INTERCROPPING INTENSITY AND CROP STRUCTURE IN COFFEE-BASED SYSTEMS AMONG ETHNIC MINORITY FARMERS IN DAK LAK PROVINCE, VIETNAM

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ABSTRACT

This study analyzes intercropping systems in coffee farms of ethnic minority households in Dak Lak province, Vietnam. Using cross-sectional survey data from 150 ethnic minority coffee households in Dak Lak province by using a purposive sampling approach. .Intercropping intensity is measured by the Density Equivalent Ratio (DER), whilecrop structure is displayed by dominance index. The results indicate that the average DER_{plot} reaches 1.26 and most farming systems operate at a moderate level of intensification. Coffee remains the dominant crop, accounting for over 70% of total system density, while other crops are integrated at relatively low densities. These findings provide useful empirical evidence for policymakers to design context-specific strategies that promote efficient and sustainable intercropping in coffee-based farming systems among ethnic minority households.

Keywords: *intercropping intensity; crop structure; ethnic minority; DER; Dak Lak province; Vietnam.*

1. INTRODUCTION

Vietnamese coffee production plays a central role in national exports and rural livelihoods, particularly among smallholder and ethnic minority farmers (Duong et al., 2026; Gaitán-Cremaschi et al., 2018; Le et al., 2020; Nguyen and Sarker, 2018). However, coffee farming systems have been increasingly exposed to multiple risks, including climate variability, price volatility, and soil degradation recently. These challenges have intensified the need for production strategies to enhance resilience and maintain productivity (D'haeze et al., 2005; Havemann et al., 2015).

In this context, diversification has emerged as a key pathway for improving the sustainability of smallholder farming systems. By growing multiple crops, farmers can spread risks, stabilize income, and make more efficient use of land and resources. Among various diversification strategies, intercropping, defined as the simultaneous cultivation of multiple crops on the same plot, has become a widely adopted practice in coffee-based systems across the Central Highlands, Vietnam (Duong et al., 2026; Ho et al., 2017; Thuy et al., 2021; Thuy et al., 2020).

However, empirical studies mainly focus on descriptive typologies, the economic, social, and environmental impacts, or the determinants of adoption (Bongers et al., 2015; Thuy et al., 2023; Phong et al., 2018). Limited attention has been paid to how intercropping systems are internally arranged. In particular, key dimensions such as intercropping intensity and system structure, the relative dominance of different crops remains underexplored. This gap is especially pronounced among ethnic minority farmers, whose distinct resource constraints and institutional conditions may significantly shape both the intensity and structure of intercropping systems (Thái, 2018a). Some studies demonstrated that resources constraints may influence potential adoptability of agroforestry innovations (Mercer, 2004).

However, previous studies have paid limited attention to the structure of intercropping systems after adoption (Thuy et al., 2019, 2021). Less is known about how farmers combine different crops, the level of crop diversification, and the dominance of individual crops within coffee-based systems.

Therefore, this study addresses three questions: (1) How intensive are intercropping practices in coffee-based systems? (2) What types of crop combinations characterize these systems? (3) What crop components play a dominant role in shaping these systems?

To answer these questions, this study aims to characterize intercropping intensity and crop structure among ethnic minority coffee farmers in Dak Lak province, Vietnam.. The findings have important implications for policies aimed at promoting sustainable intensification in coffee systems for ethnic group in Dak Lak province.

2. MATERIALS AND METHODS

2.1. Materials

Intercropping is defined as a smart agricultural practices and agroforestry which create many benefits for smallholder farmers, such as significant potential to enhance and stabilize agricultural yields, thereby contributing to improved food security and livelihoods, particularly in developing countries (Chen et al., 2019; Somarriba et al., 2024; Valérie et al., 2024). Intercropping refers to the cultivation of two or more crop species simultaneously on the same field (Brooker et al., 2015).

Agronomic approaches have traditionally relied on simplified, homogeneous representations of cropping systems, which are effective for analyzing

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monocultures but limited in capturing the complexity of multispecies systems. While existing frameworks consider interactions among management practices, long-term effects, and multi-criteria objectives, they fail to adequately address heterogeneity and dynamic plant–plant interactions. As a result, multispecies systems, such as intercropping, require new knowledge, adapted indicators, and the development of innovative models and decision rules to better reflect their complexity and support coordinated management.

Intercropping intensity is measured using the Density Equivalent Ratio (DER), which reflects the degree of land-use intensification relative to monoculture benchmarks. In addition, a dominance index is constructed to quantify the relative importance of each crop within the system. By combining these two dimensions, the study provides a more comprehensive understanding of diversification patterns among coffee ethnic farmers.

