**Jurnal Presipitasi**
Media Komunikasi dan Pengembangan Teknik Lingkungan
e-ISSN: 2550-0023

Vol 21, No 1, 2024, 249-263
Article available at homepage presipitasi

*Regional Case Study*

# Local Ecological Knowledge of Liberoid Coffee Farmers in Banyuwangi: an Ancestral Legacy in Preserving the Natural Environment

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## Abstract

This study investigates the integration of Local Ecological Knowledge (LEK) in the sustainable development of Banyuwangi Liberica coffee, focusing on coffee farmers' ancestral heritage and local knowledge systems. Practices in land management, cultivation techniques, pest control, and pruning waste utilization are examined. Through qualitative data analysis from interviews and field observations, the research highlights the depth and significance of LEK in maintaining environmental sustainability and cultural heritage. Liberica coffee farmers possess a wealth of inherited LEK, encompassing ecological dynamics, sustainable agriculture, and natural resource conservation. Farmers integrate this knowledge into decision-making, evaluating innovations through research trials. Adopting appropriate practices preserves local ecosystems and maintains Liberica coffee's authenticity. The study underscores LEK's crucial role in land management and cultivation, with seedlings and repurposing waste for soil fertility. Pruning and using shade plant branches optimize fruit production and microclimate regulation. Natural pest control minimizes chemical pesticide use, preserving the coffee ecosystem's delicate balance and supporting biodiversity. Integrating LEK not only fosters environmental sustainability but also strengthens the community's social and cultural fabric. Coffee farmers' ancestral heritage and deep connection with the land contribute to the resilience of local agricultural practices, promoting the well-being of both farmers and the ecosystem.

**Keywords**: Agroforestry, community-based agriculture, liberica coffee, local ecological knowledge

## 1. Introduction

The rich biodiversity and cultural heritage of Banyuwangi, Indonesia, have given rise to a unique coffee variety known as Banyuwangi Liberoid Coffee. Liberian coffee (*Coffea liberica*), commonly known as Liberica coffee, is an increasingly recognized and focused-upon variety in coffee (Davis et al., 2022). Banyuwangi Regency is home to smallholder farmers cultivating two cultivars of Liberoid coffee: Liberica (*Coffea liberica var. liberica*) and Excelsa (*Coffea liberica var. dewevrei*). Banyuwangi Liberica Coffee holds significant historical, cultural, and economic value in the Banyuwangi region (Hakim et al., 2022). The cultivation of Liberica coffee in Banyuwangi is deeply rooted in local traditions and has been nurtured through coffee-based agroforestry systems (Hakim et al., 2022; Hariyati et al., 2022).

Liberoid coffee garnered local and international attention with its distinct flavor and aroma (Herawati et al., 2022). However, its sustainability faces significant challenges due to climate change and

global demands. The coffee crop is particularly vulnerable to escalating temperatures and precipitation changes, posing threats to both quality and yield. To address these challenges, a comprehensive approach is crucial, encompassing climate resilience, habitat preservation, water management, soil conservation, sustainable agriculture, deforestation mitigation, biodiversity protection, and carbon footprint reduction. Holistic measures are essential for safeguarding ecosystems, biodiversity, and overall environmental integrity amid ongoing environmental changes (Gomes et al., 2020; Hakim et al., 2022; Bracken et al., 2023). Integrating Local Ecological Knowledge becomes crucial to ensure its long-term viability and offer insights into sustainable development practices (Apetrei et al., 2021; Joa et al., 2018; Martin et al., 2010). LEK represents the invaluable knowledge and wisdom accumulated by indigenous communities and traditional farmers through generations of direct interaction with their environment (Molnár and Babai, 2021). Rooted in ancestral practices, LEK encompasses a comprehensive understanding of ecological dynamics, sustainable agricultural techniques, and the conservation of natural resources (Berkes et al., 2000; Mohd Salim et al., 2023; Woodward et al., 2020).

Banyuwangi Liberica Coffee has a rich history deeply rooted in the local culture and traditional farming practices passed down through generations. These practices reflect the intricate relationship between coffee production and the surrounding ecological context (Hakim, 2017 & Hakim et al., 2022). It is essential to understand the role of LEK and its integration into sustainable development practices. LEK refers to the accumulated local communities' knowledge, practices, and beliefs in the r nain the environment. It encompasses traditional ecological knoledge, passed down through generations, and incorporates insights into sustainable resource management, adaptation strategies, and biodiversity conservation (Joa et al., 2018 & Okui et al., 2021).

Specific to Banyuwangi Liberica Coffee, Local Ecological Knowledge (LEK) assumes paramount significance, given the inherent symbiosis between coffee plantations and diverse ecosystemsThe coexistence of these plantations within a rich ecological milieu demands an acute awareness of the nuanced ecological dynamics, a facet that LEK comprehensively addresses. Insights garnered from LEK extend to agroecology, elucidating sustainable soil fertility management practices, innovative approaches to pest control, and methodologies for biodiversity conservation (Joa et al., 2018). By These nuanced aspects of LEK contribute to a holistic and context-specific understanding that is often challenging to capture solely through conventional scientific approaches. As evidenced by the studies of Charnley et al. (2007) and Mohd Salim et al. (2023) the potential value of LEK lies in its ability to synergize with scientific methodologies, fostering a balanced approach to ecological sustainability. By integrating LEK into sustainable development practices, coffee farmers can navigate environmental challenges with a nuanced perspective, leveraging both traditional ecological knowledge and contemporary scientific insights. This synthesis ensures not only the preservation of cultural heritage but also a dynamic and resilient ecological sustainability model.

