

The Resilience Effort of Indonesian Tea Smallholder Plantation by Intercropping and Agroforestry Tea Farming System

Kralawi Sita^{1*} and Tri Maruto Aji²

ABSTRACT

Indonesia's tea industry heavily relies on smallholder plantations, which contribute 50% of the national tea plantation area and 40% of production. However, smallholder tea farmers face numerous challenges, including declining soil fertility, low tea process, and the impacts of climate change. Among them are drought and the outbreak of pests and diseases, which threaten their productivity and sustainability. Intercropping and agroforestry systems have emerged as viable strategies to enhance resilience by diversifying income sources, improving ecological sustainability, and adapting to changing climatic conditions. This is happening even as many other tea farmers are choosing to convert their tea crops to other commodities considered more profitable. This study explores the implementation, benefits, and challenges of intercropping and agroforestry systems in Indonesian smallholder tea plantations. The findings reveal that these systems not only enhance biodiversity and soil health but also align with global sustainability goals such as the SDGs by fostering economic stability and environmental conservation. The intercropping and agroforestry systems involve the cultivation of vegetables, fruits, spices, and timber plants in various patterns. However, adoption remains limited due to barriers such as inadequate resources, knowledge, and policy support. The paper concludes with recommendations to promote these practices, including policy reforms, capacity-building programs, financial incentives, and market development, to ensure a sustainable and inclusive tea agribusiness ecosystem for smallholders.

Keywords: tea smallholder, intercropping, agroforestry, resilience, sustainability
International Journal of Tea Science (2025); DOI: 10.20425/ijts18203

INTRODUCTION

Indonesia, as one of the world's prominent tea producers, relies heavily on smallholder plantations to sustain its tea industry. Indonesian tea smallholders contribute significantly to 40% of national tea production and control 50% of the total national tea plantation area, yet they often face multifaceted challenges, including low tea prices, climate change, declining soil fertility, and tea conversion to other commodities that are more profitable. These issues jeopardize both productivity and sustainability, necessitating innovative farming practices that enhance resilience while ensuring economic viability (Hicks *et al.*, 2020).

Intercropping and agroforestry have emerged as potential solutions to address these challenges. Intercropping, the practice of cultivating two or more crops in the same field, not only optimizes land use but also mitigates risks associated with monocropping by diversifying income sources and reducing pest outbreaks (Altieri, 2018). Similarly, agroforestry integrates trees and shrubs into agricultural landscapes, offering ecological benefits such as improved soil health, carbon sequestration, and microclimate regulation (Nair, 2014).

For Indonesian smallholder tea plantations, especially in West Java province, where the largest tea smallholder area and highest tea smallholder production (90%) are located, adopting intercropping and agroforestry systems presents a promising strategy to enhance resilience. Studies have shown that these practices can increase biodiversity, stabilize incomes, and adapt farming systems to changing climatic conditions (Sileshi *et al.*, 2007). Despite these advantages, widespread adoption faces constraints, including limited access to knowledge, financial resources, and technical support (Van Noordwijk *et al.*, 2019).

This paper explores the resilience efforts of Indonesian tea smallholder plantations through the implementation of intercropping and agroforestry systems. It aims to analyze their

¹Indonesia Research Institute for Tea and Cinchona - Mekarsari, Pasirjambu Subdistrict Bandung Regency, West Java 40972

²PT Riset Perkebunan Nusantara - Jl. Salak No.1A, Babakan, Kecamatan Bogor Tengah, Kota Bogor, Jawa Barat 16128

Corresponding Author: Kralawi Sita, Indonesia Research Institute for Tea and Cinchona - Mekarsari, Pasirjambu Subdistrict Bandung Regency, West Java 40972, e-mail: kralawi.sita@gmail.com

How to cite this article: Sita, K., Aji, T.M. The Resilience Effort of Indonesian Tea Smallholder Plantation by Intercropping and Agroforestry Tea Farming System. *International Journal of Tea Science* 2024, 18(2):12-19.

Source of support: Nil

Conflict of interest: None

Received: 10/07/2024; **Revised:** 20/09/2024; **Accepted:** 30/12/2024

impact on productivity, environmental sustainability, and farmer livelihoods. By understanding these dynamics, the study seeks to contribute to policy recommendations and practical solutions for a more resilient tea industry in Indonesia.

The Challenges of Indonesian Tea Smallholder

In the agribusiness system framework, for more than a decade, Indonesian tea smallholders face several challenges that impact their productivity, quality, and market access. Below is an explanation of each sub system challenges face by Indonesian tea smallholders:

Upstream sub-system

Access to agricultural inputs, especially seeds and fertilizers (subsidies for smallholder tea farmers), the emerging scarcity of labor, particularly for tea harvesting (including the crisis of farmer regeneration), and pressure from land-use conversion (the area of tea plantations continues to decrease).

On-farm sub-system

Productivity is not yet optimal, the quality of tea shoots is low, the selling price of shoots and dried tea is low, production costs are high/increasing while selling prices remain stagnant or low, declining soil fertility, climate change (drought and increased pest and disease intensity), and the availability of innovative cultivation/maintenance and tea harvesting technology.

