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Agroforestry in Shade Coffee Plantations as an Emission Reduction Strategy for Tropical Regions: Public Acceptance and the Role of Tree Banking

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Support for the adoption of climate change mitigation measures in low-income regions depends on how such activities contribute to generating household income and gaining confidence from the local community. The planning of mitigation measures or pro-environmental activities need to consider the cost of deployment, customization of activities according to local conditions, and socio-cultural background and perceptions of people. This paper analyses the incentive induced "agroforestry" or "planting trees in farmland" as part of the Carbon Neutral Programme supported by the Government of Kerala in Meenangadi Grama Panchayath, Wayanad district. An increase in tree cover is proposed as a strategy for increasing carbon sequestration. Planting more trees in farmland (except grain cultivated areas) along with crops, according to farmers, may reduce crop yield and discourage farmers' participation. The Government of Kerala put forward the concept of a tree banking/tree incentive program to attract farmers to expand tree cover. A survey was conducted among 100 individuals from the Meenangadi Grama Panchayath to assess the perceptions and concerns of farmers about the proposed "Agroforestry"/Tree Banking program. The sample size was chosen from the population assuming a 9.98% error tolerance. Tree Banking Programme designed to encourage farmers to plant trees has gained public interest, and the study also documented the factors influencing the willingness of farmers for planting trees. The study revealed that the majority of the individuals (93% of the survey participants) residing in the region are interested in supporting the activities for climate change mitigation. Financial incentives announced under tree banking generated interest among farmers. 89% of the survey participants consider the incentive scheme to be an attractive option, as it can compensate for the short-term loss in crop productivity. However, farmers were very selective in choosing the tree species to be planted on their farms. Incentivization helps to make sure that a large proportion of the planted saplings will grow into mature trees. Overall, it can be

concluded that afforestation in the form of agroforestry could be potentially attractive to the farmers and contribute towards achieving carbon neutrality for tropical agricultural areas.

Keywords: sequestration, agroforestry, afforestation, incentivization, tree banking, climate change mitigation, greenhouse gas, negative emissions

INTRODUCTION

At the 21st Conference of the parties to the UNFCC in 2015, the international community adopted the "Paris Agreement" (UNFCCC, 2015), which focuses on international climate policy to keep the global warming below 2°C above pre-industrial levels. Initiating new strategies for achieving negative emissions along with active and sustained emission reductions are vital for keeping the climate temperature increase below 2°C. (Shepherd et al., 2009; McLaren, 2012; Tavoni and Socolow, 2013; Clarke et al., 2015; UNFCCC, 2015; Smith et al., 2016). Technologies for the deliberate removal of CO_2 from the atmosphere by human interventions are collectively called negative emission technologies (Fuss et al., 2014).

Mitigation strategies must be adopted in almost all sectors to stay within the limit of 2°C cost-effectively (Meinshausen et al., 2009; Rogelj et al., 2011, 2013). Around one-third of the current global anthropogenic greenhouse gas (GHG) emissions are from the land-use sector (Bellarby et al., 2008). However, several measures like avoiding deforestation and improved agricultural management can be adopted to reduce GHG emissions from the land-use sector (Smith et al., 2013). At the same time, it should be noted that lowering GHG emissions might not be sufficient or might only be achievable at a high cost for the ambitious climate targets. Thus, carbon dioxide removal (CDR) from the atmosphere becomes essential (Kreidenweis et al., 2016). Along with reducing GHG emissions, strategies for increasing carbon intake from the land-use sector can contribute to climate change mitigation (Rose et al., 2012). The goal of this project is to determine the interest of farmers in implementing a cost-effective technique for converting current agricultural land into a more competent carbon sink.

Many integrated assessment model (IAM) scenarios in the IPCC Fifth Assessment Report (AR5) targeting to keep the temperature increase below 2°C have pointed out afforestation to be an effective climate change mitigation option (Clarke et al., 2015). The climate engineering (CE) portfolio (Vaughan and Lenton, 2011) suggests terrestrial carbon dioxide removal (tCDR) strategies through carbon fixation happening during photosynthesis. Out of different CE schemes aiming at CDR, tCDR has been identified to have carbon removal capabilities at reasonably lower economic costs (Shepherd et al., 2009). At the same time, effective tCDR calls for large-scale biomass plantations (BPs) or afforestation programs, with suitable biomass allocation for sustainable carbon extraction (Klein et al., 2014) along with long-term implementation periods (Vaughan and Lenton, 2011; Caldeira et al., 2013).

