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RESEARCH ARTICLE

EXPLORING THE RELATIVE ADVANTAGES OF LOCAL INNOVATION IN AGROFORESTRY

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KEYWORDS

agroforestry, forest farmers, local innovation, relative advantage, social forestry

HIGHLIGHTS

- Promotion of local sustainable innovation developed by forest farmers.
- Focusing on bending of branches to increase coffee production in a pine-based agroforestry system.
- Using a combination of concepts of perceived characteristics of innovation.
- Techno-social, economic and ecological benefits are the key features.
- Local techniques may be prospective for developing sustainable agroforestry innovation.

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GRAPHICAL ABSTRACT

ABSTRACT

Adopting community-based innovations in agroforestry is key to enhancing livelihoods in forest farmer communities. This research aimed to explore the perceived advantages of the forest farmer technique of coffee branch bending to overcome the light limitations under the shade of a pine forest. The concepts of perceived characteristics of innovation were used to explore the advantages of this technique. Using a case study of an exclusive forest farmer clique in UB (University of Brawijaya) Forest in Indonesia, it was found that the local technique had high perceived relative advantages. Compared to the others, the bending technique increases coffee production and is easy to do. It was also found to be superior to reducing production costs and is perceived as more environmentally friendly, promoting it as a valuable sustainable practice. Technical experts need to validate it and may embrace it as a co-innovation for the available external agroforestry recommendations. Its adaptability to the local socio-ecological context and techno-economical constraints makes it a prospective innovation to be extended through social forestry programs.

1 INTRODUCTION

Decentralization of power in the form of autonomy of authority has encouraged community-based forest development schemes. In practice, Indonesia implements this through a scheme of Community Forest Management. In this scheme, communities around the forest are allowed (under contract) to participate, among other things, by planting them with productive crops other than the existing main crops. This is a response to the prolonged conflict over forest resources in the past. In principle, forest resources must be managed optimally and proportionally for mutual benefits. The long

experience of forest farmers in cultivating forest land has the potential to give rise to local innovations. It is in this context of greater freedom of expression that the question arises of whether the creation of these innovative techniques meets their specific needs. Thus, our study aimed to explore the perceived relative advantage of coffee branch bending under the shade of pine forest in UB (University of Brawijaya) Forest, a production and educational forest in East Java Province, Indonesia.

Coffee is an important crop for many forest smallholders in Java[1]. Coffee is also an alternative for agroforestry because apart from source of livelihood, it is also considered a conservation crop. However, in the research area, the cultivation of coffee in the pine forest poses a dilemma due to low coffee productivity. This is because the dense pine canopy reduces the light intensity under the stands. Therefore, it is compelling to examine how it can be managed to achieve adequate production. We observed that progressive forest farmers practiced a special technique; bending the coffee branches to overcome the limited sunlight. This innovative technique is unique and seems to have been overlooked by outsiders. This is useful because of the assumption that local innovations are essential for overall innovation development[2,3].

Previous research has been criticized as tending to emphasize the power of external technological solutions or the use of a top-down approach (e.g., innovations recommended by experts)[4,5]. A locally-based innovation policy is crucial because of barriers to the diffusion of agroforestry innovations[6]. However, studies on local innovations generally do not use relative advantage as the main concept to assess the benefits. This is despite a subjective advantage being a determinant of innovation adoption behavior[7–9]. Therefore, to fill the gaps, it is vital to explore the relative advantages of local agroforestry over external or other innovations, as seen by the forest farmers themselves.

Local innovation, like innovation in general, is the creation and improvement of creative and effective processes or ways of doing something new compared to existing practices. However, this takes place in a local context and predominantly involves the initiative of local people, communities and resources rather than externally. While the locals may not be considered innovative in other areas, these local innovations aim to take advantage of opportunities and/or address relevant local problems or specific or everyday settings, including in the case of marginalized communities[10–12]. Thus, the coffee branch bending technique is a local innovation because it was initiated by several forest farmers by utilizing local knowledge and resources to overcome the problem of low coffee productivity due to pine overshadowing.

Relative advantage is a complex concept. Definitively, the relative advantage is defined as "the degree to which an innovation is perceived as being better than the idea it supersedes"[13]. This shows its superiority compared to previous or other products or services. The concept is based on the subjective perception of users rather than objective criteria. However, this concept is useful to explain why some individuals like or are loyal to innovation in comparison to their competitors (e.g., external practices). In principle, the greater the relative advantage of an innovation, the greater the chance of being used by potential adopters. In contrast, the chances of using an innovation are smaller, when the personal advantages are perceived as low. Already used in various fields such as agricomplex, this concept is rarely used to assess local agroforestry innovations.