Off-farm subsystem

Low quality of raw materials, limited diversification of downstream tea products, availability of tea processing/downstream technology, suboptimal factory conditions and processing capacity, and lack of energy-efficient technology for processing primary tea products (green energy).

Market sub-system

Price and market certainty are lacking, the marketing chain for smallholder tea is long, the tea trade system is not yet integrated from upstream to downstream to market (market information), the product traceability system is still weak and inefficient, compliance with market demand standards is lacking, and there is insufficient education, promotion, and branding of Indonesian tea products, so they are generally still sold in a conventional form (business as usual), with the image of tea in the domestic market being perceived as 'low-quality tea'.

Support sub-system

Weak farmer institutions (bargaining position and competitiveness), weak marketing institutions, limited technical training and the long absence of tea field schools (such as SLPHT), limited access to capital models and partnerships, lack of support from other institutional ecosystems in commercializing local tea products, waste management as an impact of tourism, implementation and strengthening of regulations and policies, and insufficient information on Indonesian tea data (including spatial data, etc.)

The biggest challenges of tea smallholders in Indonesia are the low selling price of tea leaves, while the production costs continue to rise every year, causing profit margins to shrink or even disappear, and finally, most farmers decided to convert their tea plantations to other commodities. Unfortunately, many tea farmers are making efforts to maintain their tea plantations by tea intercropping with other crops and through tea agroforestry. A few of them are successful in surviving and develop, and it is one of the lessons learned about the Resilience Effort in Tea Smallholder Plantation.

Supply Chain of Indonesian Tea Smallholder Products

The majority of Indonesian smallholder tea products consist of green tea for the domestic market, with nearly 90% sourced from West Java province. Approximately 70-80% of dried green tea products are supplied to Central Java to produce scented tea (green tea infused with jasmine aroma). The supply chain for smallholder tea remains conventional, following a tiered collector trader system. Farmer groups or associations (called Gapoktan or Self-Help Group/SHG) typically also act as leaf collectors or intermediary traders. Smallholder tea leaves are then sold to smallholder green tea factories or private factories in the surrounding areas. The quality of smallholder tea leaves for smallholder green tea generally has a quality of green leaves of $\leq 40\%$. The trading flow of dried green tea products (generally unsorted) is marketed to Sukabumi through large traders or packers, who then supply 70-80% of the products to Central Java for processed tea industries (such as scented tea factories, ready-to-drink, etc.). The description of the Indonesian green tea smallholders' supply chain can be shown in Figure 1.

Role of Intercropping and Agroforestry in the Tea Farming System

Tea intercropping can be defined as growing tea with one, two, or more crops at the same time/simultaneously on a single field in regular and irregular rows. Vandermeer (1989) explained that the focus of intercropping is on maximizing the use of space and resources for short-term agricultural productivity. Mousavi and Eskandari (2011) described the three types of intercropping farming system: 1) Row-intercropping, where tea with two or more crops simultaneously is planted in regular rows. This type can easily be found in Indonesia, India, and Sri Lanka tea plantations. 2) Mixed-intercropping, where growing tea with two or more crops simultaneously with no distinct row arrangement. This type is applied in Indonesia, India, China, and Sri Lanka. 3) Strip-intercropping, where growing tea with two or more crops simultaneously in different strips wide enough. This type is also applied in Indonesia, India, China, and Sri Lanka.

Agroforestry can be explained as an efficient and integrated land use management system by raising certain agricultural crops, forest tree species, and/or animals simultaneously or sequentially on the same unit of land. Agroforestry focuses on integrating trees with crops/livestock to improve long-term sustainability, biodiversity, and ecosystem services (Nair, 1993). USDA National Agroforestry Center divided agroforestry into five types, i.e. 1) Alley Cropping, where planting tea between rows (alleys) of trees



Figure 1: Green tea supply chain of Indonesian tea smallholder

or shrubs, such as in Indonesia, China, India, Sri Lanka, and Africa. 2) Forest Farming, where cultivating tea under the protection of a tree canopy. This type is widely applied in Indonesia, China, Sri Lanka, and Africa. 3) Silvopasture, where integrating tea on grazing land for livestock (cow, goat, elephant, chicken, etc.), where specifically found in China, Sri Lanka, India, and Africa, whereas in Indonesia, it is rarely found. 4) Windbreaks, where shielding tea from the wind with trees and shrubs, are widely found in China, India, Sri Lanka, and Indonesia. 5) Riparian forest buffers reduce nutrient pollution and stabilize riverbanks by planting tea or shrubs next to streams and rivers. This type is also widely found in China, India, Sri Lanka, Indonesia, Turkey, Japan, and Africa.