Due to its high carbon sequestration potential at a moderate cost, afforestation could act as an alternative for other mitigation strategies or could exceptionally complement them (Minx et al., 2017). Smith et al. (2016) have identified that estimated costs for afforestation are lower than for other carbon removal technologies like bioenergy carbon capture and storage (BECCS) and direct air capture (DAC). Calvin et al. (2014) have also identified that afforestation is an economically attractive option. Additionally, several studies (Bala et al., 2007; Bathiany et al., 2010; Arora and Montenegro, 2011; Mahmood et al., 2014) have identified that the expansion of forests in tropical regions of the Earth can result in the cooling of the Earth's atmosphere. As a result, afforestation and agroforestry with timber-producing trees used in wood-based construction and furniture production could result in long-term carbon storage. Additionally, reducing tree felling through incentivization can also help to have long-term carbon sequestration and storage.

Because of its economic and environmental benefits, agroforestry has been recognized as an integrated approach to sustainable land use (Nair, 1993; Jose, 2009). Agroforestry has gained prominence in the context of climate change (FAO, 2013) after the Kyoto protocol. Agroforestry is an interface between agriculture and forestry and has been treated as a sustainable land use practice in developing countries, as it allows farmers to produce food, fodder, fuel, timber, and other forest resources from farmland (Jose, 2009). Tropical deforestation is responsible for 25% of the net annual carbon dioxide emissions worldwide. Agroforestry has the potential to address tropical deforestation and reduce emissions from agriculture (Albrecht and Kandji, 2003). Land-based emission reduction strategies like afforestation/agroforestry are not only effective in reducing GHG emissions but also effective in increasing carbon uptake from the atmosphere (Rose et al., 2012). Similarly, tree-rich farming systems reduce the application of nitrogen fertilizer for improving soil quality and maintaining nutritional balance and fertility (Shi et al., 2013). Trees in the croplands improve the productivity of systems and provide opportunities to create carbon sinks (Dixon et al., 1993, 1994; Krankina and Dixon, 1994; Dixon, 1995). They also play a very important role in enhancing the resilience of farming systems, reducing the vulnerability to climate change, and helping farmers earn sustainable income (Meragiaw, 2017). Adding trees to farming systems or combining crops and trees could be a solution for climate change by adopting mitigation and adaptation actions (Nair, 1993).

However, the global potential of negative emission technologies (NETs) such as afforestation needs to be studied well. Cost of deployment, effectiveness in different regions in attaining climate stabilization targets, and socio-institutional barriers including the ones in governance and public acceptance of afforestation in the form of agroforestry, need to

be understood. It is also essential to investigate whether such techniques can be implemented with the co-benefits of improving the production of food, bioenergy, fodder, and fiber to fulfill both local and global requirements. Such aspects need to be compared against the carbon benefits of agroforestry. Additionally, monitoring carbon stock dynamics is also crucial for the successful and effective implementation of agroforestry as a climate change mitigation strategy. Currently, afforestation is carried out in several parts of the globe on different scales (Van Der Walt et al., 2004; Jürgensen et al., 2014). Noticeable experience exists regarding the implementation and monitoring of afforestation on small scales (Fuss et al., 2016). However, to achieve negative emissions on a large scale, considerable upscaling is needed.

Trade-Offs

Expansion of agroforestry along the agricultural landscapes, if not properly managed, might lead to a decline in food production. Kreidenweis et al. (2016) showed that afforestation might probably result in a notable increase in food prices towards the mid of the 21st century. Other studies (Wise et al., 2009; Reilly et al., 2012; Calvin et al., 2014) have also found similar results of food price increases even with the implementation of the carbon tax. Scarcity of land for cultivation and the need for necessary investment costs in research and development aspects might increase food prices on a global average. Again, as the global population increases, the demand for food products, especially livestock products is expected to increase (Alexandratos and Bruinsma, 2012; Bodirsky et al., 2015) along with the increasing demand for bioenergy. Together these factors will increase the demand for agricultural products in the future. Afforestation demands more land area to achieve similar levels of CDR achieved through other methods like BECCS and DAC (Humpenöder et al., 2014) and could consequently have a heavy influence on land-use consumption.