Specifically, one indicator of the relative advantages of innovation is the ability to increase production[14,15]. A study shows that profit is a major factor in the decision to innovate for individuals[16], for long-term use, and the key to farmer welfare[17]. Another indicator is financial gain, such as increased revenue, reduced costs and minimized risk[15,18]. Technical factors also determine the decision to use innovation; these include ease of operation (lack of complexity), use on a limited scale (trialability) and observability[10,13]. Other types of benefits have also recently been promoted, namely improved environmental quality and long-term benefits[19]. Local innovations are often developed by indigenous or traditional communities, which generally consider the locality as a vital factor. Thus, the term profit is not only about economic (and technical), but also ecological (and social) benefits.

The advantages of local innovations for development tend to be largely unrecognized. One study showed that information about the provision of ecosystem services in agroforestry systems is relatively abundant, but there are not very many studies on management decisions or practices, and factors that affect forest farmer coffee plantations[20]. Overlooked by policymakers and experts, for years, forest farmers in Java have practiced innovative ways to meet their needs. While the new scheme of social forestry provides an opportunity for the legality of their actions. The success of technical interventions for agroforestry increases when integrating local knowledge/practices and scientific information[20]. Thus, this study aims to contribute to the body of knowledge because it reveals the

superiority of local innovations over other or external innovations.

Meanwhile, technical experts are conducting some experimental agronomic research at the research site to support sustainable practices of the coffee-pine agroforestry; this includes pruning the pine canopy, pilot coffee pruning and fertilizer management linked to socioeconomic and environmental development models[21]. Yet, forest farmers are often unsure of external innovations because of the low sensitivity of relative advantages. An example of this is the recommendation to prune pine branches to increase coffee performance under the shade of pine canopy. Though enhance productivity and ecosystem benefits, this is perceived as difficult, costly, time wasting and risky (they need to climb at a height of up to 12 m to cut the pine branches by hand). This may be acceptable, but requires subsidies to purchase trimmers to speed up work and reduce work risks[6,22]. This is consistent with the conclusion of a longitudinal review that the disadoption of external innovations can be caused by various unanticipated factors[23].

The goal of social forestry is to strengthen the authority of local communities. However, externally initiated forest conservation programs can disempower local institutions, and harm, or alienate the poorest local communities; a situation that deserves attention from policymakers[24,25]. Also, forest farmers often ignore innovations recommended by experts[23]. In fact, they may possess their own resources, that are suitable for local socioeconomic and agroecology. By featuring the local community as innovative actors of development, the adoption of agroforestry innovation may be easier[26–29] and may reduce the burden of external development agents to transfer innovation[30]. In addition, considering the vision of the UN Sustainable Development Goals: "leave no one behind", it promotes smallholders as the key innovators, or as co-creators of agroforestry development. Overall, our research can pave the way for mainstreaming or integrating local potential into the management and diffusion of agroforestry innovation in forest communities.

2 RESEARCH METHODS

2.1 Research approach

Qualitative research was used to determine behavior or processes related to personal beliefs or motives in an environment[31]. Meanwhile, an interpretive approach was proposed because it respects individual views and variation between individuals in understanding an issue[32]. Pizam and Mansfeld[33] emphasized the subjectivity in seeing a reality (perceived relative advantage of coffee branch bending), which was constructed by research participants with the help of researchers. In other words, interpretivism allows personal interpretations to construct and understand a reality meaningfully. We explore their specific ways of thinking, voices and practices for confronting local issues. Specifically, we used a case study method to explore in-depth and contextually, cooperating with relevant information sources without manipulating their behavior. Such a study does not intend to generalize the findings, but rather to reveal the inner mind of the research participants under influence of the values of the researcher[34–36].

2.2 Research area and participants

Covering 554 ha, the research area was located on the slopes of the Arjuno Mountains (1200–1900 m elevation) in Malang Regency, East Java. Currently, the forest in the research area is managed by UB Forest as an educational forest, which was previously managed by Perhutani (a state-owned enterprise that manages production forests). Our research participants lived in Sumbersari Hamlet, one of the main settlements, located in Tawang Argo Village (777 m elevation), Karangploso. The location was accessible, though slightly remote. The research participants were some forest farmers who worked under contract with forest management (known as *magersari* in the Indonesian language). They were allowed to cultivate between the stands (e.g., pine and mahogany); it is a form of plantation-crop combination[30]. Farmers in these communities (which have lived in this location for generations) often grow coffee and other food crops and horticulture, intercropped with the pine trees.