The roles of tea intercropping farming system, i.e., as an alternative pathway to sustainable tea agriculture (Lulie, B, 2017), as a new green revolution in tea intensification (Martin-Guay *et al.*, 2018), can enforce ecosystem services and environmental benefits in tea ecosystem (Glaze-Corcoran, S. *et al.*, 2020), a way forward to organic agriculture in the small tea scale (Maitra, S., & Gitari, H., 2020), and as strategy to sustainable insect-pest management (Mir, M.S., *et al.*, 2022). Whereas the tea agroforestry farming system has roles, i.e., improving food security in tea plantation (Sarvade, S., & Singh, R., 2014), as climate change mitigation, carbon sequestration, climate resilience (Toppo, P., & Raj, A., 2018; Dev., I., *et al.*, 2019), as potential contribute to biodiversity conservation and ecosystem services (Barrios, E., *et al.*, 2018), and as strategy to maintenance farmers and rural livelihood also poverty alleviation (Dou, Y., 2023). From these roles, both tea intercropping and tea agroforestry have ecological, economic, land use roles. In resource sharing, tea intercropping competes for resources like nutrients and water, requiring precise management to balance crop (tea) needs, while tea agroforestry promotes complementary resource use (e.g., deep-rooted trees accessing nutrients unavailable to shallow-rooted crops)

Overview of Intercropping and Agroforestry in Indonesia Tea Smallholder Plantation

Eco-friendly Tea Farming System (ETFS) in Intercropping and Agroforestry Systems

Tea plantation maintenance requires precision and caution, considering that tea plantations are located near conservation areas. Ecologically, it is well known that tea plantations mostly are situated in highland ecosystem areas, even adjacent to nature reserves and protected forests. Therefore, tea farmers need to continually preserve the environment and biodiversity to ensure that residential and agricultural areas below them are also preserved, including in the tea intercropping and tea agroforestry practices.

The eco-friendly tea farming system (ETFS) is an approach designed to ensure sustainability in tea plantation management. This system emphasizes environmentally friendly practices to preserve ecosystems while producing high-quality tea products. ETFS is an adaptation of the Integrated Farming System (IFS) concept by Miller (1960), which was first introduced in the 1960s as a solution to agricultural challenges such as soil degradation, resource inefficiency, and the adverse effects of monoculture systems. In the context of tea plantations, ETFS was introduced in Indonesian tea plantations by Tri Maruto Aji from Research Institute for Tea and Cinchona in 2020, incorporating nine key parameters as indicators of its success.

These parameters cover various sustainability aspects, including the integrated use of biological resources to enhance

soil productivity and health, waste management based on zero-waste principles, and tree planting as ecological boundaries and protection. Furthermore, ETFS encompasses climate-adaptive environmental engineering, water and soil conservation, biodiversity protection, and the restriction of chemical use through organic approaches. Although productivity and production costs in organic tea farming pose challenges, particularly during the initial stages, organic farming appears to offer significant benefits for environmental improvement, biodiversity, and climate change mitigation (Sita and Aji, 2017). Integrated pest management methods and carbon emission reduction in plantation activities are also prioritized to minimize negative environmental impacts.

With its holistic approach, ETFS enhances the quality and quantity of tea production and supports farmers' socio-economic sustainability. Research in Vietnam by Le *et al.* (2021) has demonstrated that agroecological practices implemented through ETFS can improve soil health, productivity, and tea quality. This system represents a vital solution for balancing production needs with environmental conservation while contributing to climate change mitigation and the well-being of local communities.

ETFS is a reference that can help tea farmers prepare Standard Operating Procedures (SOP) for good and environmentally friendly tea plantation management. Well-managed tea plantations that also maintain the surrounding environment will produce high-quality tea leaves. High-quality tea leaves are certainly obtained from well-managed tea plantations. This approach minimizes the negative impact of farming on the ecosystem while maintaining the quality and productivity of tea plants. This means that it is impossible for special/ premium/ good quality tea categories to come from tea plantations managed in ways that are not environmentally friendly and even tend to damage nature. In the future, ETFS can become one of the standards in identifying and categorizing the feasibility of tea products classified as Premium tea, Specialty tea, or Sustainable tea. So, through these practices, eco-friendly tea farming not only produces high-quality tea but also contributes to the health of the environment, reduces the ecological footprint of tea production, and ensures the sustainability of tea farming for future generations. There are nine indicators to implement this system and also align with the principles of integrated pest management, which can be shown in Figure 2 below.