Studies have reported that afforestation, as a climate change mitigation strategy, is not equally effective in all regions around the globe. Tropical regions in Asia have been identified to be a suitable choice for carbon-removal technologies like afforestation (Boysen et al., 2016). Studies by Bala et al. (2007), Bathiany et al. (2010), and Arora and Montenegro (2011) showed that planting trees in other regions might be less effective and afforestation in boreal zones might even lead to an increase in global temperature. Kreidenweis et al. (2016) argue that potential benefits can be achieved with the least impact on food production and albedo effects if afforestation is well managed and established only in tropical regions. It is also observed that policies and incentives must be organized to increase the rate of production and yield along with ensuring redistribution of funds to the section most vulnerable to the consequences of these changes (Kreidenweis et al., 2016; Jackson et al., 2017).

Another challenge for NETs like agroforestry is the selection of ideal plant species for a given location (Fuss et al., 2016). Several aspects, including the ability of species to grow at the location, atmospheric and climatic adaptability, and competition to food crops must be studied to identify the optimal choice of plant species. Sustainability research focused on the ecological, economic, and social consequences along with strategies to recover abandoned lands is required for proper and effective implementation of afforestation (Knoke et al., 2014).

However, afforestation as a climate change mitigation strategy can be applied immediately, even if it is on small scale, as it is just planting trees. The social acceptance of small-scale agroforestry is not expected to be challenging as it provides other ecosystem services like fuel supply and biodiversity conservation along with carbon sequestration (Barlow et al., 2007; Onaindia et al., 2013; Humpenöder et al., 2014). However, the social acceptance significantly depends on the agroforestry's impact on normal agricultural practices and income sources of the local population.

Nature-based climate solutions can only be effective if they are developed and implemented with a focus on the interests and requirements of indigenous communities. This is because the long-term viability of ecosystem conservation and carbon storage requires local support and it depends on the decisions of such communities (Fleischman et al., 2020). The economic benefits received by the indigenous community from such ecosystems encourage them to conserve and restore such ecosystems. Therefore, understanding the requirements of indigenous communities is critical for the success of nature-based climate change mitigation strategies like agroforestry.

Brazil's recent deforestation reduction strategy (Assunçao et al., 2015; MacDicken et al., 2015; Tollefson, 2015), China's large-scale afforestation program (Peng et al., 2014), and African nations' initiative to restore degraded and deforested land (Gueye, 2018) are some examples of successful projects indicating that afforestation is having better prospects for success in upcoming years. Continuous yield increases and generous research investments along with a high price for CO_2 emissions and attractive incentives for freeing up agricultural land for afforestation are requisites for achieving ambitious climate targets through afforestation (Kreidenweis et al., 2016).

Afforestation in the form of agroforestry might also open new opportunities with short-term jobs for tree planting and preserving. Industries relying on wood products like paper, construction, wax, furniture, flooring, and bio refineries may flourish utilizing wood and other resources. The burning of wood as a fuel should be discouraged as it results in carbon emission to the atmosphere, and preferences should be given to long-lasting, sustainable products from wood (Fuss et al., 2016). These efforts can help in long-term carbon storage and atmospheric carbon removal.

The effectiveness and feasibility of an incentive mechanism-oriented agroforestry project as a negative emission strategy in a tropical region are presented here. The study also tries to determine individuals' perceptions and level of awareness toward agroforestry as a climate change mitigation strategy. This work also aims to find out alternative methods to implement agroforestry in the tropics by surveying individuals in the region.

Background

Kerala is a state on the southwestern coast of India. Kerala is known for its rich heritage of Agroforestry systems (Kumar, 2006). Farmers in the plains and midlands of Kerala cultivated trees (eg. nutmeg tree) and coconut together and developed them into unique agroforest systems. In the high ranges of Kerala farmers over time developed various agroforestry systems along with major crops like cardamom, pepper, coffee, and cocoa.

Meenangadi is a village in the Wayanad district in the State of Kerala, India. The region is rich in biodiversity and is in the Western Ghats. Coffee-based agroforestry is a practice adopted by farmers across the Wayanad region. Coffee agroforestry supports other crops like pepper, tubers, and mixed trees. Coffee agroforestry is unique in the sense that it supports diverse endemic trees of conservation value along with commercially important fruit trees.