The selection of research participants was targeted, including participants that had the specific knowledge and experience[37] of the coffee branch bending technique. The primary source of information was a forest farmer with long experience with bending techniques. Next, the snowball method was employed to find two other forest farmers who also practiced or had practiced the technique. We relied on them as the main information sources because of their long experience with branch bending and their persistent use of this technique. Data collection was continued until it had reached saturation point (no longer providing additional information). In addition to the participants from whom data was collected, there were two other practitioners of the technique who lived outside the village. Due to a dispute over land sharing for forest management, they eventually resigned and their position

became unknown. During focus group discussions (FGDs) it was revealed that some forest farmers, did not actually practice the target technology for reasons such as skepticism or choosing to grow vegetables or other crops.

The description of each research participant is as follows. The first research participant was Mr. G, considered an innovator, or a progressive forest farmer aged 55, with a high school education level. His education was higher than his peers who generally only graduated from elementary school. His late father was a former foreman with Perhutani. This may explain why he had the courage to recently innovate with several types of agroforestry. He was our main information source because we had interacted for a long time and he has used variants of the bending technique. He was also active in local social organizations (e.g., forest farmer groups), is relatively cosmopolitan (open or exposed to external ideas) and had had experience in coffee cultivating, traditional processes and trading.

The second participant was Mr. F, the inventor of coffee branch bending. He was a senior forest farmer aged 59. Although only graduated from elementary school, he was the inventor of the target technique. It was from him that the knowledge of this technique was first shared with Mr. G and followed by another forest farmer, namely Mr. S (the third research participant). He was considered the early adopter of branch bending and applied the technique throughout his coffee-pine farm, which was located in a relatively remote forest area. Aged 50 and graduated from middle school, he can be classified also as a progressive forest farmer because of his relatively broad relationship with outsiders and commercial orientation.

2.3 Data collection

A combination of data collection techniques was applied for this study. We employed in-depth interviews to each research participant to explore technical procedures of bending techniques and the perceived advantages. Also, FGDs were held with the three key research participants to get a more complete picture of the case being studied. In addition, another FGD was also held, involving 10 other forest farmers to get response on the bending technique and get an overview of other local agroforestry issues.

The guided questions were: “What is coffee bending and how is it done?” “How is this method started and why is it done?” “What are the advantages?” “How much is the production cost of bending technique?” “How much is the production?” and “How does the process and production compare with the unbending?”. Other questions flowed freely during the interview because the process was flexible. For the purposes of data triangulation, field observations were also made at several sites. This was to obtain an appreciation of the bending technique on site.

This research was conducted at the beginning of 2022, in the early stage of the COVID-19 pandemic. Consequently, data collection was more difficult because of the social distancing policy, while health protocols were implemented. Complementary data collection via mobile phones was also undertaken, although the local communication network was sometimes unstable. Data verification was done by revisiting the study participants twice, after the pandemic had subsided in early April 2022.

2.4 Data analysis

Data analysis and interpretation were performed by opening a dialog room with the participants and the research team. This was useful to reveal the perceptions and practices of using bending techniques by forest farmers individually and collectively. These were done out with the following steps[34]: (1) preparation of interview transcripts (interview results were recorded and transcribed to be examined intensively), (2) review and discussions by the researchers to confirm data validity, (3) encoding and categorization of the data in themes, (4) comparison of the findings with former research and concepts, (5) presentation the data analysis, completed with figure and tables, and (6) objective discussion and reflection on the findings for interpretation and application.

To validate, we triangulated the data[34] using: (1) different information sources (bending users, the non-users), (2) different techniques (personal interviews, FGDs, field observations), and (3) member checking (asking for confirmation from research participants). To confirm data reliability, we checked errors in the transcripts to avoid ambiguous meanings and shared the findings with the research team and other experts.

The findings were structured, starting with information on coffee-pine cultivation and experience with coffee branch bending. It was followed by an analysis of perceptions of the relative advantage of the coffee branch bending. Afterwards, discussions on the findings were administered, involving combining, recapitulating and comparing the findings with

previous research, theories and concepts while reflecting on the case under study. Based on this our approach to reporting the implications and applications for the bending practices was decided.