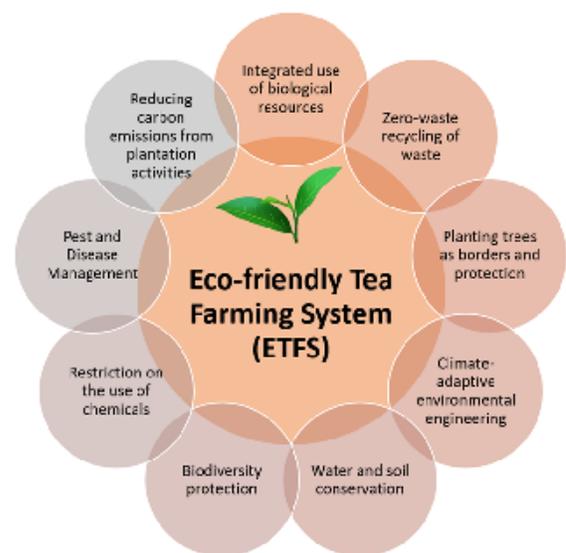


Figure 2: The indicators of ETFS



Resilience Effort in Intercropping and Agroforestry

Mostly the age of tea plants in Indonesia’s smallholder plantations is 65% more than 15 years, and 88% are planted by multi-cropping (intercropping and agroforestry) system. The tea productivity of tea smallholders is around 1.500–2.500 kg/ha/year. A study on the tea intercropping system with horticulture by Sita *et al.* (2018) showed a low input for teats that gives an efficiency of about 45% for the replanting or tea pruning phase. Although the income from tea is currently small, it can still provide a regular daily income for their family.

The commodities on tea intercropping farming system in Indonesia tea smallholder: 1) Row intercropping: Vegetable and horticulture (chili, cuisine, cabbage, tomato, and Papper) in Young Tea period and Pruning phase; 2) Mixed-intercropping: Fruit, Spices, and Wood (Banana, Avocado, Mangosteen, Durian Orange/Lemon, Clove, Cardamon, Macadamia, Bogor Tree, and Sengon Tree) along tea cycles; 3) Strip intercropping: Vegetable, Fruit (Coffee, Mangosteen, Lemon/Orange), Spicy (Clove), Crop/Timber (Pinewood, Sengon, Bogor, Eucalyptus). The commodities on tea agroforestry farming system in Indonesia tea smallholder: 1) Alley cropping: Tea and Rubber or Shade/Timber Trees (Sengon, Bogor, Silver oak); 2) Forest Farming – Social Forestry: Tea under the timber/ pine wood or eucalyptus; 3) Silvopasture: Tea with chicken or honey bee; 4) Windbreaks: Tea and shade trees/windbreaker tree (Ki Bogor, Silver Oak, Myopsis); 5) Riparian forest buffers – mostly as tourism spot: Tea near Situ or River or Lake (Pangalengan, Rancabali,

Gunung Mas)

The Impact and Benefit of Intercropping and Agroforestry for Sustainable Tea Production

By tea intercropping or tea agroforestry, tea producers contribute to sustainable tea production systems that align with global SDGs. These practices cannot only enhance economic resilience for tea farmers but also improve nature conservation and livelihood and promote ethical production and consumption patterns according to sustained supply. The contribution to improving the livelihood of tea farmers can increase income, access, and equality of tea smallholders. This contribution aligned with SDG 1 by giving more stable income from diversified tea farming practices, SDG 2 by allowing farmers to grow food crops alongside tea, SDG 3 by using lower chemical (fertilizers, pesticides, herbicides) use, improving access to nutrient-rich foods from plant diverse food crops, and enhancing cleaner air and water from trees and other crops in agroforestry, SDG 4 by knowledge sharing and training, empowering tea farmers and local communities, SDG 5 by fostering inclusive practices such as training for women tea farmers, empowering women economically through selling activity of intercrops and microfinance support, and reducing systematic barriers to participation, the last SDG 8 by diversification of income sources can increase stability, profitability and reduced vulnerability.

From the contribution to sustain supply can increase



Figure 3: Tea intercropping model in Indonesia tea smallholder: 1) Row intercropping; 2) Mixed-intercropping; 3) Strip intercropping

