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Clusterization of Agroforestry Farmers using K-Means Cluster Algorithm and Elbow Method

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ABSTRACT

Proper policy is crucial to support the development of forest areas. Therefore, good planning based on supporting data is crucial. All information considering farmers' conditions and interests in Talang Mulya Village, situated around Wan Abdul Rachman Forest Park, is urgently needed. So far, policies and programs launched have only been general and inappropriate to implement for the whole farmers. The main objective of this research was to perform fast agroforestry farmers clustering with differences in the main characters to each other using the K-means clustering algorithm and Elbow method based on 10 variables of social and land cultivation conditions. Results showed that agroforestry farmers in Talang Mulya Village could be best divided into 4 clusters with the proportion of 30%, 40%, 23.3%, and 6,67% for clusters 1, 2, 3, and 4, respectively. Agroforestry farmers were dominated by farmers with the specific characteristics of the lowest number of families working on the land and the cultivated main plant species with a sufficient level of formal education, family dependents, farming experience, household members that help in the farm, size of land area, expenditure and income from land cultivation, and maintenance activities. The research results could be used as a consideration for determining specific and targeted activity programs to increase the cultivation capabilities and welfare of farmers in Talang Mulya Village.

1. Introduction

Agroforestry systems can be applied to increase the potential for environmental services and reduce land degradation (Fahad et al. 2022; Santos et al. 2019; Tomar et al. 2021). The advantages are obtained by incorporating various plant species in the same land, time, and management in spatial arrangement. Therefore, the ecological function can be obtained by increasing the soil's ability to maintain its fertility and water absorption and providing a habitat for macro and microfauna. In addition, direct economic benefits can be obtained gradually by farmers (Liu et al. 2022; Octavia et al. 2022).

The agroforestry system has been known for a long time and implemented by farmers around Wan Abdul Rachman Forest Park (Tahura WAR) (Murniati et al. 2022; Suharti et al. 2022) by cultivating trees and crops (Wanderi et al. 2019), as well as medicinal plants or fisheries and livestock (Santoso et al. 2021) and beekeeping around and within the Tahura WAR area. However, a recent study reported that the farmer household's level of food security around Tahura WAR is still low (Rohmah et al. 2020). It might be due to the lack of knowledge on silvicultural techniques used to match site conditions. Another reason was that unpropped programs and activities that had been carried out have not overcome the root of the problem in a sustainable and specific manner according to the characteristics of each farmer (Qurniati et al. 2019; Safe'i et al. 2021; Santoso et al. 2022).

Suitable and proper policy is urgently needed for developing forest areas (Ahmad et al. 2020; Benedek et al. 2018; Gebre and Gebremedhin 2019; Raihan and Tuspekova 2022). Therefore, a good planning base and the availability of supporting data are crucially needed for policymakers (Ali et al. 2020; Baskent 2020). All information considering farmers' conditions and interests as stakeholders who have vital roles in Tahura WAR is necessary. So far, the policies and programs are from external parties only in general, so it is deemed inappropriate to implement for the whole farmers. Therefore, it is essential to carry out a study involving socio-economic and land cultivation conditions variables as the basis for clustering agroforestry farmers (Hatulesila and Mardiatmoko 2021; Reith et al. 2022; Saidou et al. 2021).

The clustering of agroforestry farmers based on their characteristics and uniqueness can be used to quickly determine appropriate and qualified policies (Gosling et al. 2020; Heredia-R et al. 2020; Piñeiro et al. 2020; Santoso and Saftarina 2020) for developing Tahura WAR in the present and future. The K-means clustering algorithm and the Elbow method can be used as a quick and precise solution to find out the ideal number of clusters or agroforestry farmer groups around Tahura WAR. This activity is expected to become the basis and material for determining Tahura WAR development for generating more efficient outcomes in terms of time, effort, and cost. Therefore, this study aimed to determine the socio-economic and land cultivation conditions by agroforestry farmers around Tahura WAR and to cluster agroforestry farmers based on the existing conditions using the K-means cluster algorithm and Elbow method.