3 RESULTS

Before the transfer of management, the forest in the study area was supervised by Perhutani. In 1995, three innovative forest farmers have planted coffee trees among the pine trees, with first harvests of the coffee two years after planting. By law, prior to the 2000s reform era, forest management prohibited individuals from growing any crops under pine stands. As time passed, the local community planted various types of crops without approval. Experience showed that only several types of plants were suitable for local conditions, including coffee. This plant was currently one of the existing pine-based agroforestry practices (Fig. 1). Entering the fifth year (1999), coinciding with the euphoria of political reform in Indonesia, people felt free to control some areas of state forest lands. They started experimenting with coffee cultivation (2001), and the coffee branch bending was invented (2005). Some years after the reform, in 2006, members of communities were allowed to cultivate crops after a prolonged conflict over the use of state forest lands. Since the end of 2016, forest management had been delegated to UB Forest, and promoted as an educational forest (Fig. 1).

Farmer learning experiences occurred over a relatively long period of time. This case was specific because the dense pine canopy (c. 70% density) reduces significantly the penetration of sunlight under the stands. By comparison, the usual practice of agroforestry cultivation was with medium pine cover (50%) to get adequate sunlight. The practice of coffee branch bending by some forest farmers was intended to increase coffee production under the shade. In practice, this technique loosened the space between coffee branches so that the light received by the branches was more intense (evenly distributed). There were three forest farmers in the research location (Sumberwangi) who routinely used the bending technique. Cultivation of coffee with the branch bending technique involved: (1) planting coffee next to pine trees; (2) spacing between coffee and pine to avoid excessive competition, usually with coffee plants on a 6 m × 6 m grid; and (3) bending coffee branches in all directions.

Fig. 1 Coffee-pine agroforestry cultivation system in UB Forest (a) and the researcher observed the coffee growth under pine trees (b).

The main indicators derived from the concept of relative advantage were production and quality; costs, revenue and income stability; implementation; and perceived environmental impacts. The following were findings on the perceived relative advantages of coffee branch bending.

3.1 Production and quality

Initially, the research participants planted coffee without bending treatment. Over time, they were inspired to bend some of the plants. Mr. F told about his experience,

> In the first year the production was still the same, one and a half ounces each. The fourth year, [each] reaches two to a quarter of a kilogram. Until that time the plant was still not bent. At that time the plant was still not bent. In the fifth year, I started to try [the bending technique]. But in this year ... until the ninth year [some of the plants] were dismantled [by forest management].

In the interview, the forest farmer explained that it took quite a long time (that is, entering his fifth year) before practicing the bending technique. This is practiced after scrutinizing the unsatisfactory growth of coffee plants. Even then, it was a struggle because initially there was a ban on planting anything other than the main crops operated by forest management. Shortly, through a local experiment and careful observation, forest farmers came to the belief that coffee production with bending is higher than the normal technique without bending. This claim was confirmed by others, during a focus group discussion. He expressed the difference in the results of the two treatments and the social constraints he had to face,

> In the fifth, my experience with bending, the production is more than seven kilograms. Without bending, the maximum is only three and a half kilograms per tree. Sometimes, with

no bending, production even decreases, although it rises again. In addition, three and a half kilograms is the maximum due to the small number of branches. The production is only in certain places [branches], and cannot be in other places, because the branches have been cut. This is in contrast to bending, where bent or broken branches can still produce coffee cherries.

It was claimed that in addition to more overflow production, coffee branch bending caused unexpected positive impacts on the workers and the surrounding area. In an in-depth interview, Mr. F, the inventor, emphasized, "[coffee cultivation] with bending technique, lots of fruit ... good ... now the shade is lush ... the dry season continues to thrive."

3.2 Cost, revenue and income stability

The production cost of the bending technique was relatively low, which was only for maintenance as needed, as claimed by the research participants. The needs for fertilizer for any coffee cultivation depends on the age of the coffee. Manure was applied two or three times annually, depending on the age of the plant. Meanwhile, mineral fertilizers are not required for bending; mulch is believed to replace mineral fertilizers. Mr. G claimed that the bending technique could reduce weeding from twice to only once and negate mineral fertilizers. With regards to trimming, there is a need for additional mineral fertilizers (three times per year), namely after pruning (for the first and second years).The requirement for seedlings is 1650 seedlings per ha. Usually forest farmers themselves sow coffee seeds, or look for seeds that grow under coffee trees. He underlined the benefits of bending and the time for the application,

No fertilization, no problem, just weeding. The bending [time] adjusts the shoot that is when it is appropriate to bend. Weeding only once in March, only as necessary, when [the coffee branch] is bent. Buying fertilizers is a constraint. So it is hard for them [forest farmers] to find loans (personal interview, Mr. G).