The integration of local ecological knowledge (LEK) in sustainable production practices has been demonstrated through various case studies and examples, highlighting the effectiveness and benefits of incorporating traditional wisdom into agricultural systems. Previous research emphasizes recognizing and incorporating Indigenous Traditional Ecological Knowledge (TEK) in land management through partnerships between Indigenous communities and academia (Gordon et al., 2023). Furthermore, integrating traditional and local ecological knowledge into forest biodiversity conservation provides valuable lessons applicable to agricultural systems (Charnley et al., 2007). Collaboration between scientists and local communities is essential for comprehensively understanding agricultural systems, combining traditional knowledge with scientific research (Molnár and Babai, 2021). The broader field of sustainability science supports integrating local knowledge systems in agriculture, emphasizing the need to preserve and incorporate indigenous farming practices (Apetrei et al., 2021; Guo et al., 2021). These studies demonstrate the effectiveness and benefits of integrating local ecological knowledge into sustainable agricultural systems, promoting environmental sustainability and the well-being of farming communities.

The research gap in understanding Local Ecological Knowledge (LEK), particularly in the context of coffee varieties such as Banyuwangi Liberica, significantly impacts sustainable practices in coffee agriculture. Mardiani et al. (2022) study on the volcanic slopes of East Java reveals nuances in farmer perceptions of soil organic matter management and earthworm interactions, exposing a critical gap in explicit knowledge. The multiplicity of earthworm species and divergent farmer views underscore the untapped wealth of indigenous insights. Simultaneously, (Nguyen et al., 2020) study in northwest Vietnam underscores the importance of LEK research, showcasing the intricate tapestry of local ecological knowledge among farmers. The integration of scientific knowledge into this landscape becomes imperative, accentuating the urgency of addressing the research gap to enhance the sustainability of coffee agriculture practices.

The significance of this research lies in exploring and documenting the invaluable LEK held by Banyuwangi Liberica coffee farmers, with a focus on how the research gap regarding this specific coffee type impacts LEK in sustainable agricultural practices. Through this exploration, we aim to deepen our understanding of how LEK contributes to the preservation of cultural heritage, the promotion of ecological sustainability, and the long-term viability of Banyuwangi Liberica coffee production. Bridging this research gap is vital for emphasizing the importance of integrating LEK into sustainable development practices, ultimately fostering environmental stewardship and empowering local communities. Previous research provides a foundation, but our study aims to delve specifically into the nuances of LEK within the context of Banyuwangi Liberica coffee, offering targeted insights that can inform sustainable agricultural practices and contribute to the resilience and adaptive capacity of local farmers

## 2. Methods

This research was conducted from December 2022–March 2023 in Kalipuro District, Banyuwangi Regency. Kelipuro District was chosen as the research location based on observations that it is one of Liberica's coffee cultivation hotspots. Kalipuro District is located at coordinates 8.1782° S, 114.3777° E with the northern administrative boundary bordering Wongsorejo District, the southern part with Glagah District, Giri District, and Banyuwangi City, the eastern part with the Bali Strait, and the western part with Licin District (BPS Kabupaten Banyuwangi, 2022). Plantations managed by the community dominate the use of the land. Details of the research site and land use are in Figure 1.

### 2.1. Location Determination

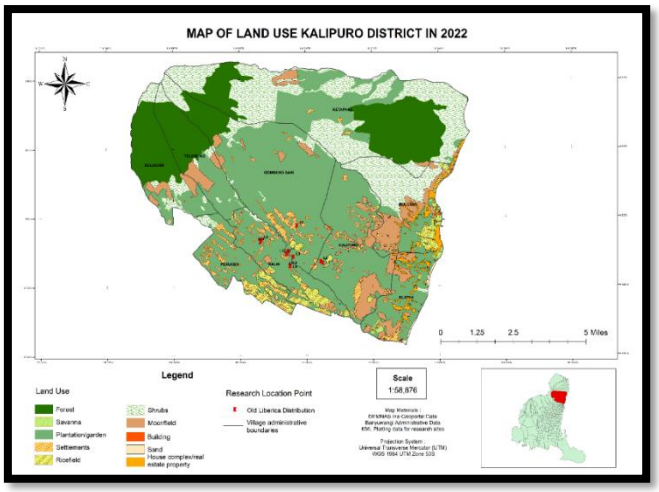


**Figure 1.** Map of research locations and land use in Kalipuro District

The location determination method employed in this research follows a purposive approach, whereby the research area is deliberately selected based on the known presence of research objects within the area (Etikan, 2016 & Crabtree and Miller, 2023). The selection of Kalipuro District as the research

location is justified by the prevalence of Liberica coffee cultivation in the area. This district serves as a suitable site for studying the integration of local ecological knowledge (LEK) in the sustainable development of Banyuwangi Liberica coffee due to the abundance of coffee farms and the significance of coffee production in the local agricultural landscape. To gather data for this research, multiple coffee farms belonging to key respondents were selected as the research sites. These farms represent crucial sources of information and insights into the cultivation practices, ecological knowledge, and sustainable development approaches related to Banyuwangi Liberica coffee.