2. Materials and Methods

2.1. Location and Time

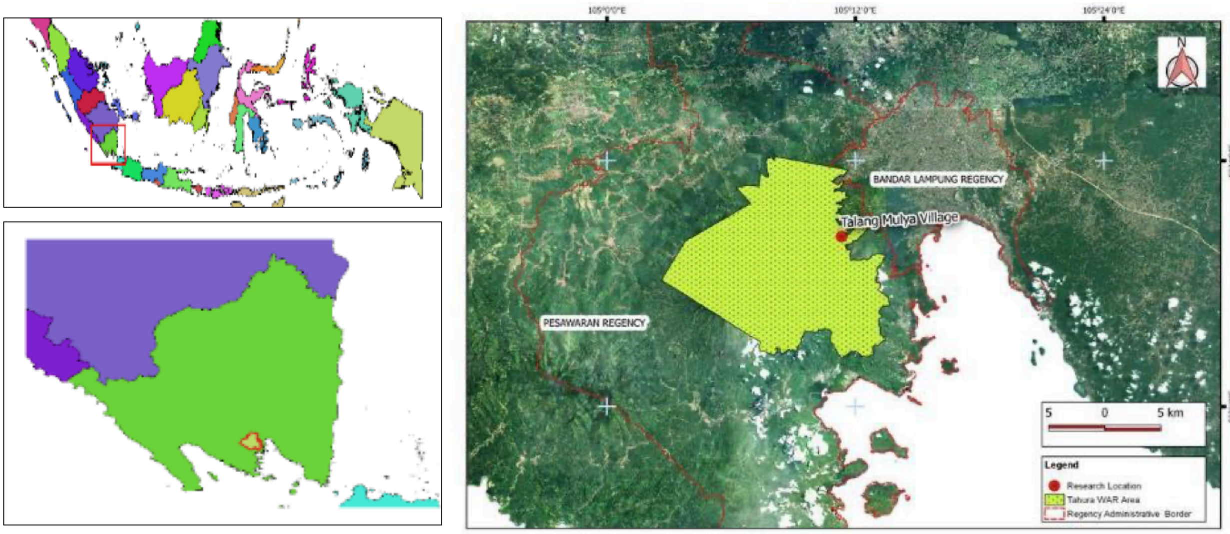
The research was conducted in Talang Mulya Village, one of the buffer villages of Tahura WAR that is included in the administrative area of Teluk Pandan Sub-District, Bandar Lampung City, Lampung Province (**Fig. 1**). Data collection was conducted from May to July 2022.

2.2. Data Collection

The research was performed using the quote sampling method to limit the number of respondents to obtain effective and efficient research due to limited time, natural conditions, human resources, and costs (Dasuki and Jaeroni 2020; Limono and Semuel 2018; Nurlinda et al. 2021). Selected respondents were farmers who cultivated their land by applying an agroforestry system. Respondents were limited to 30 farmer's families who were observed to determine the socio-economic and land cultivation conditions using validated questionnaires.

Both primary and secondary data were used in this research. Primary data was directly collected through a survey method using a questionnaire. The main information of primary data used in this study consists of: (a) farmers' social conditions, including name, address, gender, age, level of formal education, family dependents, farming experience, expenditure, and income, and

(b) land cultivation conditions, including household members helping in the land (person, land area, plant species, and maintenance activities. Secondary data was obtained from various sources as additional information to support the research, such as monograph data of the village, elevation data, and others.



Map sources: Attachment to the decree of the minister of forestry and plantations No. 256/KPTS-II/2000 (processed, 2000); Google Earth Pro Imagery (2022); Potensi Desa Map (BPS, 2020); SPOT 6 Imagery (Bappeda Lampung, 2018)

Fig. 1. Research location of Talang Mulya Village, in the administrative area of Teluk Pandan Sub-District, Bandar Lampung City, Lampung Province.

2.3. Data Analysis

The data was analyzed using 'R Studio' to perform descriptive statistics and clustering. Clustering was carried out using the K-means cluster algorithm and Elbow method to conclude the best number of a cluster for agroforestry farmers around Tahura WAR. The formulas used in this study are described in detail below.

2.3.1. Descriptive statistics

The collected primary data were analyzed using descriptive statistics (Dhiani et al. 2021; Novitasari et al. 2022), such as the number of samples, the minimum value, maximum value, and average value or mean that was calculated using the following formula:

$$X = \frac{\sum x}{N} \quad (1)$$

where X is the mean, $\sum x$ is the total value, and N is the number of samples.