Through a local experiment, a forest farmer learned that bending coffee branches continuously increases coffee productivity. In 2003, when he began to learn, coffee production with bending was significantly higher; he experienced two and a half times higher with the new technique. He claimed that these results continued for years ahead, even when the coffee plants had aged.

In the fifth year, at that time I tried [bending]. But at that time ... there was until the ninth year it was dismantled [by forest management]. In the ninth year its production reached 15 kg. In unbending plants, production decreases, which is approximately 6 kg.

As a result, the financial benefits of the bending technique were more pronounced. At the time of the study, the price was decreasing, which was 4000 IDR·kg^{-1}. With coffee production of around 2800 kg, farmers earned a gross income of up to 11,200,000 IDR·ha^{-1}. For comparison, the estimated gross income with pruning is 6,720,000 IDR, and without any treatment is 4,480,000 IDR (about 15,000 IDR to 1 USD). The financial comparison of the three techniques is in the Table 1. As a note, the majority of forest farmers sold their harvest as whole fruit.

Research participants revealed that the bending technique helped forest farmers to obtain a more stable income compared to other techniques, such as pruning coffee branches or replanting. Although even with bending, these coffee plants only produced about 50% of the normal. This is because, as

Table 1 Comparison between coffee branch bending, pruning and without bending/pruning (FGD results with three research participants)

Revenue component	Bending	Pruning	Without bending/prunning
Seeds	1650[1]	1650[1]	1650[1]
Costs for treatment (IDR)	No costs[1]	2,310,000[2]	No costs[1]
Costs for weeding (IDR)	1,190,000[3]	2,310,000[2]	2,310,000[2]
Mineral fertilizers per year	No	3 times (year 1 and 2)	No
Manure per year	2–3 times	2–3 times	2–3 times
Yield estimation (kg)	2800	1680 (60% of bending)	1120 (40% of bending)
Minimum gross income (4000 IDR·kg^{-1})	11,200,000	6,720,000	4,480,000
Maximum gross income (8000 IDR·kg^{-1})	22,400,000	13,440,000	8,960,000

Note: [1]Done by themselves. [2]Equivalent to 33 working days (70,000 IDR·d^{-1}; 4 h·d^{-1}; about 15,000 IDR to 1 USD). [3]Equivalent to 17 working days.

they claimed, there is still food for the plant from the fallen branches. In contrast, plant rejuvenation was considered problematic because they had to wait for relatively a long time to produce. While the harvest interval when pruned was about 4 years. This was a critical time frame because they needed cash to support their families. They also grew medicinal plants (e.g., ginger), but the price was relatively low. Mr. G argued that branch bending not only kept his income stable but also produced 40% more than pruning. They sold coffee in various forms, commonly as whole fruit; or powder, with higher profits but with a consequence of more complicated processes. The market sector for coffee grounds was the modern coffee shops in the nearby city, Malang.

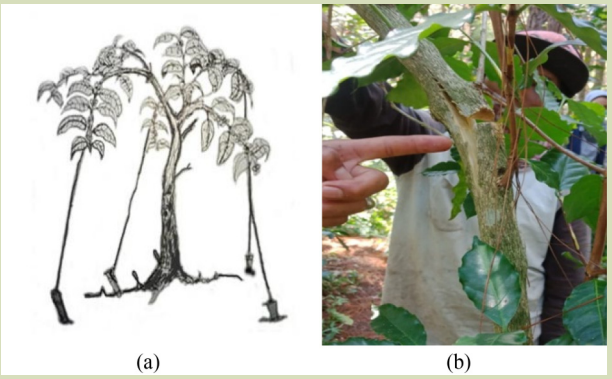

Fig. 2 Variations of coffee branch bending: arching the branches (a) and cracking the branches (b).

3.3 Implementation

Branch bending not only increased productivity and reduced costs but also made harvest easier. This practice (as detailed below) involves tying the tips of the branches with ropes pegged to the ground or cracking the branches, so the bent branches are closer to the ground facilitating picking of the coffee fruit. This was important for the recruitment of women for coffee picking due female worker being generally of lesser stature than males. Also, people did not need to travel from their village to buy fertilizers, as this was deemed to be unnecessary.