Meenangadi is on an ambitious journey to be India's one of the first carbon-neutral villages. The local governing body proposed a project named "Carbon Neutral Meenangadi" with the support of the Government of Kerala (Local Self Government Department, 2017; Isaac, 2018, 2019, 2020; Jayakumar et al., 2018). Carbon neutrality can be achieved by balancing the measured amount of carbon released into the atmosphere through different activities, with an equal amount sequestrated into carbon pools or sinks. After a detailed analysis, it was found that increasing the green cover can be the optimal and economically feasible strategy towards the goal. Wayanad is a region with a considerable forest area; planting trees or afforestation in public space is not enough to reach the goal, and all abandoned land has trees. Therefore, planting trees in private holdings, including agricultural landscapes, plantations, and wastelands, was initiated. There was a growing concern over carrying out afforestation in agricultural landscapes. Afforestation in the area might result in the conversion of agricultural area to an agroforest, which can lead to a decrease in food production and a decrease in the income of farmers and individuals if not properly managed. Therefore, the opinion and concerns of individuals and farmers must be collected along with the planning and development of the project. Therefore, a survey was conducted among the farmers and individuals to gather their views and ideas on the project's development.

The Government of Kerala has introduced a tree banking program (Isaac, 2018, 2019), giving incentives to farmers for planting trees. Objectives of the survey included checking the level of awareness and interest of individuals in climate change mitigation through planting trees on private land. The survey is also aimed to estimate the extent to which the local governing body could successfully attract the farmers towards this project by providing financial support as an incentive. Furthermore, it was tried to determine the level of increase in people participating in the agroforestry/afforestation programs in response to the increase or decrease in financial incentives for tree planting. Finally, the project is also expected to result in figuring out the approximate number of trees that could be planted in the private-owned land area of Meenangadi.

Questions were prepared so that any option chosen by an individual could indicate the factors influencing the individual in decision making. The resulting data could indicate the interests of the community. From this, an analysis could help in broadly defining the opinion of the individuals in the locality. The survey is also expected to document the concerns of farmers over planting trees in their farmlands. The same is the case with their expectation of incentives for compensating for the loss in crop productivity if they adopt agroforestry.

MATERIALS AND METHODS

The survey questionnaire was designed in both English and the regional language Malayalam. The survey questionnaire included five sections, out of which four of them covered concerns about diverse aspects of the implementation of afforestation in the form of agroforestry as a climate change mitigation strategy in the region (**Supplementary Appendix S5**). All items except the ones enquiring about the respondents' general details and socio-demographic details had multiple options. The answer options for each question varied in number and type according to the objectives.

The sections of the survey covering concerns about diverse aspects of the implementation of the project focused on checking the level of climate change awareness of individuals, checking whether afforestation in the form of agroforestry is implementable in human settlements without reducing the income of small-scale farmers, determining whether the individuals support the strategies adopted by the government to promote afforestation in the form of agroforestry. The five different sections of the questionnaire were:

- General details—This part was to get basic information on the person being interviewed. The details included socio-demographic details including educational qualification, annual income, number of family members and total land area owned. These data could help in correlating the socio-demographic variables like gender, age, level of education, and net household income with the data from the following sections investigating the awareness about climate change and its impacts, and the choice of plant species.
- Concern about climate change—This section looked at the concerns of the individual towards the conservation of nature and his/her awareness about climate change and its aftereffects. The awareness about climate change was measured by asking the respondents "Do you think that climate change is happening?", "What might be the potential cause of climate change?", "Do you think planting trees will reduce the effect of climate change?"; the concerns about afforestation by "What kind of land is suitable for afforestation—private or public land?"; the concerns about support from the government by "What kinds of support are you expecting for making individuals participate in afforestation?". From the data generated from the response of individuals, insights could be generated

regarding the percentage of the population having climate change awareness, knowledge about the benefits of afforestation, etc.

- Investments—The section focused on the financial aspects including the annual agricultural budget of the farmer, the reduction in crop yield anticipated if trees are planted in and around the agricultural land, and the kind of support expected from the local governing body and State government. The data from this section could help to understand the financial status of the population. The resulting data from this section can be correlated with the responses from other sections to investigate how the financial status and annual income of the population influence their outlook towards climate change and climate change mitigation strategies.
- Preference of sapling species—This section includes inquiries about the landowner's choice of plant species that he/she would like to plant on their land. This section also includes questions to explore the concerns of farmers in accommodating the saplings along with existing crops. Results from the section could help in deriving the influence of aspects like financial status, climate change awareness, financial benefits during harvesting, and level of education on their choice of plant species. Additionally, this section could also help to figure out which factor has the major influence on the population in choosing the plant species.
- Participation of family members—This section contains questions to check how family members manage to successfully participate in agriculture. Additionally, the section helps to understand how female members execute their roles in agricultural practices.