### 2.2. Respondent Determination Method

The selection of respondents was carried out using snowball sampling technique, which determines the key respondent (key person) and then other respondents based on information from the previous respondent. In snowball sampling, the researcher asked for help from the initial respondent to recommend other people who fit the research criteria. The criteria for the selected informants were Liberika coffee farmers in Kalpiro Subdistrict who were over 17 years old with >5 years of coffee farming experience. Thus, the sample grew exponentially over time (Crabtree and Miller, 2023). Data collection was carried out using in-depth interviews with 48 respondents from four villages include Kalipuro, Gombengsari, Bulusari, and Tlemung. These respondents were selected based on the criteria of having a coffee plantation with an area of more than 0.5 ha and being involved in coffee agroforestry for at least 5 years.

### 2.3. Data Collection Methods

Data collection is carried out using primary and secondary data. The secondary data collection stage is carried out by collecting supporting data such as administrative and land use maps in Kalipuro District, Banyuwangi Regency, and information on the socio-economic condition of the community through reports from related agencies. Meanwhile, secondary data includes climate and rainfall data in the Kalipuro District area, the Banyuwangi Regency Government Annual Report 2021/2022, and Kalipuro District Profile Data 2021/2022, which are then further analysed as data to support the results and discussion of research. Additionally, observations and the implementation of focused group discussions (FGD) were conducted to gather comprehensive data

### 2.4. Data Analysis Methods

Qualitative data analysis in this study was carried out using triangulation methods and quantitative data with descriptive quantitative analysis. The triangulation method is a data examination technique that utilizes something other than data for checking purposes or as a comparison with data. The triangulation techniques used by researchers in this study are source, method, and time triangulation (Crabtree and Miller, 2023 & Dwiastuti, 2017). The results of the triangulation analysis are then outlined in the form of a concept that describes the actual condition of the journey of Liberica coffee in Banyuwangi Regency to Geographical Indications.

# 3. Result and Discussion

## 3.1 Local Ecological Knowledge of Liberika Coffee Farmers in Caring for Coffee Fields as Part of Their Ancestral Heritage

In the rich agricultural landscape of Banyuwangi Regency, Liberika coffee cultivation is interwoven with a tapestry of local ecological knowledge (LEK) passed down through generations. This knowledge manifests itself in many ways, including the diverse names farmers use to identify Liberika coffee, such as *Glondok* Coffee, *Nangka* Coffee (Jackfruit Coffee), Forest Coffee, *Buriyah* Coffee, *Ekselsa* Coffee (excelsa coffee), and Liberika Coffee (Liberica Coffee). These names are not mere linguistic labels, but rather encapsulate a deep understanding of the coffee plant's physical attributes, ecological context, and the integration of modern knowledge interventions. By exploring the successful integration of LEK in the sustainable production of Liberica coffee, this section reveals the complex relationship between ancestral heritage and the care shown by farmers for their coffee plantations. The findings explain the role of LEK in shaping sustainable practices and maintaining Liberica coffee heritage in Banyuwangi Regency from the cultivation process to pest control.

The in-depth analysis of the role of Local Ecological Knowledge (LEK) in the sustainable production of Liberica coffee reveals a complex and intricate interplay between traditional wisdom and modern agricultural practices within the context of Banyuwangi Regency. LEK deeply embedded in the farming traditions passed down through generations, serves as a foundational element in shaping sustainable practices throughout the coffee cultivation process. At its core, LEK manifests in various aspects of Liberica coffee production, from the choice of farming methods to pest control strategies. The diverse names used by farmers to identify Liberica coffee, such as Glondok Coffee, Nangka Coffee, Forest Coffee, Buriyah Coffee, Ekselsa Coffee, and Liberica Coffee, go beyond mere linguistic labels. Instead, they encapsulate a profound understanding of the physical attributes of the coffee plant and its ecological context. The integration of modern knowledge interventions into these traditional names signifies a dynamic adaptation of LEK to incorporate contemporary insights (Hakim, 2017; Nguyen et al., 2020; Gordon et al., 2023).

The sustainable production of Liberica coffee, as elucidated by LEK, goes beyond just agricultural practices; it represents a custodianship of ancestral heritage. Farmers, acting as stewards of their land, draw upon LEK to inform decisions related to cultivation methods and resource management. This custodial role extends to pest control, where the wisdom accumulated over generations becomes instrumental in developing strategies that are not only effective but also environmentally sustainable. Moreover, LEK plays a pivotal role in maintaining Liberica's coffee heritage by influencing decisions at every stage of production. From planting and nurturing to harvesting, farmers leverage their accumulated wisdom to navigate the challenges posed by the dynamic environmental conditions in Banyuwangi Regency. This nuanced understanding enables them to adapt their practices in response to changing circumstances, ensuring the resilience and sustainability of Liberica coffee cultivation (Charnley et al., 2007; Guo et al., 2021; Tridakusumah et al., 2021). LEK acts as a guiding force in the sustainable production of Liberica coffee, contributing to the preservation of cultural heritage and the ecological integrity of the agricultural landscape in Banyuwangi Regency. The dynamic nature of LEK, influenced by both traditional practices and modern knowledge, underscores its significance as a bridge between the rich history of Liberica coffee cultivation and the evolving landscape of sustainable agriculture.