Meanwhile, Mr. F explained in an FGD, "I, myself, tried to bend it [the coffee branch]. It turns out that the coffee cherries are abundant, and the fruit is good. Picking the fruit is also easy ... less grass, easy harvesting method and energy saving. So everything that I have not trimmed I bend. Then, the grass is reduced ... saving [cost and energy]."

From the results of FGDs, in-depth interviews, and field observations, it was revealed that the bending technique, regardless of the variation, was seen as easy. We were informed that the practice of bending coffee branches varied: (1) Arching the branches: using ropes, they tied the ends of the branches of the coffee plant to a height of about 0.5 m above the ground. This was to loosen the space between the branches to overcome the limited light in the pine shade; (2) Cutting off part of the branches (not formally pruning completely, but rather breaking the branch). They simply broke the branches in a way that let them droop but still remain productive. In this second technique, after harvesting, the broken branches were cut completely (Fig. 2). The picture on the left is a bending technique by curving a coffee branch (the original sketch came from a forest farmer). The photo on the right shows the farmer cutting only part of the stem (cracking it) and then laying it down without using ropes. Immediately shoots grow around the injured part of the branch. This was different from the usual or recommended pruning technique, where the branches were cut off completely.

Also, commenting on efforts to obtain mineral fertilizers, Mr. G underlined,

> Actually, without using fertilizer there is no problem, because the weeding can be used as mulch. Trimming requires mineral fertilizers that is in the first and second year. Plants still need manure two to three times. This is so that when fruiting there will be no or reduced need for mineral fertilizers. Fertilization after trimming is usually done at the beginning of the rainy season. This is done in August to October, then there is another third fertilization in March.

Attempts to obtain mineral fertilizers are a serious issue. The remote location is an obstacle in itself because it requires extra energy, time and cost. Mr. S expresses these problems by saying: "Besides far to get it, fertilizer is also expensive."

3.4 Perceived environmental impacts

Forest farmers believed that coffee branch bending had a high level of recyclability for the following reasons:

(1) It produced more leaf fall, which was claimed to be useful as mulch. Mr. F argued, "more coffee leaves fall ... every year some fall and cover the weeds ... humidity is maintained ... there is no erosion; the environment is good." Thus, as claimed, the abundance of fallen leaves due to branch bending is not only a waste but also a recyclable multifunctional resource, which is degraded into mulch and at the same time inhibits weed growth.

(2) The bending technique was an integral part of the use of seeds that are adaptive to local conditions. It was believed that this technique was only appropriate for a local cultivar called Kopi Jawa (Java Coffee). They believed that the advantages are strong plants, many fibrous roots, fast growth and high production. This may be cultivar Linie S, part of the Arabica coffee group, which was suitable for cultivation in the highlands and surviving in the shade of pine trees. With the scarcity of seeds in the local area, they also felt the need to preserve seeds as a form of conservation. Mr. S emphasized, "This is related to the issues of [difficulty getting seeds for] trees, so [we] are not looking for seeds anymore ... we still need [existing] coffee varieties."

The bending procedures had long plant life and coffee harvest. Technically, the implementation of branch bending (arching or breaking coffee branches) encourages the growth of new shoots. Experience had taught forest farmers that shoots immediately appear in the area where the branches were broken or arched, with the broken branches still able to produce, albeit less than normal. It was only in the second year that the broken branches need to be cut so that the shoots can grow properly. One of the study participants explained bending, "This is so that the shoots can grow well…the baby [shoots] can grow. However, [this portion] is only capable of producing 50%." By comparison, when pruned or rejuvenated, they had to wait a few more years for production. Thus, branch bending led to more durable and intensive plant use.

One of the primary issues in coffee-pine agroforestry was the use of inputs. Mr. G emphasized that many forest farmers prefer to use manures (from chickens and/or goats) and mulch than mineral fertilizers because of financial reasons. Meanwhile, unlike pruning and rejuvenation, the coffee branch bending did not rely on large amounts of agrochemical inputs. It was enough to use manure as organic fertilizer, sometimes with a small number of mineral fertilizers; while plant maintenance was applied as necessary. Pruning, in contrast, required an adequate intake of mineral fertilizers for boosting shoot growth. In an in-depth interview with Mr. G clarified this issue, "When the plant is pruned, the roots need to be stimulated ... fertilized so that it grows quickly because the plant is stressed!"