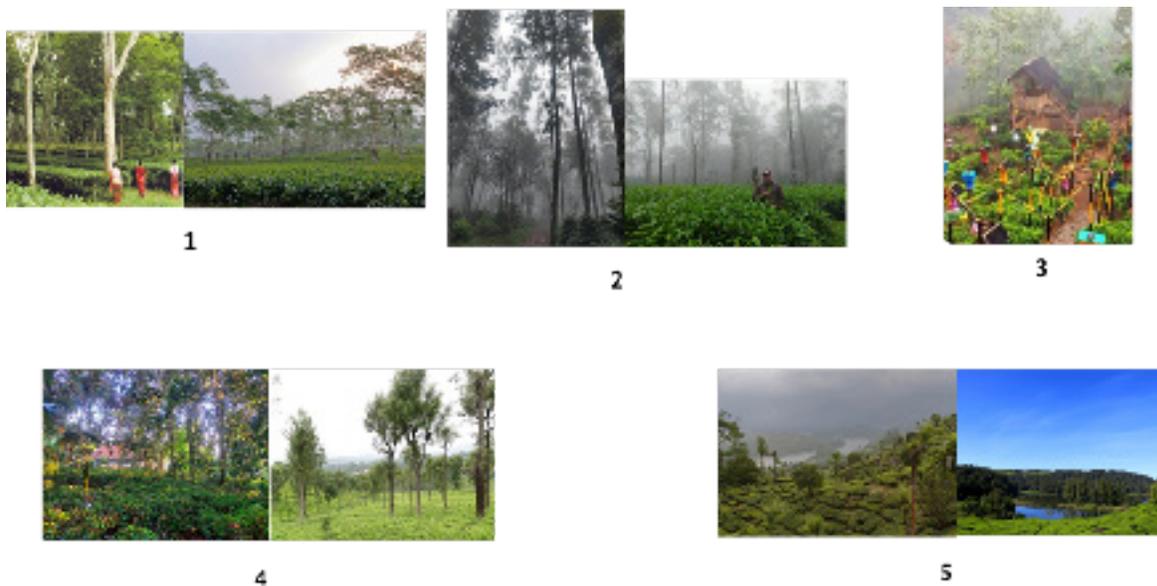


Figure 4: Tea agroforestry model in Indonesia tea smallholder: 1) Alley cropping; 2) Forest farming – social forestry; 3) Silvopasture; 4) Windbreaks; 5) Riparian forests buffers in tourism spot

productivity and quality. This contribution aligned with SDG 9 and SDG 12. Tea intercropping and tea agroforestry bridge SDG 9 and SDG 12 by creating sustainable agricultural systems that are innovative, resilient, and resource-efficient/ low input. These practices encourage responsible production while supporting industrial and infrastructural advancements in the tea sector. It needs support for finance and input access, technical training, and innovation. Responsible tea production means strengthening tea smallholders' market demand by increasing the purchase of sustainable tea, promoting consumer awareness lifestyle, and responsible consumption of tea products (certified tea products).

The contribution of tea intercropping/ agroforestry systems to nature conservation is aligned with SDG 6 by reducing soil erosion and improving water retention, protecting local water resources, SDG 7 by providing biomass and promoting the use of sustainable biomass energy as a circular economy, SDG 13 by providing sequester carbon and reduce GHG emissions and reducing reliance on synthetic fertilizers, SDG 15 by enhancing biodiversity, restore degraded lands and improve soil health. All this synergy accelerates progress toward achieving sustainability in tea production while advancing broader global development goals, as is shown in Figure 4. below.

Below is an explanation of the relationship of tea intercropping and tea agroforestry systems with impact and benefit in the context of sustainable tea production:



Figure 5: Sustainable tea production (Source: Adopted from Sita et al., 2023)

The Challenges of Intercropping and Agroforestry in Tea Smallholder Plantations

The challenges of intercropping and agroforestry in tea smallholder plantations are multifaceted, involving agronomic, socio-economic, and policy-related factors. While these practices offer numerous benefits, their adoption and long-term success face several hurdles. Below is a detailed description of the challenges of intercropping and agroforestry in Indonesian tea smallholder plantations.

Table 1: The impact and benefit of tea intercropping and tea agroforestry systems

The impact/benefit	Key aspects/indicator
Social security	Manage the labor shortage on tea and improve labor relations and jobs. Reduce migration from rural to urban. Enlarge the social networking and teamwork between tea farmers to technology, products, and markets. Help and educate the poor tea farmers/ households on intercropping and agroforestry technology. Increase social awareness of the tea supply chain and value chain. Stimulate cultural activities
Economic benefit	Increase productivity, quality, and diversified yield Improve the income by additional income/ diversify sources of income Input efficiency/ Low-input, i.e., land, fertilizer, pesticide, herbicide, etc. Optimize the use of all available resources Increase food security of tea farmers and its community Increase livelihood and well-being of tea smallholders
Ecology sustainability	Climate change mitigation – enhance carbon sequestration. Increased biodiversity and conservation. Improve soil health and water availability and quality. Manage the balancing pes and disease bio-control Soil erosion control. Protection from wind/frost.
Politics and governance enforcement	Enhance the support economic incentives system. Increase the opportunity, knowledge, and skills of farmers. Strengthen the role and capacity of farmers and its supply chain institutional. Build an integrated/synergy ecosystem structural/ sectoral partnership. Strengthen the control and supervision of the functions

Sources: Jose (2009); Kumar, et al. (2011); Beillouin, et al., (2019); Timsina (2018); Nair (2007); Ruben and Heras (2013)



Table 2: The challenges of intercropping and agroforestry in Indonesia's tea smallholder plantation