### 3.1.1 Coffee Cultivation

Liberika coffee cultivation entails a distinct approach adopted by farmers, beginning with "cukulan" coffee seeds. "cukulan" refers to coffee seeds that naturally emerge from red coffee beans that have fallen from productive coffee trees and germinate in the soil. Farmers prioritize seeds originating from the vicinity of mature coffee trees, as these are believed to possess robust supporting roots and long-term viability. The farmers perception regarding coffee adaptation to the local environment aligns closely with Western science, encompassing the ethical perspective that plants thriving in a specific location are

influenced by their genetic makeup and the local environmental conditions in which they grow (Sastrapradja and Widjaja, 2010). In Western science terms, this perspective encompasses the principles of plant genetics and environmental science, asserting that the success of a plant species in a given area is determined by its inherent genetic traits and its ability to interact harmoniously with the local environmental factors. The shared recognition between farmers' empirical observations and Western science principles underscores a convergence in acknowledging the fundamental role of genetics and environmental compatibility in the adaptation of coffee plants to specific locales (Mazzocchi, 2018). The utilization of "cukulan" coffee seeds embodies the farmers astute understanding of the coffee plant's adaptability and resilience within the context of their specific ecological setting (Bracken et al., 2023).

Coffee cultivation diverges from conventional agricultural practices as it necessitates planting shade trees to establish and maintain an optimal microclimate suited to the coffee plants' requirements. Farmers typically incorporate various shade trees such as bananas (*Musa sp.*), coconut (*Cocos nucifera*), rasidi (*Gliricidia sepium*), and durian (*Durio zibethinus* L.), with some favoring lamtoro (*Leucaena leucocephala*) as the most favorable shade tree. Farmers procure ready-to-plant shade tree seeds, including lamtoro (*Leucaena leucocephala*) and rasidi (*Gliricidia sepium*. The initial step involves planting shade trees, followed by the coffee plants after approximately one year. In a one-hectare coffee plantation, an average of 1500-1600 trees is cultivated, with a spacing of 2x3 meters. The average amount of coffee bean harvest in 1 hectare ranges from 300-400 kg. The process of harvesting Liberica beans is labor-intensive, underscoring the effort required for a yield that justifies the endeavor (Davis et al., 2022). The coffee trees, reaching impressive heights of up to 20 feet (6 meters), pose a challenge as the coffee cherries tend to be concealed amidst the abundant foliage. This height and the foliage complexity make it demanding for workers to meticulously pick all the ripe coffee cherries, adding a layer of intricacy to the harvesting process.

Once a year has passed, farmers proceed with the planting of Liberika coffee. The process entails digging the soil to a depth of 50 cm, then placing the seeds in the holes. The "reversal" method is employed, whereby the darker-colored bottom soil is positioned on top while the lighter-colored topsoil is placed at the bottom. Notably only the planting hole is filled with soil, while the remaining 75% is left unfilled. This approach minimizes roots' upward growth and stimulates fibrous roots' development. Typically, the remaining 75% of the hole is filled with litter and soil collected from the surroundings of the newly planted coffee trees. The average planting distance favored by Kalipuro farmers is either 2 m x 2.5 m or 2.5 m x 3 m, as the garden layouts often adhere to inherited designs passed down from previous generations.

### 3.1.2 Coffee Fertilization

Liberika coffee farmers in Banyuwangi Regency employ annual fertilization practices to maintain soil fertility and support optimal growth. Organic fertilizers derived from cow or goat manure constitute the primary fertilization method adopted by farmers. The production of manure involves a fermentation process wherein a mixture of 1 liter of EM 4 (Effective Microorganisms) and 1 liter of drops is combined with 1 ton of goat manure, 50 kg of "*katul*" (rice bran), and 2twoquintals of "*grajen*" (sawdust from non-teak wood), coffee skins, or cocopeat. This mixture is then fermented for a period of 21 days. Typically, this fertilizer blend is adequate for fertilizing one hectare of land.

Another organic fertilizer utilized in Liberica coffee cultivation is *rencek*, which refers to the unused stems of animal feed. These stems are placed beneath the coffee plants, specifically in the "*rorak*" or "*gandungan*" area. *Rorak* is a dead-end channel or building in the form of a manhole of a specific size made in the field of terrace cultivation and parallel to the contour line, which functions to trap/trap surface flow and eroded soil and can be useful as a storage medium for organic matter. *Rorak* is made after seeds are planted in the field and is made every year in productive plants. This additional organic fertilizer contributes to the nutrient supply and overall soil health in the coffee plantation.

The application of cow or goat manure in Liberika coffee cultivation represents a deliberate choice by farmers to employ organic fertilizers derived from locally available resources. Cow or goat manure is

an excellent nitrogen source, a key nutrient for promoting vegetative growth and overall plant health (Bracken et al., 2023; Hariyati et al., 2022). These organic fertilizers supply essential nutrients to coffee plants and enhance the soil's organic matter content, improving its structure and water-holding capacity (Prijono et al., 2021). Moreover, beneficial microorganisms in organic fertilizers facilitate nutrient cycling and promote symbiotic relationships with coffee plants, improving nutrient uptake efficiency and overall plant resilience (Soemarno et al., 2022). By incorporating traditional ecological knowledge into their farming practices, Liberika coffee farmers recognize the value of organic fertilizers in sustaining soil fertility and reducing the environmental impact of synthetic fertilizers (Sauvadet et al., 2019). This approach aligns with the principles of sustainable agriculture, which emphasize the importance of minimizing chemical inputs and maximizing the utilization of local resources (Soemarno et al., 2021). The integration of organic fertilizers enhances soil fertility and contributes to the conservation of soil biodiversity and the preservation of ecosystem services (Prijono et al., 2021; Soemarno et al., 2021). Moreover, by utilizing locally available organic materials, farmers reduce dependency on external inputs, thereby promoting self-sufficiency and economic resilience.