2.2. Methods

Data collection and study context

This study is based on a cross-sectional survey using a sampling frame constructed from official list provided by local authorizes. To ensure sample consistency, only farms with market-oriented crops cultivated for at least three consecutive years are included. If farmers have more than two plot, the largest farm is chosen to representative the general practices in the region.

In addition, the sample is chosen based on three criteria: (i) cultivated coffee with other crops on the plots, (ii) they practiced market-oriented intercropping, meaning that the associated crops were grown primarily for sale rather than home consumption, and (iii) their intercropping system had been maintained for at least three years. A purposive sampling approach was used to select ethnic minority farmers with coffee-based intercropping systems. Households were selected based on the relevance of their farming practices to the study objectives.

Based on selection criteria and excluding incomplete observations, the final sample consists of 150 coffee-based intercropping ethnic households in Dak Lak province, Vietnam.The survey collected detailed information on household characteristics, farm conditions, and cropping systems at the plot level. Key variables include demographic characteristics (age, education, household size), farm attributes (coffee area, water availability, soil conditions), and intercropping practices, including crop densities and years of intercropping experience.

All surveyed farms practice intercropping within coffee systems, allowing the analysis to focus on differences in the intensity and structure of intercropping.

Intercropping intensity is measured using the Density Equivalent Ratio (DER), which captures the combined planting density of multiple crops relative to their respective monoculture standards (Malézieux et al., 2009; Rigal et al., 2023).

$$DER_i = \sum \frac{D_i}{D_i mono}$$

where D_i is the observed density of crop i (trees per hectare), and D_{imono} is the recommended monoculture density for crop i.

The D_{imono} values were used as reference points to compare crop density in intercropping systems. Actual planting densities may vary across farms due to differences in farm conditions and management practices. Therefore, DER values represent relative crop density compared with recommended monoculture standards.

A DER value equal to 1 represents a monoculture-equivalent system, while values greater than 1 indicate intensified intercropping through crop stacking. Standard monoculture densities were defined following current recommendations as 1,100 coffee trees·ha^{-1} 1; 1,300 pepper poles·ha^{-1}; 210 avocado trees·ha^{-1}; 200 durian trees·ha^{-1}; and 280 macadamia trees·ha^{-1} (MARD, 2005, 2017, 2002).

In addition, DER is decomposed by crop type to assess the contribution of coffee and associated crops to total system density.

$$DER_{plot} = DER_{coffee} + DER_{perennial\ crops} + DER_{fruits}$$

To characterize the distribution of intercropping intensity, farms are classified into three groups based on DER_{plot} values for description classification to describe differences in intercropping intensity among farms: low (DER ≤1), moderate (1<DER≤1.5), and high (DER>1.5). This classification reflects increasing levels of diversification and land-use intensification, from systems close to monoculture to highly intensified intercropping systems.

To capture the internal structure of intercropping systems, a dominance index is computed for each crop based on its relative contribution to total system density:

$$\text{Dominance}_i = \frac{DER_i}{DER_{plot}}$$

Where DER_i is the density equivalent ratio of crop i. This index ranges from 0 to 1 and indicates the relative importance of each crop within the system.

3. RESULTS AND DISCUSSIONS

3.1. Characteristics of surveyed farmers and farm in the research site

The ethnic households show characteristics in the research sites. The average age is 43.3 years, with relatively low education levels (mean = 3.12), indicating generally low formal education among ethnic farmers. Fortunately, household size averages 4.85 members which can provide the available labor in the present and in the future, in case intercropping systems require higher labor resources (Thuy et al.,

2019). However, access to credit remains limited, with only 42.7% of households.

From a farm perspective, coffee remains the dominant crop, with an average density of 992 trees per hectare and an average yield of 2.21 tons per hectare. Coffee plantations are relatively mature, with an average age of 13.7 years (Table 1). Notably, all surveyed farms practice intercropping with diversified types of crops including other perennial crops and fruits.

Table 1. Sample distribution

Variable	Obs	Mean	Min	Max
Age (Years)	150	43.30	25	73
Education (1=No school; 2= Primary school; 3= Secondary school; 4 =High school; 5 = Vocational college; 6 = University	150	3.12	1	6
HH size (people)	150	4.84	2	9
Media use (0= No; 1= Yes)	150	.68	0	1
Credit (0= No; 1= Yes)	150	.42	0	1
Water sufficient (0= No; 1= Yes)	150	.04	0	1
Soil flat (0= No; 1= Yes)	150	.40	0	1
Intercropped Area (Ha)	150	1.44	.1	7
Intercropped experience (Years)	150	12.21	0	31
Density coffee (Trees)	150	992.00	500	1,875
Coffee Age (Years)	150	13.70	1	31
Yield per ha (Ton)	150	2.21	.057	5.33

Source: Data collected in 2025-2026.