The population of Meenangadi is 33,450 according to the 15th Indian Census taken in 2011. This study presents the findings from a survey having a sample size of 100 respondents from different parts of the Meenangadi region (**Supplementary Appendix S1** for the confidence level calculation). Additionally, correlations like "effect of individual's level of education on the selection of plant species", "influence of mean annual income of a society on the climate change mitigation outlook of individuals" etc., are expected to be identified by combining the results from different sections.

An important methodological issue to be recognized is how to obtain public concerns in quantitative surveys, since carbon neutrality and climate change mitigation methods are complex topics on which the public might not necessarily have a lot of information and awareness. Drawing out public perceptions and concerns on social issues needs careful attention to what, why, and how questions are being asked. This helps to ensure that respondents are able to understand the questions being asked and increases the chance of respondents being motivated to answer them.

RESULTS AND DISCUSSION

Individuals were surveyed from seventeen different regions of the Meenangadi area to ensure even participation. The survey was conducted ensuring the representation of individuals from both genders, individuals with different economic and educational statuses. 72.4% of the individuals interviewed were farmers.

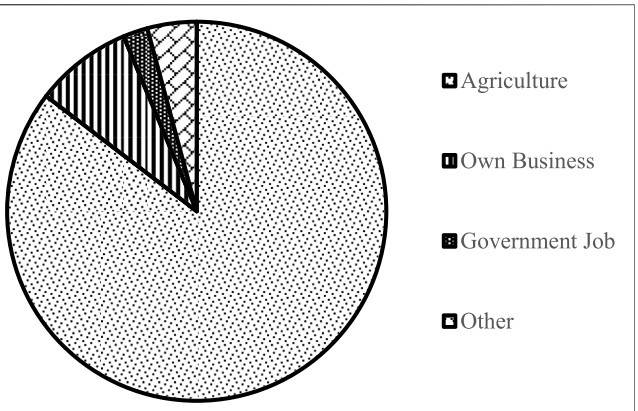

FIGURE 1 | Major sources of income of individuals interviewed from Meenangadi.

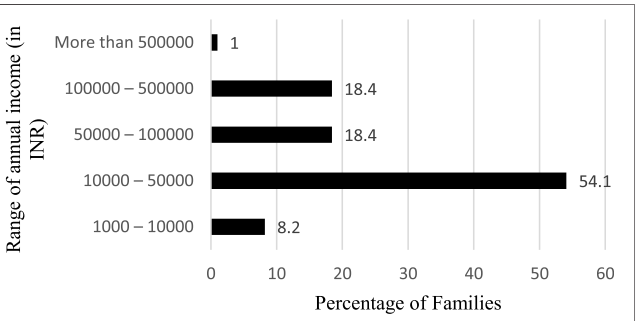

FIGURE 2 | Income of families of individuals interviewed.

TABLE 1 | Crops cultivated by individuals.

Major crops cultivated	Percentage of families cultivated
Coffee	82.3
Rubber	20.8
Coconut	38.5
Areca Palm	61.5
Pepper	29.2
Jack fruit Tree	9.4
Others	29.2

Most of the families (about 50%) consist of three or four members. Around 60% of families rely on the income from a single person. However, 30% of families have two earning members. Almost 85% of families rely on agriculture as a significant source of income (**Figure 1**). This data and other census data from government departments show that most families depend on a single person's income generated from agriculture (Department of Economics and Statistics, 2011; Directorate of Census Operations Kerala, 2011). Therefore, agriculture is the backbone of Meenangadi's economy.

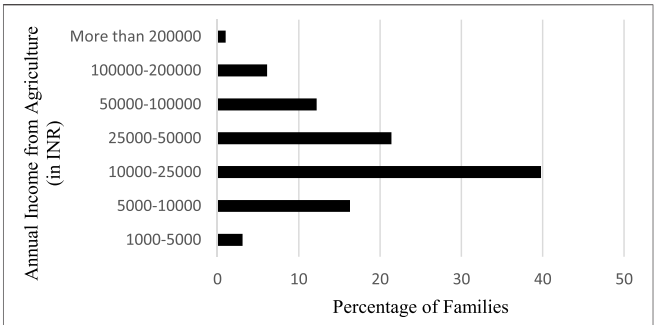

FIGURE 3 | Families' annual income from agriculture.