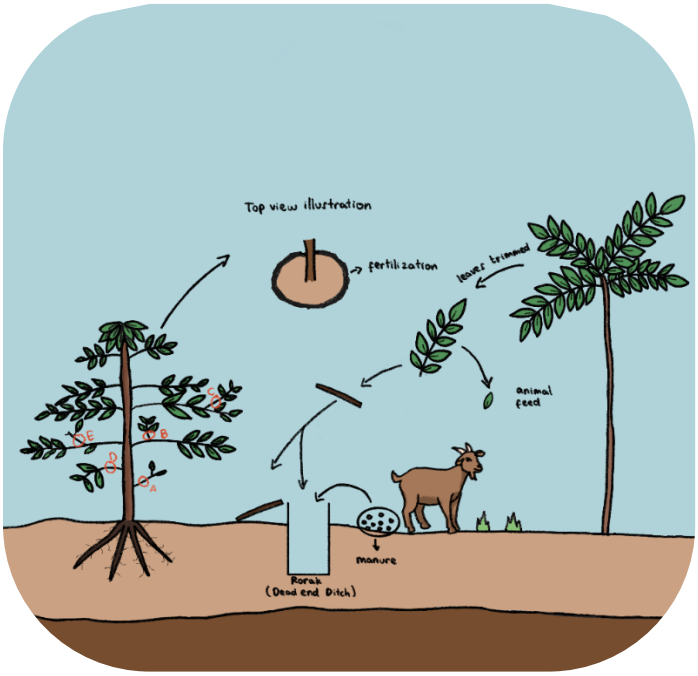


**Figure 2.** Illustration of coffee fertilization

### 3.1.3 Land Clearance

Farmers in Banyuwangi Regency employ various land maintenance practices to ensure the optimal growth and development of Liberica coffee plants. One of these practices involves the removal of grass that competes with coffee plants for nutrients and resources. This grass-cleaning process is carried out using different tools and techniques. "*Kesrek*" is a grass-cleaning method where farmers use a hoe, a traditional agricultural tool resembling a spade or hoe, to remove the grass surrounding the coffee plants. This manual method allows farmers to uproot the grass and create a clear space around the coffee plants, reducing competition for essential resources such as water, sunlight, and nutrients (Prijono et al., 2021).

Another grass-cleaning technique farmers employ is "rabas", which involves using a sickle to cut and remove grass grown around the coffee plants. A sickle is a curved-blade tool designed for precise cutting, enabling farmers to selectively remove grass while minimizing damage to the coffee plants. By employing the "*rabas*" method, farmers can maintain a clean and weed-free environment around the coffee plants, facilitating their healthy growth and minimizing the risk of pests and diseases. In addition to "*kesrek*" and "*rabas*", farmers also utilize "*jombretan*", which involves the use of other weapons or tools to clean the grass. These weapons or tools may vary among farmers, depending on their preferences and

the availability of resources. "*Jombretan*" serves as an alternative method to "*kesrek*" and "*rabas*", allowing farmers to effectively remove grass and ensure the unimpeded growth of the coffee plants. By regularly implementing these grass-cleaning practices, farmers prevent weed infestations, enhance the overall health of the coffee plants, and promote better air circulation within the plantation (Prijono et al., 2021; Soemarno et al., 2021). These manual land maintenance techniques reflect the integration of local ecological knowledge and traditional farming practices, contributing to the sustainable production and management of Banyuwangi Liberica coffee.

### 3.1.4 Coffee branch pruning

Pruning is an essential practice in Banyuwangi Liberica coffee cultivation, with farmers utilizing specific techniques and local terms to guide their pruning activities. The farmers distinguish various types of pruning based on the growth characteristics and desired outcomes. For instance, "Top" or "*Tarobusen*" refers to removing upward-growing coffee branches to control plant height and facilitate easier maintenance. "Tags" or "*Empang*" denote the pruning of productive secondary branches to redirect the plant's energy towards primary branches, leading to increased yield. Farmers also address branches that lean downwards, known as "Worm branches" or "*cabang cacing*" by pruning them to promote better light exposure and balanced growth. "*Alier*" pruning involves managing twisting branches, and the "Fan branches" or "*cabang kipas*" technique targets sideways-growing branches to enhance light penetration and overall productivity. Farmers selectively prune non-fruit-bearing branches, referred to as "hair branches" or "male branches," to optimize resource allocation and maximize fruiting capacity. Farmers demonstrate their profound understanding of coffee plant growth patterns and ecological dynamics through these pruning practices, contributing to sustainable and productive Liberica coffee cultivation. Some of the pruning terms used by farmers are listed in Table 1.

**Table 1.** Pruning terms used by farmers

| No | Coffee Pruning | Local Terms |
|---|---|---|
| **1** | Pruning coffee branches that grow upwards | *Top, Tarobusen* |
| **2** | Pruning producing secondary branches | *Tag, Empang* |
| **3** | Pruning secondary branches that grow leaning downward so that they get minimal sunlight | *Cabang cacing* |
| **4** | Pruning twisted branches | *Alier* |
| **5** | Pruning sideways secondary branches shaped like fans and covering sunlight to productive branches | *Cabang Kipas* |
| **6** | Pruning delicate branches that do not bear fruit | *Cabang rambut* |
| **7** | Pruning slightly elongated and non-fruitful coffee branches | *Cabang laki* |
| **8** | Pruning newly grown secondary branches and overcrowding | *Wiwil* |