The standard deviation was calculated using the following formula:

$$\sigma = \sqrt{\frac{\sum(xi - \mu)^2}{N}} \quad (2)$$

where σ is the standard deviation value, N is the number of samples, xi is the sample value, and μ is the average value. Standard error was measured using Equation 3:

$$SE = \frac{\sigma}{\sqrt{n}} \quad (3)$$

where SE is the standard error value, σ is the standard deviation value, and n is the number of samples.

2.3.2. K-means clustering

The Elbow Method was used to determine the ideal number of clusters after sequentially analyzing data sets derived from primary data. This method used the workflows of the K-means clustering algorithm. It was obtained from the distribution of respondents into clusters with distinctive characteristics within each cluster and differences from one another between clusters. Determination of the K value, or the number of clusters anticipated by the researcher, is the first step in the computation (Adrianto and Fahmi 2016; Parlina et al. 2018). K value in this study was set for a value between 2 and 10, with no restrictions on the times of iteration calculations. The variables involved in this study, among others: age (X1), the level of formal education (X2), family dependents (X3), farming experience (X4), household members helping in the land (X5), land area (X6), plant species (X7), expenditure (X8), income (X9) and maintenance activities (X10).

2.3.2.1. Initial clustering

Hung et al. (2005) suggested the work order in the K-means clustering procedure as follows:

a. Input the initial data set of n data points X = {x1, ..., xn}.
b. Choose the value of K or the expected number of clusters.
c. Compute the centroid (Cj) or starting point of clustering in the clustering method of partitioning clustering for the K cluster value from the data set.
d. Assign each point to the nearest cluster using distance measurement.
e. Recalculate the centroid of each cluster K with the number of data m to find the new cluster centroid (Vj) (Equation 4), and count the number of squared errors (E) (Equation 5):

$$Vj = \frac{\sum_{l=1}^{n} m(Cj|Xi)xi}{\sum_{l=1}^{n} m(Cj|Xi)} \ldots\ldots\ldots\ldots\ldots\text{(formula 1) where } j = 1, \ldots.k. \quad (4)$$

$$E = \sum j=1 \sum xi \prec Cj \| xi - vj \| \ldots\ldots\ldots\ldots\text{(formula 2) where } i= 1,\ldots n, \text{ and } j= 1,\ldots,k \quad (5)$$

f. Repeat steps 3 and 4 until convergent conditions occur, where the criteria for convergent conditions are no more placing data points into new clusters, changes in the error function (E) are below the threshold, or the number of iterations has been reached.

Clustering work was employed using R studio software and several syntax sequence numbers of cluster numbers starting from 2 to 10 clusters for the K-means clustering algorithm.

2.3.2.2. The best number of clusters

Calculation of the SSE of each cluster value was used to achieve the best cluster number Elbow method (Irwanto et al. 2012). The K value chosen was based on the highest difference value from the SSE obtained by the grouping procedure for each K value. Visual inspections were also conducted to determine the K value as the Elbow technique method (Bholowalia and Kumar 2014).

2.3.2.3. Standardization of cluster variable values

After determining the best number of clusters, the characteristics of each group were known by recalculating the average of each variable which was considered as the characteristics of each farmer using a standardized value. The formula used is as follows:

$$X = \mu + Z.\sigma \quad (6)$$

where X is the sample mean (in-group variable), μ is the population mean, Z is the standardization value, and σ is the standard deviation.

After the number and members of each group were determined, the analysis continued with the recalculation of the standardized mean value for each variable for each group. The resulting standardization describes the unique characteristics of each group.

3. Results and Discussion

3.1. Farmers' Social Conditions

Based on the characteristics of farmers, it was revealed that agroforestry farmers around Tahura WAR are dominated by elderly farmers, with an average age of 47.17 years, and dominated by men, with an average of 86.7%. The remaining amount of 13.3% is women. Farmers only reached a level of formal education with an average of 5.27 years or not accomplished elementary education. The number of family members dependent on the family head is an average of 3.33 people. Some of them also do other work besides farming (33.3%), and 66.7% only focus on their farm. More detailed information on farmers' social conditions is shown in **Table 1.**

Table 1. Descriptive statistics of farmers' social conditions variables

Variables	N	Min	Max	Mean	Std. error	STDEV
Age (years old)	30	27	72	47.17	2.47	13.52
Level of formal education (years)	30	0	15	5.27	0.65	3.58
Family dependents (persons)	30	0	6	3.33	0.24	1.32
Farming Experience (years)	30	5	52	25.10	2.79	15.31
Income (thousands of IDR/year)	30	300	25,000	6,146.67	1,348.35	7385.20
Expenditure (thousands of IDR/ year)	30	400	100,000	14,866.67	3,581.08	19614.37

Notes: N= number of samples, Min = minimum, Max.= maximum, Std. error = standard error, and STDEV = standard deviation.