Around 54% of the population has an annual income between 115 and 550 euros (**Figure 2**). Major crops cultivated are coffee (*Coffea canephora* and *Coffea arabica*), areca palm (*Areca catechu*), coconut (*Cocos nucifera*), pepper (*Piper nigrum*), rubber (*Hevea brasiliensis*), and jack tree (*Artocarpus heterophyllus*). Most of the farmers in the region cultivate coffee (**Table 1**). The presence of trees with shades will, if not planted properly, might result in a reduction in the coffee yield. Therefore, planting trees in coffee plantations is expected to affect the farmers and the population of the Meenangadi region since a major part of the annual income of the population is from agriculture (**Figure 3**). Hence, care must be taken while finding a suitable space for planting the saplings. Otherwise, when grown, these saplings might become a threat to the crops, and the farmers will be forced to cut the trees down.

Out of the individuals interviewed, 93.9% feel that there is climate change. This value is higher than those reported by previous studies from similar lines of research (Hazarika et al., 2021). The higher number in Meenangadi may be due to the fact that Wayanad has been declared a climate change hotspot (Four Districts Categorised as Climate Change Hotspots—The Hindu, 2015) and has been affected by floods and landslides in recent years, moreover, the ongoing carbon neutral programme has given wide awareness about the causes and effects of climate change among the local community. Anyways, the numbers show that the population of Meenangadi is aware of the changes happening to their surroundings, local climate, and ecosystem. Most individuals identify climate change as an increase in average atmospheric temperature, reduction in crop yield and unexpected changes in the weather pattern. Most of the individuals (around 80%) believe that one of the reasons for climate change is deforestation. Whereas around 70 per cent suggest pollution is also a potential cause. Individuals also feel that population explosion, fossil fuel usage and plastic usage are other probable causes.

Eighty-seven per cent of the population in Meenangadi believes climate change is mitigable. Though acceptance studies related to negative emission or emission reduction technologies are limited (Wenger et al., 2021), acceptance studies conducted across the various parts of the world suggest that among the available negative emission technologies (NETs) afforestation has the highest acceptance rate (Braun et al., 2017; Jobin and Siegrist, 2020; Wenger et al., 2021). The response from individuals interviewed from Meenangadi is also in agreement with these findings. Out of the whole set of individuals who believe that climate change is mitigable, 95% chose afforestation as a suitable strategy to mitigate climate change. 45% believe that reducing the use of plastic is a way to mitigate climate change, whereas about 40% consider reducing fossil fuel usage as the best choice. However, 30% feel that protecting the existing forest cover is the best way to mitigate climate change. These observations indicate that society is aware of some of the climate change mitigation strategies.

A study (Schirmer and Bull, 2014) conducted in Austria revealed that the important parameter in decision-making in acceptance of afforestation-reforestation programmes is the design of the programme. Schirmer and Bull (2014) in their study have also shown that people are willing to adopt afforestation, if the programme supports the use of native species, planting in a smaller area of land, and also if it offers some co-benefits either for the environment or livestock etc., Other studies have reported that awareness of climate change leads to behavioural change in individuals and might even urge them to take up climate change mitigation strategies (Halady and Rao, 2010; Okaka and Odhiambo, 2018). Therefore, it will be easier to convince individuals of Meenangadi to adopt proper and scientific methods to mitigate climate change.

Around 96% of individuals are interested in environmental protection activities and 83.3% feel that planting trees is a suitable option for Wayanad. This indicates that individuals are ready to accept an agroforestry project. Around 70% of the individuals feel that planting trees should take place on both private and public lands. Seventy-seven per cent opt that public land alone is not enough for a large-scale afforestation project aiming towards resisting climate change. This means that most of them realise that more trees should be planted on privately owned lands to mitigate climate change. Therefore, it appears that agroforestry as a concept is acceptable for the group interviewed. This result is reasonably in agreement with the findings from the previous studies (Barlow et al., 2007; Onaindia et al., 2013; Humpenöder et al., 2014).