Integrating local ecological knowledge (LEK) in pruning practices is a testament to the ancestral heritage of Banyuwangi Liberica coffee farmers. Farmers showcase their in-depth knowledge of the coffee plants and unique requirements by employing specific pruning techniques and using local terms to describe these practices (Hakim et al., 2022 & Rukmana, 2014). These pruning methods shape the coffee trees' physical structure and influence their physiological functions, ensuring optimal light exposure, airflow, and resource allocation (Ruiz-García et al., 2021). The careful selection and removal of branches based on their growth patterns and productivity potential result in enhanced yield and quality of the coffee harvest. By incorporating LEK into pruning activities, farmers harness traditional wisdom and adapt it to the local context, thereby promoting sustainable production practices and maintaining the long-term viability of Banyuwangi Liberika coffee cultivation. Using indigenous terminology to describe these pruning practices reflects a deep-rooted cultural and traditional knowledge system (Joa et al., 2018).

### 3.1.5 Utilization of Pruning Waste

Pruning waste plays a significant role in the sustainable management of Liberika coffee plantations in Banyuwangi Regency. Farmers effectively utilize pruning waste by incorporating it into the "*rorak*" or "*gandungan*" system. This practice involves collecting and depositing the pruned branches and foliage in designated areas within the plantation. The prunings of shade plants, such as *rasidi* (*Gliricidia sepium*) and *lamtoro* (*Leucaena leucocephala*), are also repurposed as animal feed.

It is important to note that livestock predominantly consumes the leaves of the prunings, while the stems, known as "*penrape*", remain unused. However, these "*penrape*" stems serve a valuable purpose as compost material within the "rorak" system. Placed at the base of the coffee trees, the penrape stems facilitate the minimization of unwanted grass growth. Over approximately three months, the *penrape* stems undergo a natural decomposition process within the rorak system. This decomposition process contributes to soil nutrient cycling dynamics and accumulation of organic matter. As the *penrape* decomposes, it releases essential nutrients and compounds that become available for uptake by the coffee plants, promoting their growth and development. Furthermore, the decomposition of *penrape* conimprovesil structure, moisture retention, and microbial activity enhance overall soil fertility.

The integration of pruning waste into the *rorak* system and its subsequent utilization as compost material exemplifies the farmers commitment to sustainable agricultural practices (Soemarno et al., 2021). Farmers minimize the need for external inputs such as synthetic fertilizers by effectively managing organic waste through on-site composting. This approach aligns with sustainable agricultural principles by reducing the reliance on chemical inputs and mitigating potential environmental pollution risks (Bracken et al., 2023). Additionally, the circular nutrient flow established through the incorporation of pruning waste into the *rorak* system exemplifies a closed-loop system, where organic matter is recycled and reused within the coffee plantations (Djufry et al., 2022; Rukmana, 2014; Wulandari et al., 2022).

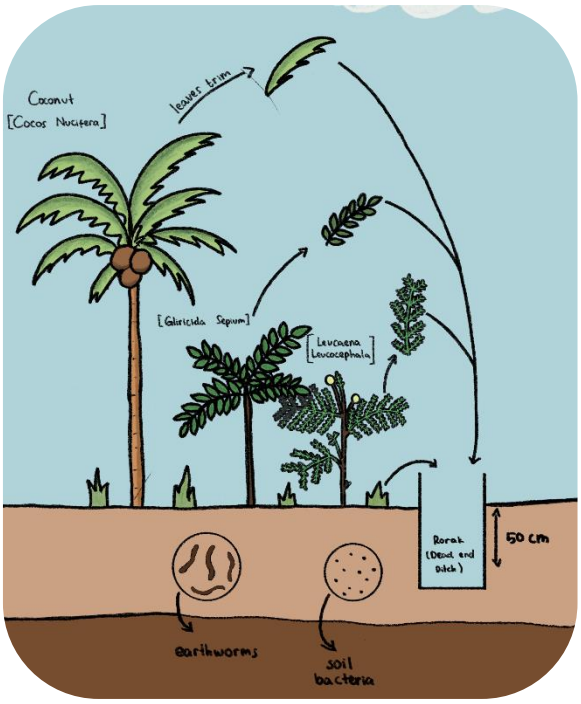


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**Figure 3.** Illustration for utilisation of pruning waste

### 3.1.6 Pest and Disease Control

Farmers in Banyuwangi Regency employ various strategies to control pests and diseases in Liberika coffee cultivation, with a preference for utilizing organic materials. One commonly utilized method involves harnessing the properties of mindi plants (Melia azedarach). Farmers prepare a pest-repellent solution by crushing two "*kepel*" mindi leaves and mixing them with 10 liters of water, spraying

them onto coffee plants. Farmers favor this organic pest control method, as it helps minimize the population of pests in the coffee plantation. In the context of local measurements, "*kepel*" refers to the amount of material that can be held in one hand. Farmers in Banyuwangi Regency utilize approximately one "*kepel*" of mindi leaves, equivalent to the amount that can be held in one hand, for preparing the pest-repellent solution. This local measure is a practical and convenient way for farmers to determine the appropriate amount of mindi leaves to use in the mixture.