Aspect	Key indicator
Man	<ul style="list-style-type: none"> The knowledge and skills capacity of tea intercropping/ agroforestry The farmer institutional coordination under agriculture or forestry ministry management Labor management from outside the area
Machine and Technology	<ul style="list-style-type: none"> Not all tea plants in intercropping or agroforestry are suitable for large machines for maintenance or harvesting Technology carbon stock and sequestration in intercropping/ agroforestry Technology GAP of tea in agroforestry
Method	<ul style="list-style-type: none"> Traceability system for the tea supply chain from intercropping agroforestry Machine learning to map the tea area, population, variety/clones that are suitable for intercropping and agroforestry
Material	<ul style="list-style-type: none"> The consistency of quality of green/tea leaf Transportation to input factors or the tea leaf from location/garden to collection point and vice versa The availability of tea seed/clone, especially for the forestry community
Money and economy	<ul style="list-style-type: none"> The competitive wage of labor between crop Allocation for production input expenses will increase if farmers don't innovate by producing their inputs such as bio-fertilizers/pesticides. Reduce the yield and the profit if the tea and other trees/crops doesn't grow better if it planted together. Enlarge income sources not only from the crops but also from the ecosystem (agrotourism – ecotourism) Access to credit/ finance
Image	<ul style="list-style-type: none"> Increase sustainability potential from the pressure of deforestation of other crops - WTP. Increase biodiversity and conservation management in intercropping and agroforestry.
Policy and regulation	<ul style="list-style-type: none"> Land protection and land tenure regulation Support of guidelines regulating practices for tea in intercropping/agroforestry (GAP, GHP, GMP, etc.). Partnership Development system for tea agroforestry utilization (fuelwood, tourism for tea dev.)
Social	<ul style="list-style-type: none"> The tea cultural value in intercropping/agroforestry than monoculture The management of labor (including gender roles) when planting or harvesting time. The farmer's institutional role re-enforcement in cultivation, marketing, and business, and financial access
Market	<ul style="list-style-type: none"> Low prices of tea/green leaf Lack of market information Standard and certification for product export Product diversification for value-added product
Environment	<ul style="list-style-type: none"> The dynamic of new pests or diseases in tea plants from other crops The micro effect from unsuitable crops Biodiversity management Payment of ecosystem services from intercropping and agroforestry

The Policy and Management Support for Intercropping and Agroforestry Tea Farming System

To support intercropping and agroforestry systems in tea farming in Indonesia needs the policy and management support ecosystem. It is crucial for promoting sustainable agriculture, improving tea farmers' livelihoods, and ensuring the long-term viability of tea production from tea smallholder plantations. Xie *et al.* (2022) research highlights the importance of strengthening policy support, technical assistance, and social network development to enhance the dissemination of ecological agricultural technology. Indonesia as one of the seventh largest tea producers in the world, faces increasing pressure to adopt more sustainable farming practices. Intercropping and agroforestry provide viable solutions to improve productivity while maintaining environmental health. However, effective policies and management strategies are necessary to support these systems. Below is a detailed explanation of the policy and management support needs for intercropping and agroforestry in Indonesian tea farming systems.

- Improve the tea smallholders and their institutional (farmers groups) capacity on tea intercropping/ agroforestry system

through field school or technical guidance, especially GAP and GHP, production bio-input by themselves, and tea harvesting. These programs are annually implemented by relevant agencies for both plantation and forestry collaborate with R&D institutions and universities also NGOs, although still on a small scale and still needs to be greatly improved. Lessons learned in Kenya (Mitei, 2012) highlight the capacity-building efforts established through the partnership between Lipton Tea and KTDA. This collaboration provides an excellent example of how a Farmer Field School (FFS) approach to extension has laid the foundation for a large-scale implementation of more sustainable production practices across rural Kenya.

- Increase the tea population with high-quality/high-yield tea clones. The tea population in tea smallholder plantations is mostly under 70%, and nearly 50% of the tea is immature and damaged. Moreover, Indonesian tea plantations, including tea smallholder plantations, are currently facing the impacts of climate change, especially drought, so drought-resistant seed technology is greatly needed.
- Improve the access and incentives for input factors. The production costs of tea plantations have been increasing

year by year. In contrast, tea prices (including green leaves) remain relatively stable, making it difficult for many farmers to maintain their plantations optimally. The subsidy for fertilizer, the availability of low-input technologies, and incentives for tea plantations is essential to maintain the existence of smallholder tea plantations from conversion. Intercropping and agroforestry practices in tea can serve and support strategies to achieve a more balanced allocation of inputs for tea plants.

- Facilitate the good traceability or certification of tea, including their partner ecosystem. Consumers are increasingly aware of the quality, healthiness, transparency, and traceability of the products they consume. Strengthening certifications for plantations, such as Lestari, Organic, GAP, etc., is crucial to maintaining a fair and responsible tea supply chain from tea smallholders.
- Develop the tea market information system. The lack of information about tea prices has limited farmers' bargaining position. Policy support can ensure that tea farmers have access to accurate, timely, and consistent market information. This can help reduce market distortions, improve price discovery, and increase tea farmers' bargaining power in the digitalization era; a developing and promoting digital platforms can make the system more effective and efficient.
- Facilitate the access of investment or financial/ credit. There are Kredit Usaha Rakyat or People's Business Credit (KUR-BRI) schemes implemented to support smallholders by offering low-interest loans to help improve production, productivity, and sustainability. Facilitating access to investment or credit is critical for enabling tea smallholders in Indonesia to adopt intercropping and agroforestry practices. These systems offer multiple benefits, such as increased productivity, income diversification, environmental sustainability, and better market access. However, the high initial costs and long-term payback periods of these systems require financial support. By providing specialized financial products, improving access to loans, and offering training and insurance, the government and financial institutions can empower smallholders to make the transition to more sustainable and profitable farming practices. This will not only enhance the livelihoods of smallholder farmers but also contribute to the long-term sustainability of Indonesia's tea industry.
- Develop the value added of tea products and their ecosystem in agroforestry/intercropping systems. There are several programs to support the added value of tea smallholder green leaves and tea products, such as certification, tea processing machines in the home industry/small scale, and tea diversification products. However, the tea farmer target of the program is still not widespread and evenly distributed. Developing value-added tea products and leveraging the ecosystem benefits of agroforestry and intercropping is crucial for the long-term success and sustainability of tea farming. By adding value to tea products and diversifying income sources, smallholder farmers can increase profitability, reduce risks, and enhance environmental sustainability. However, this requires robust policy and management support, including research and development, financial incentives, market access, and infrastructure development. With the right support, tea farmers can harness the full potential of agroforestry and intercropping systems, contributing to the sustainable growth of the tea industry while improving the livelihoods of