Chicken manure was cheaper, but goat manure was considered more effective for coffee growth. Usually, forest farmers combined these manures to reduce costs. Usually, manures were applied two or three times annually with a minimum use of about 1 t·ha^{-1}. While, the application of mineral fertilizers was essential when pruning branches, particularly when roots begin to spread. Also, the forest farmer believed that the use of mineral fertilizers will need to increase to reduce leaf loss and maintain productivity levels. In the bending technique, however, there were no, or low-intensity mineral fertilizers used, giving a relatively limited environmental pollution.

In short, the coffee bending technique is perceived by the initiators as having more advantages over other techniques, such as without branch bending or pruning. Economically, the technique is more profitable (i.e., the yields are roughly 50% greater, more consistent and increase over time, with lower production costs). Other advantages are that the implementation of the production and harvesting process is easy (safe and convenient), as well as seen as ecologically sound.

4 DISCUSSION

The purpose of this study is to describe the relative advantages of coffee branch bending practice in UB Forest. Overall, the coffee branch bending (curving and cracking) technique has perceived relative advantages compared to the common coffee branch pruning or without bending. As agencies, progressive forest farmers have the capacity to shape their surrounding circumstances[38]. They invented and acknowledged the superiority of this technique; we have also observed it in the field for confirmation. Otherwise, they might have abandoned this technique from soon after initiation.

For techno-social benefits, coffee branch bending seems to be more worker-friendly, because of the practicality for the operation, maintenance and harvest. We observe that this gives an advantage to female workers who need comfort and safety at work[39]. The technique, for example, is simple, does not change much with common practice, and is much safer than pruning pine branches which requires a ladder to cut the branches[6]. Another study on a system of rice intensification, an agri-innovation introduced by the government, shows that farmers are reluctant to accept due to incompatible with existing practices while technically complicated[40]. This is also consistent with other recent studies that the simplicity of new agri-environmental technologies is central to innovation adoption[41,42].

Indeed, profit in terms of financial gains, especially increased revenue, reduced costs and minimum risk is a major factor in the decision to innovate for individuals[15,16,43]. This has the potential to increase forest farmer income and welfare. For

them, this factor is extremely critical given their apparently financial limitations[6]. Generally, coffee branch bending is also environmentally friendly as other agroforestry systems, giving an unexpected additional benefit. These would keep their finance available in the long-term while lowering external inputs[19,43].

Our findings are also consistent with the positive perceptions of an innovative conservation application, known as Agricultural Best Management practices; its benefits are time savings, reduced inputs, higher quality of agricultural land and the environment, and higher compatibility (with existing agricultural systems), while the impacts are observable[44]. In our research, the observability factor is the more abundant coffee fruit production and the perceived better environmental quality, providing additional inner satisfaction for the bending practitioners.

Under various constraints, progressive forest farmers have learned, created and developed traditional ecological knowledge or wisdom[45,46]. This is not an easy process, and the knowledge they possess is the result of a long-term trial-and-error efforts. They require persistence, may experience social conflicts, or have to negotiate with authorities[6]. Logically, considering the prolonged experience, the innovation is meaningful, whether it may give financial or non-financial gains. This is consistent with the views of other researchers who for a long time have believed that farmers have their own rationality[47,48]; and the diversity of initiatives, cognizant of the constraints and limitations of external information[19].

The local situation is specific, where light is quite limited (c. 30% light penetration). This imposes a significant limitation to the photosynthetic process of plants. In contrast, forest farmer resources are limited to intervention, such as applying agrochemical inputs. Meanwhile, external innovation is generic, assuming that it is done under normal circumstances. Thus, their insight is indispensable, anticipating the chronic problem of external innovation rejections[23] and reducing the high burden of formal development agents[30]. It provides avenues for mainstreaming local innovations for sustainable agroforestry development[49] while contributing to realizing the vision of 'leave no one behind,' as voiced in the UN Sustainable Development Goals.

However, the diffusion of the coffee branch bending is needs to be clearly examined. This local innovation is seemingly an exclusive entity, belonging to the local social clique. It is because the communication method in such forest communities is interpersonal, or farmer-to-farmer[30]. This is distinct from the mode of extension agents who typically use a more open group communication approach (e.g., farmer groups). Also, the learning media for local innovation development uses the forest farmer plots. However, regular extension workers use demonstration plots. As a result, the surrounding community barely sees the many advantages of the technique. Also, the technique is somewhat controversial for several reasons (seen as unusual by those outside the clique or contradictory to the policy of the power-holders/forest management)[50].