Ants are considered pests by farmers due to their ability to inflict damage on coffee beans, thereby facilitating the entry of other pests. Farmers categorize ants as ordinary insects and pests, highlighting their potential to cause harm. Another common pest in Liberika coffee plantations is the powder caterpillar, known for its detrimental impact on coffee cherries. The presence of powder caterpillars can lead to premature rotting of red coffee cherries before the scheduled harvest. To combat these pests, farmers adopt a preventive measure that involves soaking the coffee cherries from the first and last harvests in boiling water, followed by floating them. This method eliminates pest eggs on the cherries' surface, as the high temperatures of boiling water effectively kill the eggs. Farmers have observed substantial quantities of pest eggs, with reports of up to 250 eggs per coffee cherry. This proactive pest control approach helps safeguard the quality and yield of Liberika coffee by minimizing the risk of infestation and subsequent crop damage (Tridakusumah et al., 2021). By implementing these organic pest control strategies, Liberika coffee farmers in Banyuwangi Regency emphasize the importance of sustainable and environmentally friendly practices (Kusumawati et al., 2022; Shriver et al., 2015). These practices not only mitigate the impact of pests and diseases but also ensure their coffee crops' overall health and productivity. By utilizing natural methods, farmers minimize the reliance on synthetic pesticides, reducing potential environmental risks and promoting the ecological balance within their agricultural systems (Turner, 2014). The transition from synthetic pesticides to natural methods, specifically biopesticides, is imperative for mitigating environmental risks associated with conventional pesticide use (Daraban et al., 2023). Conventional pesticides, characterized by slow degradation and adverse impacts on ecosystems, raise concerns for environmental pollution and human health. In contrast, biopesticides, derived from natural sources, offer an environmentally friendly alternative with rapid degradation and reduced non-target effects. Their incorporation into Integrated Pest Management programs enhances sustainability, providing benefits such as residue management and lower risks to beneficial insects. Despite challenges related to production costs and shelf life, biopesticides demonstrate potential for widespread adoption, especially in developing countries where wild flora and cost-effective production options prevail (UNEP, 2023). The integration of organic pest control measures in Liberika coffee production demonstrates the farmers commitment to sustainable agriculture and the preservation of their coffee crops (Shriver et al., 2015; Soemarno et al., 2021). By prioritizing environmentally friendly practices, farmers contribute to the long-term viability and resilience of the coffee plantations (Djufry et al., 2022; Gradual et al., 2021) while promoting the production of high-quality Liberika coffee beans.

### 3.2 Characteristics of Local Ecological Knowledge among Liberika Coffee Farmers in Banyuwangi

Farmers cultivating Liberika coffee in Banyuwangi Regency possess a wealth of local ecological knowledge (LEK) that has been passed down through generations and refined over time (Charnley et al., 2007). This knowledge encompasses a deep understanding of ecological dynamics, agricultural practices, and the sustainable management of natural resources. It is important to recognize that farmers adoption of new technologies and information is not a uniform process (Molnár and Babai, 2021). While various technological advancements and external information may enter their environment, not all are embraced and incorporated into their practices (Sharifian et al., 2023). Farmers, as the primary actors intimately acquainted with their local agricultural conditions, exhibit a distinct form of wisdom, commonly referred to as farmer wisdom, in their resource management approaches. Integrating external inputs with existing knowledge forms the foundation for developing new knowledge among farmers (Gordon et al., 2023; Guo

et al., 2021; Tridakusumah et al., 2021). When introduced to innovations, farmers engage in a series of practical trials to assess the effectiveness and benefits of these innovations within their specific context. Based on the results of these trials, farmers make informed decisions regarding the adoption and implementation of the innovations. Successful outcomes catalyze the adoption and dissemination of knowledge among farmers (Joa et al., 2018).

Local farmers can adapt external innovations to suit their individual needs and limitations. This process of adaptation and customization ensures that the knowledge is tailored to the local agroforestry systems and aligns with the available resources and constraints (Kusumawati et al., 2022; Ruiz-García et al., 2021). Moreover, when farmers successfully adopt and apply these innovations, they become agents of knowledge transfer, sharing their experiences and insights with other farmers within their community. This dynamic technology dissemination and knowledge-sharing process enables the diffusion of sustainable agroforestry practices among farmers (Gradual et al., 2021; Hakim et al., 2022). The importance of agroforestry practices becomes evident through the lens of local ecological knowledge. As a sustainable land-use system combining crops with trees and shrubs, agroforestry offers numerous benefits such as enhanced soil fertility, improved biodiversity, climate resilience, and increased farm productivity (Bracken et al., 2023; Gomes et al., 2020). Local farmers, equipped with traditional knowledge systems and wisdom, are pivotal in integrating agroforestry practices into their Liberika coffee cultivation. Their deep understanding of ecological interactions, soil fertility management, shade regulation, and biodiversity conservation contributes to the sustainable development of agroforestry landscapes (Djufry et al., 2022; Gomes et al., 2020). By recognizing and respecting local ecological knowledge and integrating it with modern innovations, Liberika coffee farmers in Banyuwangi Regency promote adopting sustainable agroforestry practices, ensuring the preservation of their ancestral heritage and the well-being of their agricultural landscapes.

### 3.3 Linkage of Ancestral Heritage in Caring for Liberika Coffee Fields with Environmental Sustainability

The linkage between ancestral heritage and the care of Liberika coffee fields encompasses a profound connection with environmental sustainability. Farmers in Banyuwangi Regency, guided by their rich heritage and local ecological knowledge (LEK), undertake agricultural practices that harmonize with the natural environment (Turner, 2014; Virtanen, 2019). This unique interplay between ancestral wisdom and sustainable land management is crucial for ensuring the longevity of Liberika coffee cultivation and preserving the surrounding ecosystem. Drawing upon their ancestral knowledge, farmers employ traditional methods in caring for Liberika coffee fields, deeply rooted in the principles of environmental sustainability (Virtanen, 2019; Whyte, 2018). This heritage-driven approach recognizes the intrinsic value of the natural resources and ecosystem services the environment provides. Farmers intimate familiarity with the local landscape enables them to make informed decisions that minimize environmental impact and enhance the resilience of the agroecosystem (Bracken et al., 2023; Gordon et al., 2023).