Agroforestry farmers around Tahura WAR are dominated by men, which is similar to conditions in other places in Lampung, elsewhere in Indonesia, and several other countries (Desalgne et al. 2022; Fauziyah 2018; Gebrehiwot et al. 2018; Kalanzi et al. 2020; Manginsela et al. 2021; Susanti et al. 2021). The age of agroforestry farmers around Tahura WAR is also dominated by the older farmers, with a few young farmers (≤ 30 years), that was similar to several areas in Indonesia and other countries (Burano and Siska 2019; Dewi et al. 2021; Pujiono et al. 2021; Rozaki et al. 2021; Sauvadet et al. 2020).

Another characteristic is the low formal education of agroforestry farmers, which is also found in various regions (Akinwalere and Okunlola 2019; Kaba et al. 2020; Nuryati et al. 2019; Shennan-Farpón et al. 2022; Suyadi et al. 2019). The low level of farmer education indicated the low level of farming family welfare and the potential for land management and obtained income.

Family dependents can be related to the welfare of agroforestry farmers. The number of family dependents is closely associated with family income and expenses (Farooq et al. 2018; Jha et al. 2021; Nuryati et al. 2019; Pujiono et al. 2021). The increasing number of family dependents will increase family expenses, so farmers must consider every change in their farming to minimize risk as a form of accountability to the family (Baker 2018).

Farmers' experiences affect the ability to manage land, including perceptions related to rainfall and soil fertility (Jha et al. 2021), recognition of the tree species and properties (Rigal et al. 2018), and also incur annual costs (Do et al. 2020).

3.2. Farmer's Land Cultivation Properties

Four variables were employed to define farmers' land cultivation conditions around Tahura WAR. The results showed that the land cultivation conditions varied among farmers. Farmers have long farming experience, high expenditure, and maintenance activities throughout the land. However, it has low input regarding family members involved in land cultivation, the total area of cultivated land, the number of plant species, and income from the cultivated land. This fact should be the main emphasis for regulators and academics as evaluation to ensure future programs will be proper and precise. More detailed information is presented in **Table 2**.

Table 2. Descriptive statistics of farmer's land cultivation conditions variables

Variables	N	Min	Max	Mean	Std. error	STDEV
Family involved (person)	30	0	3	1.43	0.133	0.73
Land area (ha)	30	0.25	3	1.52	0.130	0.72
Plant type (types)	30	1	7	2.90	0.255	1.40
Maintenance activities (kinds)	30	0	7	4.07	0.410	2.23

Notes: N= number of samples, Min = minimum, Max.= maximum, Std. error = standard error, and STDEV = standard deviation.

The results showed that only 42.94% of family members help with the land cultivation of the dependent family members, so the head of the family mainly manages agroforestry land. This low family labor input happened because the family members were still of school age, and other adult family members chose to avoid becoming farmers. These trends were similar to previous research on coffee-based agroforestry farmers in Tanggamus District, Lampung Province, which was inefficient because labor assistance from family members was only 37.22%, thus increasing the cost of hired labor (Ismono et al. 2022). Farmer families also assist in land cultivation through various activities such as collecting poultry eggs, feeding farm animals, and weeding in farm fields. Therefore, they do not have leisure time to go and play with other kids (Ahmad et al. 2021). For a low-income family, women's family members involved in agriculture could be intent during the seasons when areas need more labor (Mulyoutami et al. 2020).