smallholder farmers.

- Promoting the sustainable production of tea intercropping/ agroforestry as well as the compensation for its ecosystem services. Tea farmers adopting sustainable practices provide significant public benefits through ecosystem services, such as cleaner air, water conservation, biodiversity preservation, and cultural and recreational services. However, they often bear the costs of transitioning to and maintaining these systems without direct financial returns. Compensation mechanisms can address this imbalance by incentivizing and sustaining sustainable practices, one example is through the PES scheme. Payment for Ecosystem Services (PES) can be direct payment (replanting/ rehabilitation program), premium price for tea labeled as "sustainably grown," input subsidies (seedling, fertilizer, etc.), carbon credits, trust fund, community-based PES (such as: payment for a group of tea farmers who collectively manages a watershed or reforestation).

CONCLUSION AND RECOMMENDATION

Economic pressures, environmental degradation, and the impacts of climate change increasingly challenge the resilience of Indonesian tea smallholder plantations. Intercropping and agroforestry systems present viable solutions to these challenges, offering both environmental and socio-economic benefits. The tea intercropping and agroforestry systems involve the cultivation of vegetables, fruits, spices, and timber plants in various patterns. These farming systems enhance biodiversity, improve soil fertility, conserve water, and mitigate climate risks while simultaneously diversifying farmers' income sources. These systems have the potential to offer a more sustainable and inclusive smallholder tea agribusiness ecosystem. Moreover, they align with global sustainability goals, such as the SDGs, contributing to sustainable agriculture and rural development. However, their adoption remains limited due to barriers such as inadequate access to resources, market information, and policy support.

The challenges, which may also form part of future resilience strategies, include increasing productivity, quality, and the capacity of farmers and tea pickers, as well as the market competitiveness of smallholder tea through the enhancement of the value-added of their tea products. Key findings underscore the importance of: 1) Promoting intercropping and agroforestry practices as strategies for climate resilience and sustainable tea production by implementing an eco-friendly tea farming system (ETFS); 2) Establishing an enabling environment through policy incentives, financial support, and capacity-building programs; and 3) Recognizing the ecosystem services provided by sustainable tea farming and compensating farmers through mechanisms such as Payment for Ecosystem Services (PES).

Several recommendations can be considered, i.e., 1) Develop policy to support the tea smallholder ecosystem in adopting these systems; 2) Conduct capacity building and knowledge sharing program (lesson learned and best management practices); 3) Expand financial access and incentives for tea smallholders who implementing sustainable practices; 4) Develop and strengthen the market of tea farmers product; 5) Invest in R&D to develop the innovative technology which can adapt and mitigate the climate change impact, improve the tea productivity and optimize land use in intercropping or agroforestry systems; 6) Create the systems to monitor and evaluate the impacts or the successful models of intercropping or agroforestry tea farming systems. By addressing these recommendations, stakeholders can empower Indonesian tea



smallholders to transition toward resilient and sustainable farming systems, ensuring the long-term viability of the tea sector while contributing to environmental conservation and rural livelihoods.

CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

ETHICAL REVIEW

This article does not contain any studies with human participants or animals performed by any of the authors