3.2. The intensity of intercropped systems

Table 2. The Density equivalent Ratio in intercropping systems

Variable	Obs	Mean	SD	Min	Max
1.$DER_{perennial\ crops}$	**150**	**0.29**	**0.46**	**0.00**	**3.75**
DER_{Pepper}	150	0.08	0.12	0.00	0.76
DER_{Macca}	150	0.04	0.14	0.00	1.07
DER_{Cashew}	150	0.16	0.46	0.00	3.75
2.DER_{fruits}	**150**	**0.07**	**0.14**	**0 .00**	**1.03**
$DER_{Avocado}$	150	0.03	0.07	0.00	0.47
DER_{Durian}	150	0.04	0.12	0.00	1.00
3.DER_{Coffee}	**150**	**0.90**	**0.17**	**0.45**	**1.70**
DER_{plot} (1+2+3)	**150**	**1.26**	**0.51**	**0.45**	**4.88**

Source: Data collected in 2025-2026.

The results reveal that coffee remains the main component in coffee-based intercropping (DER =0.9, Table 2). The DER_{plot} reaches 1.26, indicating that most intercropped farms achieve high-use intensity than mococulture.

Furthermore, the distribution of DER values shows strong heterogeneity among other crops. Perennial crops contribute more significantly than fruit trees, with average DER values of 0.29 and 0.07, respectively.

Additional crops contribute relatively small shares to total density, with cashew (0.16), pepper (0.08), durian (0.04), macadamia (0.05), and avocado (0.03), respectively. This indicates that diversification is primarily achieved through supplementary planting rather than replacement of coffee.

3.3. Dominance of intercropping systems

Table 3. The dominance of intercropping systems

Variable	Obs	Mean	SD	Min	Max	Order
$Coffee_{Dominance}$	150	0.70	0.17	0.23	1.00	1
$Pepper_{Dominance}$	150	0.06	0.08	0.00	0.39	6
$Cashew_{Dominance}$	150	0.08	0.15	0.00	0.76	2
$Durian_{Dominance}$	150	0.03	0.07	0.00	0.44	3
$Macca_{Dominance}$	150	0.03	0.09	0.00	0.60	4
						5
$Avocado_{Dominance}$	150	0.02	0.05	0.00	0.29	5

Source: Data collected in 2025-2026.

Table 3 shows that coffee is the dominant crop in the intercropping systems, with an average dominance index of 0.70. This indicates that coffee still plays the central role in farm structure. This is

logical in the real context that rather than replacing coffee, farmers tend to integrate a limited number of additional crops that are compatible with existing management practices and available resources (Thai 2018a).

Other crops contribute a smaller proportion to the system. Among associated crops, cashew has the highest dominance value (0.08), followed by pepper (0.06). Durian, macadamia, and avocado have relatively low dominance values. This pattern is consistent with the farming conditions of ethnic minority households in the study area (Thái 2018a). Many households are located in remote areas, where land conditions may not be suitable for some fruit crops, such as durian. In addition, cashew is relatively easy to manage, more tolerant to drought conditions, and requires lower input levels compared with some other crops (Mensah et al., 2025). These characteristics may make cashew a more suitable option for households with limited capital and technical knowledge. Meanwhile, crops such as pepper and durian require higher management skills and investment, which may limit their adoption among ethnic minority farmers.

The results suggest that farmers mainly diversify their coffee farms by adding other crops while maintaining coffee as the main production crop.

3.4. Distribution and typology of intercropping systems

To combine intensity and dominance indicators, intercropping systems can be categorized into distinct types. Most farms are characterized by moderate intensity (100 out of 150 households) and strong coffee dominance with DER of 1.3 (Table 4). A smaller group of farms exhibits low intensity (42 households), while only a small proportion of farms (8 households) belong to the higher intensity group. This is explained that these households may face constraints in capital, irrigation, and access to extension services. Such constraints may limit the adoption of highly intensified intercropping systems. At the same time, maintaining moderate diversification helps reduce production risks while remaining within available household resources. The presence of a small group of high-intensity intercropping systems should not be interpreted as a uniformly superior production strategy. While higher DER values reflect more intensive use of land through crop stacking, they may also introduce important trade-offs. Excessive planting density can increase competition for light, water, and nutrients, potentially reducing the productivity of individual crops, particularly coffee, which remains the core crop in these systems (Tran, 2024; Van Long et al., 2015). This is consistent that ethnic group limited their resources such as capital, input cost, varieties and technical knowledge (Thái, 2018a, 2018b). This approach allows farmers to balance productivity, risk, and management complexity.