While there are many perceived advantages of coffee branch bending, our observations and FGD with people outside the clique suggest that not many local forest farmers are adopting this technique. Maybe, visually, the plants look untidy. This raises skepticism, both for forest managers and local communities. Sometimes an unfavorable social atmosphere (e.g., disagreements on profit sharing in the above case) can also cancel the adoption process of local innovation regardless of its relative advantages. This is what we call adoption mortality, and also known dis-adoption[13]. The coffee branch bending tends to be viewed with skepticism by both forest management and the community itself. We would say that social compatibility, or social encouragement or influence for the technique, is relatively low and an inhibiting factor for the diffusion to wider social levels[13,51]. In this sense, what remains undetermined is the mechanism of diffusion of the bending technique.

Individuals with particular experiences, such as the coffee branch bending promoters, should be considered positive deviants[52]. It refers to the idea of a group of individuals who have unusual practices but are more successful or have strategic and innovative values in solving problems than their peers, under limited resources or knowledge[53–55]. Over time, it seems that the negative stereotype that innovative forest farmers are unacceptably eccentric is fading away. Our further discussions with the progressive forest farmers show that the technique seemed to have been quietly adopted and then adapted by the nearby outsiders, by changing the plant cultivar that suits their area. However, it is beyond this research, requiring another study to examine this.

5 IMPLICATIONS AND CONCLUSIONS

Without undue generalization, this study can serve as a lesson

learned for relevant studies. Exclusively created and developed by a forest farmer cohort, the coffee branch techniques under over pine canopy shading need to be appreciated. The implication is that this local innovation needs to be validated. It may open a way to incorporate it into the agroforestry innovation pool. By mainstreaming innovations of experienced practitioners the adoption may be easier than relying only on external innovations. The innovative perspectives and practices of forest farmers are locally relevant given the lengthy process of discovery, learning and evaluation of various economic and non-economic benefits. This coffee branch bending innovation is meaningful due to limited financial availability as farmers in remote areas. For these reasons, the results of this study can assist strategic choices by involving them to pursue sustainable agroforestry development.

In reflection, outsiders need to know the specialty of innovative forest farmers rather than suspect or discredit them. Uncovering the advantages of bending coffee branches through farmer-stakeholder meetings is a benefit for all. A follow-up discussion with the wife of Mr. F showed that they are used to optimizing woodland for mixed agroforestry-garden to meet family needs, sometimes with their own creativity to cope with challenges, such as nutrient competition between plants. This does not only consider economics but also meets special needs. An example is to enjoy the unique taste of local coffee produced under pine over-shading which is purported to be superior compared to those in stores. Reflecting on the lack of recognition and past conflicts experienced between farmers and forest management, support from power holders and stakeholders is vital given the impression of the superiority of local innovation.

The claimed ecological benefits of coffee branch bending techniques (e.g., to improve forest environmental performance) are likely to be common for agroforestry. However, given the risk of over-interpretative, it would valuable from them to be the subject of further validation.

Field observations and follow-up discussions with the participants indicated that their agroforestry system is sensitive to various external influences, such as falling coffee prices, a fair profit-sharing system and the possibility of current extreme weather. Such challenges can jeopardize the coffee plantations as well as degrade the local wisdom. Thus, thinking inside-the-box[56], which is using an internal perspective to address issues, is recommended. The exclusive forest farmers have continuously learned local innovation through pragmatism and experimentation, and internally circulated through interpersonal discussions and imitation. As an implication, the communicative intervention strategies need to involve the experienced locals, as an effective channel for adoption of innovation. This is in accordance with the transformative discourse of behavior change, which is environmentally sound and population-relevant[57].

To conclude, local innovation is not only unique but also meaningful for forest farmers for providing various perceived relative advantages. However, we remains some uncertainty about adoption of this innovation by their peers. The use of a participatory extension strategy is necessary, that is by promoting extension cooperation with local social potential and stakeholders. Further research is needed, for example, to look at communication between forest farmers and the wider networking for the local innovation learning and diffusion and/or adaptation of coffee branch bending. So far, it appears that the diffusion processes remains confined to the inner circle.

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Compliance with ethics guidelines

Edi Dwi Cahyono, Eka Pradesti, Cahyo Prayogo, Suhartini, and Riyanti Isaskar declare that they have no conflicts of interest or financial conflicts to disclose.

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