REFERENCES

- Altieri, M. A. (2018). *Agroecology: The Science of Sustainable Agriculture*. CRC Press.
- Barrios, E., Valencia, V., Jonsson, M., Brauman, A., Hairiah, K., Mortimer, P. E., & Okubo, S. (2018). Contribution of trees to the conservation of biodiversity and ecosystem services in agricultural landscapes. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 14(1), 1-16.
- Beillouin, D., Ben-Ari, T., & Makowski, D. (2019). A dataset of meta-analyses on crop diversification at the global scale. *Data in Brief*, 26, 104484.
- Dev, I., Ram, A., Bhaskar, S., & Chaturvedi, O. P. (2019). Role of Agroforestry in the current scenario. *Agroforestry in Climate Resilience and Rural Livelihood*; Dev, I., Ram, A., Kumar, N., Singh, R., Uthappa, AR, Handa, AK, Eds, 1-10.
- Dou, Y., Li, Y., Li, M., Chen, X., & Zhao, X. (2023). The role of agroforestry in poverty alleviation: a case study from nujiang prefecture, southwestern china. *Sustainability*, 15(15), 12090.
- Glaze-Corcoran, S., Hashemi, M., Sadeghpour, A., Jahanzad, E., Afshar, R. K., Liu, X., & Herbert, S. J. (2020). Understanding intercropping to improve agricultural resiliency and environmental sustainability. *Advances in agronomy*, 162, 199-256.
- Hicks, C., Woroniecki, S., Fancourt, M., et al. (2020). Harnessing social-ecological resilience for sustainability transitions. *Nature Sustainability*, 3(3), 189-199.
- Jose, S. (2009). *Agroforestry for ecosystem services and environmental benefits: An overview*. *Agroforestry Systems*, 76(1), 1-10.
- Kumar, B. M., & Nair, P. K. R. (2011). *Agroforestry systems and environmental quality: economic perspectives*. *Advances in Agronomy*, 110, 47-86.
- Le, V. S., Lesueur, D., Herrmann, L., Hudek, L., Quyen, L. N., & Brau, L. (2021). Sustainable tea production through agroecological management practices in Vietnam: a review. *Environmental Sustainability*, 4(4), 589-604.
- Lulie, B. (2017). Intercropping practice as an alternative pathway for sustainable agriculture: A review. *Academic Research Journal of Agricultural Science and Research*, 5(6), 440-452.
- Maitra, S., & Gitari, H. (2020). Scope for adoption of intercropping system in organic agriculture. *Indian J. Nat. Sci*, 11(63), 28624-28631.
- Martin-Guay, M. O., Paquette, A., Dupras, J., & Rivest, D. (2018). The new green revolution: sustainable intensification of agriculture by intercropping. *Science of the total environment*, 615, 767-772.
- Miller, W.G., (1960). Farm Tenure Perspective of Vertical Integration. *Journal of Farm Economics*, 42(2), pp.307-316.
- Mir, M. S., Saxena, A., Kanth, R. H., Raja, W., Dar, K. A., Mahdi, S. S., ... & Mir, S. A. (2022). Role of intercropping in sustainable insect-pest management: a review. *International Journal of Environment and Climate Change*, 12(11), 3390-3403.
- Mitei, Z. (2012). Growing sustainable tea on Kenyan smallholder farms. In *Sustainable Intensification* (pp. 59-66). Routledge.
- Nair, P. K. R. (1993). *An Introduction to Agroforestry*. Kluwer Academic Publishers.
- Nair, P. K. R. (2007). The role of trees in sustainable agriculture: An agroforestry perspective. *Agricultural Systems*, 69(1-2), 3-15.
- Nair, P. K. R. (2014). *Agroforestry Systems in the Tropics*. Springer.
- Pusat Penelitian Teh dan Kina (PPTK). 2022. Naskah Akademis Specialty Tea. PPTK. Bandung. *Limited published*.
- Ruben, R., & Heras, M. (2013). The impact of eco-certification on the market and livelihoods of smallholders: Evidence from the tea sector in Sri Lanka. *Journal of Agricultural Economics*
- Sarvade, S., & Singh, R. (2014). Role of agroforestry in food security. *Popular Kheti*, 2(2), 25-29.
- Sileshi, G., Debusho, L. K., & Akinnifesi, F. K. (2007). Stability of yield benefits of maize–gliricidia intercropping system in Malawi. *Agricultural Systems*, 94(2), 282-291.
- Sita, K., & Aji, T. M. (2017, August). THE PROSPECTS AND THE CHALLENGES OF ORGANIC TEA FARMING DEVELOPMENT IN INDONESIA. In *Proceeding of International Seminar of Organic Agriculture in the Tropics (OrgaTrop)*.
- Sita, K., Gunadi, R., Aji, Anggita, S., Aji, T.M. 2023. Overview of Tea Industry and Sustainable Tea Value Chain of Indonesia. *Journal of Guangxi Vocational and Technical Collage* 17 (4): 67-74
- Timsina, J. (2018). *Can agriculture be sustainable? The role of integrated farming systems*. *Agriculture & Food Security*, 7(1), 14.
- Toppo, P., & Raj, A. (2018). Role of agroforestry in climate change mitigation. *Journal of Pharmacognosy and Phytochemistry*, 7(2), 241-243.
- USDA National Agroforestry Center: <https://www.fs.usda.gov/nac/>
- Van Noordwijk, M., Hoang, M. H., Neufeldt, H., et al. (2019). Agroforestry solutions for buffering climate variability and adapting to change. *Frontiers in Environmental Science*, 7, 12.
- Vandermeer, J. (1989). *The Ecology of Intercropping*. Cambridge University Press.
- Xie, K., Zhu, Y., Ma, Y., Chen, Y., Chen, S., & Chen, Z. (2022). Willingness of tea farmers to adopt ecological agriculture techniques based on the UTAUT Extended Model. *International Journal of Environmental Research and Public Health*, 19(22), 15351.