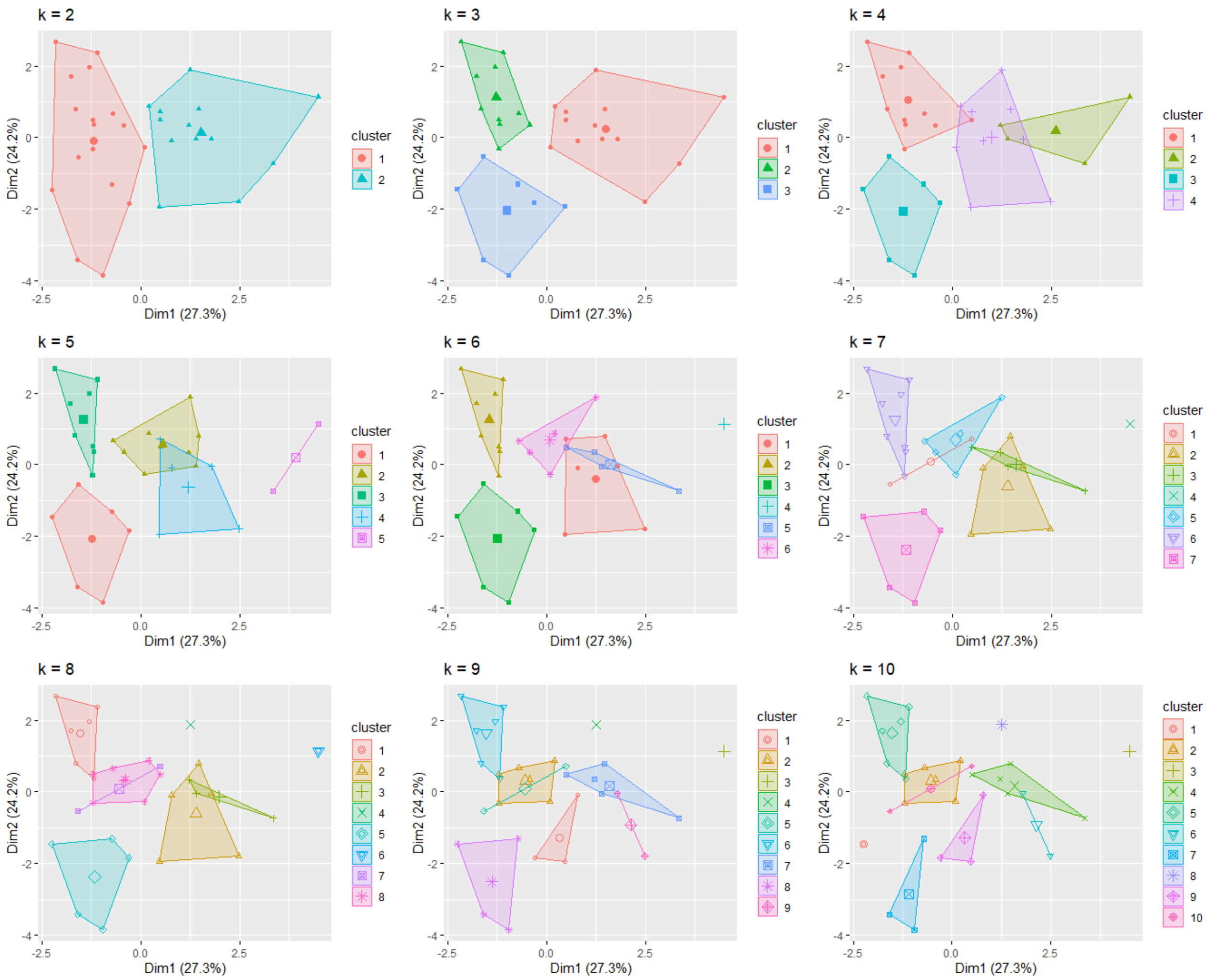
Another research in *Inga* and *Camëntsá* Communities in Putumayo, Colombia, showed that family labor in the agroforestry system is an essential part of the production costs and became the main key to the use and conservation of biodiversity and, consequently, most families' food security and livelihoods (Bucheli et al. 2021).

The average area of cultivated land by farmers in this study (1.52 ha) is slightly larger than farmers in Sumber Agung Village, Bandarlampung City (1.25 ha) (Kholifah et al. 2017), and Wiyono Village, Pesawaran Regency (Bella et al. 2019) which is located nearby to the study area. The size of the land area was considered to have a significant influence on total farmer income (Achmad et al. 2022; Desmiwati et al. 2021). In addition, plant types were also considered a significant factor influencing the farmer's income (Achmad et al. 2022). The result showed that farmers in Talang Mulya have 1 to 7 types of main plants that role as a family income generator. The difference in the number of types of plants is caused by the area of land and the number of family members involved in land cultivation.