In addition, high-intensity systems typically require greater management capacity, labor input, and technical knowledge to maintain system balance. Without adequate resources and knowledge, such systems may become inefficient or even counterproductive in the long run. This may explain why only a small proportion of farmers adopt highly intensified intercropping, despite its apparent potential for increasing total output (Ho et al., 2021). By contrast, the prevalence of moderate-intensity systems suggests that farmers tend to adopt a more balanced strategy, combining diversification benefits with manageable levels of complexity. Meanwhile, low-intensity systems are likely to reflect binding constraints, particularly in terms of capital, labor availability, and access to knowledge.

These findings indicate that intercropping systems follow different development pathways. Some farmers maintain traditional coffee-based systems with minimal diversification, while others gradually intensify through moderate crop integration. Only a few farms transition toward highly diversified and intensified systems.

Table 4. Intensity of coffee based intercropped systems

DER intensity	Mean	SD	Number of sample plots
Low intensity	0.86	0.12	42
Moderate intensity	1.30	0.22	100
High intensity	2.90	0.92	8

Source: Data collected in 2025-2026

Overall, these findings indicate that intercropping intensity reflects not only differences in resource endowments but also strategic choices under trade-offs, where higher intensity does not necessarily imply better performance.

4. CONCLUSIONS

This study provides a comprehensive overview of intercropping systems in coffee farms of ethnic minority households in Dak Lak province.

First, intercropping is universal across all surveyed farms, indicating that it has become a standard production practice rather than an optional strategy. However, the results reveal that intercropping is highly heterogeneous. While the average DER value (1.27) indicates moderate intensification, most farms operate within a moderate range, with only a small proportion adopting highly intensified systems. This suggests that farmers tend to balance diversification with constraints related to labor, capital, and management capacity.

Second, the structure of intercropping systems remains strongly coffee-centered. Coffee accounts for the majority of total system density, while other crops

such as cashew, pepper, and fruit trees play supplementary roles. This indicates that diversification is primarily achieved through complementary integration rather than structural transformation, with farmers maintaining coffee as the core crop.

Third, the coexistence of different intensity levels and dominance patterns suggests that intercropping systems follow multiple development pathways. Some farms remain close to monoculture conditions, others adopt moderate diversification, and only a few transition toward highly intensified systems. This reflects differences in household strategies, resource endowments, and risk management approaches.

To sum up, the findings demonstrate that intercropping should be understood not as a binary practice but as a continuum of system configurations, shaped by both economic opportunities and production constraints. The combined use of DER and dominance indicators provides a useful framework to capture this complexity and offers valuable insights for designing policies that support sustainable intensification in coffee-based farming systems.This study has several limitations. First, the analysis is based on cross-sectional data. Therefore, it cannot capture changes in intercropping systems over time. Second, the study focuses on describing intercropping intensity and crop structure. It does not examine the determinants or impacts of different intercropping patterns. Finally, the findings are limited to ethnic minority coffee households in Dak Lak province. Future studies should use longitudinal data to explore changes in intercropping systems and evaluate their economic, social, and environmental outcomes.

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MỨC ĐỘ VÀ CẤU TRÚC XEN CANH TRONG HỆ THỐNG CANH TÁC CÀ PHÊ CỦA NÔNG HỘ DÂN TỘC THIỂU SỐ TẠI TỈNH ĐẮK LẮK

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TÓM TẮT

Nghiên cứu này tập trung phân tích hệ thống canh tác xen canh trong vườn cà phê của nông hộ dân tộc thiểu số ở Đắk Lắk. Sử dụng dữ liệu điều tra cắt ngang từ 150 nông hộ dân tộc thiểu số, được lựa chọn theo phương pháp chọn mẫu có chủ đích.Cường độ xen canh được đo lường thông qua chỉ số Tỷ số mật độ tương đương (DER) và cơ cấu cây trồng đượcphản ánh bằng chỉ số ưu thế.. Kết quả cho thấy, chỉ số DER trung bình đạt 1.26 và phần lớn mức độ thâm canh ở mức trung bình tại địa bàn nghiên cứu. Ngoài ra, cây cà phê vẫn là cây trồng chủ đạo, chiếm hơn 70% tổng mật độ hệ thống, trong khi các cây trồng khác được tích hợp với mật độ tương đối thấp. Nghiên cứu cung cấp bằng chứng thực nghiệm hữu ích cho các nhà hoạch định chính sách trong việc thiết kế các giải pháp phù hợp với bối cảnh địa phương, nhằm thúc đẩy phát triển hệ thống xen canh cà phê theo hướng hiệu quả và bền vững đối với nông hộ dân tộc thiểu số.

Từ khóa*: Mức độ xen canh, cấu trúc cây trồng, dân tộc thiểu số, tỷ số mật độ tương đương, tỉnh Đắk Lắk, Việt Nam*

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