The critical aspect of this linkage is the farmers understanding of the importance of biodiversity conservation and the promotion of ecological balance. Using beaten seedlings in Liberika coffee cultivation plays a pivotal role in preserving the authenticity of the local coffee species (Gordon et al., 2023; Gradual et al., 2021; Kusumawati et al., 2022). By utilizing ''cukulan'' seedlings that have naturally germinated from fallen red coffee beans, farmers ensure the continuity of the specific characteristics and genetic makeup of the Liberika coffee variety. This practice contributes to preserving the unique flavor profiles and cultural heritage associated with the local Liberika coffee (Hakim, 2017; Slámová et al., 2021). Incorporating the residues from land clearing and pruning back into the soil is significant for maintaining soil productivity. These organic residues serve as valuable food sources for soil-dwelling insects, which aid in the decomposition process (Soemarno et al., 2022, 2021). By breaking these organic materials, complex compounds are transformed into simpler forms that plants can readily absorb (Prijono et al., 2021).

The augmentation of soil fertility through the intensified use of organic fertilizers plays a pivotal role in optimizing plant growth and enhancing crop productivity. This shift in agricultural practices is particularly noteworthy in the context of local coffee farmers, where a discernible trend toward increased utilization of organic fertilizers is observed. A notable illustration is provided by a farmer who, in the past, applied organic fertilizer at a rate of 10 kg per plant but has since elevated the dosage to 25 kg per plant. Moreover, a collective initiative among a group of farmers involves the production of liquid fertilizer, aimed at augmenting the organic material content. The liquid fertilizer is perceived as advantageous for its enhanced plant absorbability. This transition underscores a concerted effort among local farmers to leverage organic fertilizers as a means to fortify soil fertility, thereby contributing to the overall enhancement of agricultural sustainability and productivity (Soemarno et al., 2021).

The pruning of coffee branches and shade plants is based on their specific form and function. Pruning unproductive coffee branches allows for the optimal fruit-bearing capacity of coffee plants. This practice encourages the channelling of resources towards productive branches, leading to higher yields and better overall crop quality. Similarly, pruning shade plant branches contribute to maintaining microclimate conditions within the coffee plantation. By regulating the intensity of sunlight, air circulation, and temperature, the microclimate is optimized, providing an ideal environment for coffee growth and development (Manningtyas and Furuya, 2022; Ruiz-García et al., 2021; Rukmana, 2014). The integration of livestock within coffee fields establishes a vital connection between animals, humans, and plants. This approach aligns with the principles of a circular economy in agriculture, where resources are maximized, and waste is minimized. Livestock can contribute to nutrient cycling by converting organic residues and by-products into valuable manure, which can be utilized as natural fertilizers. This integration fosters a symbiotic relationship between coffee plants, livestock, and humans, promoting sustainable resource utilization and reducing waste (Hida et al., 2023; Soemarno et al., 2021).

Using natural ingredients in pest management practices ensures the preservation of the food chain cycle within the coffee ecosystem. By avoiding chemical pesticides, farmers safeguard the presence of beneficial insects that play essential roles in pollination, pest control, and overall ecosystem balance (Guo et al., 2021; Kusumawati et al., 2022; Rukmana, 2014). This approach prevents the unintended destruction of significant insect populations and maintains the ecological equilibrium within the coffee plantation. Embracing natural pest management strategies aligns with sustainable agricultural practices that prioritize environmental preservation and the promotion of biodiversity. The linkage of ancestral heritage with the care of Liberika coffee fields showcases a deep commitment to environmental sustainability. Traditional wisdom, local ecological knowledge, and sustainable land management practices underpin the harmonious coexistence of agricultural production and environmental stewardship (Joa et al., 2018; Manningtyas and Furuya, 2022; Turner, 2014). By upholding their ancestral heritage, Liberika coffee farmers in Banyuwangi Regency embody the vital role of cultural heritage in shaping sustainable agricultural practices and ensuring the long-term preservation of the natural environment.

## 4. Conclusions

The study reveals that farmers in Banyuwangi Regency possess a rich repository of Local Ecological Knowledge (LEK) that underpins their sustainable management practices in Liberika coffee cultivation. This ancestral wisdom, accumulated over generations, encompasses various aspects of ecology, agriculture, and forestry, shaping their decision-making processes when adopting innovations. By conducting simple research trials, farmers assess the effectiveness and benefits of new practices, ensuring the adoption of viable and beneficial approaches. The inheritance of knowledge from one generation to another underscores the continuity and resilience of local agricultural practices. Farmers unknowingly integrate environmentally friendly methods into their land management, preserving the authenticity of Liberika coffee by utilizing "cukukan" seedlings and enhancing soil fertility by returning land-clearing and pruning waste to the soil. The profound exploration of farmers LEK highlights their

holistic and sustainable approach to Liberika coffee cultivation, reflecting their deep understanding of the interconnectedness between humans, nature, and the coffee production system. Preserving and perpetuating this invaluable local knowledge maintains the cultural heritage and contributes to the environmental sustainability of Liberika coffee cultivation in Banyuwangi Regency.

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