Another variable in the research in the form of maintenance activities showed the results in 0 to 7 maintenance activities carried out by each farmer. This tendency indicates that some farmers do not perform maintenance activities on their land. This behavior also occurs among farmers in Sumber Agung Village, especially their reluctance to apply fertilization (Wanderi et al. 2019). In general, farmers did not carry out routine fertilization with the presumption that this was unnecessary because the agroforestry lands were situated inside the forest area (Santoso et al. 2022).

3.3. Agroforestry Farmers Clustering

The clustering for farmers was investigated by involving 10 research variables, namely age (years old), formal education (years), family dependents (person), farming experience (years), family involved (person), land area (ha), plant species (kinds), expenditure (IDR per year), income (IDR per year), and maintenance activities (kinds). The result revealed that the best cluster for farmers was four clusters (K=4) validated using the Elbow method, so researchers were more convinced in determining the number of clusters (Cui 2020). The center point or centroid of cluster members for numbers K 2 to 10 is shown in **Fig. 2.**



Notes: Dim 1 (27.4%) and Dim 2 (24,2%) stand for the best variance value output derived from the dimensionality reduction (Eigenvalue) algorithm (Qi et al. 2018), which operated on the original data sets from ten input variables.

Fig 2. The cluster plot for K=2 to K=10 (51.5% cumulative percentage of total variance).

3.4. Agroforestry Farmers Group Characteristics

Based on the results, the best clustering of agroforestry farmers was four groups (**Fig. 3**), which has close similarities among group members and significant differences between groups (Herman et al. 2022; Manfouo and Von Fintel 2022; Nunti et al. 2019; Yuan et al. 2022). Each agroforestry farmer group is described as follows (**Table 3)**.

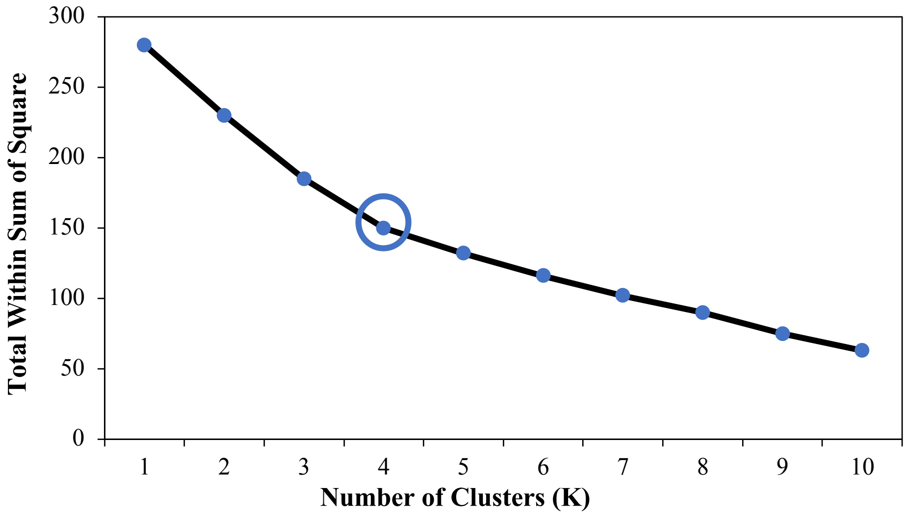


Fig. 3. The optimal number of agroforestry farmer's clusters validation using the Elbow method.

Table 3. Agroforestry farmer's group characteristics

Group	Proportions (%)	Variables									
		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
Cluster 1	30.00	30.81	11.50	2.99	7.85	0.17	0.98	2.88	1,732	7,133	5.42
Cluster 2	40.00	41.89	3.11	3.19	22.87	2.24	1.17	1.53	6,747	10,158	2.38
Cluster 3	23.33	71.74	5.17	5.59	54.55	1.43	2.31	6.17	3,006	10,141	6.58
Cluster 4	6.67	45.65	0.00	1.55	24.48	2.00	3.01	2.36	25,742	152,384	0.92

Notes: X1= age, X2= the level of formal education, X3= family dependents, X4= farming experience, X5= household members helping in the land, X6= land area, X7= plant species, X8= expenditure, X9= income, and X10= maintenance activities. Black-colored letters= sufficient value, red-colored letters= the least value, and green-colored letters= the highest value.

