climatic factors are relatively stable factors influencing the farmer's choice of silvicultural and management practice. Meanwhile, socio-economic factors of local communities can change in the medium term. The variety of SSPF cropping patterns in the Ciamis Regency was related to the socio-economic conditions of the landowners and local biophysical conditions. Aside from farmers, people with primary jobs tend to apply cropping patterns that do not require intensive management, such as the mixed-tree lots pattern. Landowners generally apply tree crops patterns with adequate capital for cost-cutting, land preparation, and replanting certain species. Likewise, the influence of agro-climatic and biophysical conditions in the selection of tree species is closely related to the suitability of local species. Furthermore, Africa tree species, optimal at an altitude of 600-900 with a minimum rainfall of 1200 mm/year (Schabel & Latiff, 1997), were widely cultivated in Sukamantri Sub-district. Sukamantri, located at an average altitude of 775 m above sea level with 2558 mm/year of rainfall (BPS Kabupaten Ciamis, 2020), was one of the causes that Africa species was more developed in this region. The teak and rubber species were widely cultivated in the Banjaranyar sub-district, presumably because the area was directly adjacent to the Perum Perhutani and PT Perkebunan Nusantara region, which cultivates both species as their primary commodity. These state-owned companies certainly cultivate the teak and rubber species because of their suitability for the biophysical conditions of the local area. This is consistent with statement that altitude can affect biophysical conditions, plant species suitability, community culture, and road access, affecting stand characteristics. Likewise, Blanco et al. (2019) state that the SSDF reflects the agricultural systems, practices, and traditions, which are the socio-cultural heritage.

5. CONCLUSIONS

The SSPF in Ciamis Regency are classified into three groups of cropping patterns, based on the stand structure and species composition. Meanwhile, excluding the TSD variable is liable to increase the grouping quality in the TSC analysis. The first group was a tree crops pattern in the form of even-aged stands with one or two tree species as the primary commodity, planted with regular spacing without understorey cultivation. The second group was the mixed-tree lots pattern which consisted of uneven-aged multispecies without any crops. The third group was the agrisilvicultural pattern that combined uneven-aged and different tree species with crops and a clumped distribution of trees. The current cropping patterns were relatively consistent with the traditional SSPF grouping. However, the stand performances reflect a series of management practices following the socio-economic dynamics of the landowners. The results open opportunities for further analysis of the relationship between existing cropping patterns and the socio-economic characteristics of landowners and the strategies needed for the sustainable development of the SSPF.

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