3.4.1. Cluster 1

The proportion of Custer 1 reached 30%. The main characteristics of this group are the youngest age among other agroforestry farmers, the most prolonged formal education, the shortest farming experience, the least family involved working on the land, and the least expenditure and income for cultivating the land, even though that many kinds of land maintenance activities are carried out. Other variables such as family dependents, size of land area, main cultivated plant species, and maintenance activities can be categorized as sufficient.

Younger farmers are more inclined to adopt agroforestry (Mahmood and Zubair 2020) and are more prone to save soil quality for future generations (Murendo et al. 2019; Papadopoulos et al. 2017). It appeared in the high number of land maintenance activities they carried out.

3.4.2. Cluster 2

The proportion of Cluster 2 reached 40%. The main characteristics of this group are the lowest number of the family involved in working on the land and the main plant species cultivated. However, other variables such as formal education, family dependents, farming experience, household members helping in the farm, size of land area, expenditure and income from land cultivation, and maintenance activities can be categorized as sufficient.

Agroforestry cultivation costs were mainly related to labor, including support from family members (Padovan et al. 2022). Family labor contributes to reducing production costs in agroforestry systems (Bucheli et al. 2021). Farmers from this cluster have the lowest input from family labor affected in the income generated, although they have sufficient land area and maintenance activities that have been carried out.

3.4.3. Cluster 3

The cluster proportion reached 23.3%, with the main characteristics of this group being the highest number of age, family members, farming experience, main cultivated plant species, and maintenance activities. In contrast, other variables such as formal education, household members that help in the land, land area size, expenditure, and income from land cultivation and maintenance activities can be categorized as sufficient.

Farmers in this cluster have sustainably implemented an agroforestry system because of their long farming experience. They diversify the main types of crops so that they get income from various sources by implementing different maintenance activities (Dessie et al. 2019; Shah et al. 2021). Agroforestry business activities can meet the needs of a decent and sustainable life (Fitri 2022).

3.4.4. Cluster 4

The proportion of Cluster 4 reached 6.67%, showing the main characteristics of the lowest number of formal educations, family dependents, and maintenance activities but recorded to reach the highest number for land area, expenditure, and income from land cultivation, sufficient for the age, farming experience, and main cultivated plant species. Furthermore, farmers in the Cluster 4 achieved the highest income from land sourced from cocoa (*Theobroma cacao L.*), which has a high selling price and regularly produces weekly.

The low education level of farmers around the Tahura WAR has been reported in previous studies (Octavia et al. 2022; Utami et al. 2020). Cocoa became the main crop cultivated by farmers around Tahura Wan Abdul Rachman for years (Maulita et al. 2022; Prasetyo et al. 2019). Although currently, the cocoa plants around Tahura WAR are attacked mainly by pod rot disease, which is suspected to be caused by the pathogenic fungi of *Phytophthora* spp. (Asmarahman et al. 2020). Farmers in this cluster have not experienced it, so it has not affected their income because they had intensively controlled the disease using chemical fungicides. It has been evident from their high amount of expenditure on maintenance activities.

4. Conclusions

Agroforestry farmers in Talang Mulya Village are dominated by farmers from Cluster 1 and Cluster 2 (total 70%), whose encounter major issues with the number of the family involved in working on the land and lack of main plant species cultivated. However, they have received sufficient formal education but lack adequate farming experience. Therefore, it affected land cultivation performance, reflected in the scanty income, even though many land maintenance activities have been carried out. On the opposite, another 6.67% of agroforestry farmers (Cluster 4), consisting of farmers who have the lowest length of formal education, family dependents, and maintenance activities but generated the highest number of land area, expenditure, and income from land cultivation. In contrast, another 23.3% (Cluster 3) of agroforestry farmers consist of farmers with the highest age, family members, farming experience, cultivated main plant species, and maintenance activities that could be considered sufficient in land cultivation performance. However, most farmers have been facing significant problems in the availability of labor and land area size, which limits the number of main economic plant species and the lack of farming experience. Therefore, increasing farmers' capacity with more intensive agroforestry training is urgently needed to increase crop productivity with minimal labor input requirements.

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