Around 90% of individuals feel that providing saplings and financial support will attract more people to the project. They also feel that an incentive mechanism will serve the purpose. In short, this might mean that the upcoming global agricultural shift resulting in increased afforestation (in this case in the form of agroforestry) in the tropics as predicted by earlier scenario studies by Kreidenweis et al. (2016), might be acceptable to people of Meenangadi and similar regions. Furthermore, this approach will help them to prepare in advance and to adapt to the anticipated inevitable global strategies aiming at ambitious climate targets. 83.7% of individuals said that they have enough land to plant trees, and they are ready to plant trees in a scattered manner. Out of the rest 16.3%, 8.2% are unable to plant new saplings because their land is already occupied with crops and trees, but they are interested in the project.

Eighty per cent of individuals feel that the presence of more trees might affect the crops and their yield. However, 61.2% of them are ready to incur a slight loss in their crop for mitigating climate change. It appears that accommodating mutually

TABLE 2 | Types of trees the individuals of Meenangadi prefers to plant.

Type of trees	Preference of people interested (in percentage)
Fast-growing trees with use-value	12.2
Fast-growing trees with commercial value	22.5
Non-native fruit trees	46.9
Native fruit trees	58.2
Non-native timber yielding trees	64.3
Native timber yielding trees	69.4

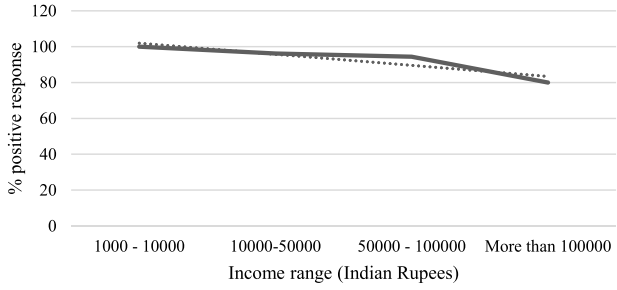

FIGURE 4 | Annual income vs. Outlook towards afforestation.

contradicting ideas of afforestation and reduction in crop yield is one of the main challenges in implementing agroforestry projects. Thus, a project aiming for carbon neutrality should be devised without having a huge negative impact on the financial stability and food security of the families of farmers and individuals who are cooperating with the project. Interestingly, there is a clear opportunity for income increase for farmers with shade coffee conversion and planting trees (**Supplementary Appendix S2**), which is yet to be fully recognized by farmers. Therefore, the incentive mechanism should be developed in such a way that it makes the program attractive to the farmers. The availability of incentives makes sure that the farmers get an opportunity to have additional income in between, if and when needed, since the income from the timber is expected only after a long period and when the trees are matured enough.

Most of the families (more than 50%) and individuals prefer to plant either timber yielding trees or fruit trees (**Table 2**). Individuals are ready to plant both native and non-native trees. In the table (**Table 2**), the trees with "use value" represent trees planted to meet the needs like food, fodder, fibre, and firewood. The trees with "commercial value" represent trees providing marketable output. Trees with commercial value are nurtured for income generation (for example, from selling timber etc.).

About 80% of individuals have more than 30 mature trees on their land. More than 90% of individuals plan to retain the existing trees. Around 64% of the individuals said that they would not cut down any existing trees even if they were not provided with any extra incentives for them. But the rest said that they would retain if an incentive is provided, even if the incentive amount is small. Ninety per cent of individuals also expect to maintain the saplings (that will be planted as part of this project) as long as possible if the incentive is provided as an interest-free loan against the tree as collateral property. At the same time, around 10% feel that a loan with low interest is a better option.

For the questions regarding agricultural management practices, responses indicate that most of such practices are still carried out by men. In 40.9% of families, trees are planted by men, while in 49% of families, it is done together by both men and women. The decision to plant trees in the land is taken by both men and women together in 56.3% of families, and in about 38% of families, the decision is taken by men alone. The space for planting trees is found by men in about 50% of families, whereas in 44.3% of families, it is done by both men and women. The process of weeding is done by men alone in 49% of families while it is done together by men and women in 40.6% of families. Irrigating the field is done by men in around 86% of families and is done by women in around 12% of families. From the above results, it can be observed that major tasks in the agricultural sector are still carried out by men in a significant number of families. However, in a significant part of the remaining group, the activities are carried out by men and women together. Therefore, it is clear that men still dominate the agricultural sector of this society. Most of the women in the region are concentrated in carrying out household activities, and they often generate income for families through cattle rearing and odd jobs.

The above results indicate that there is still a large area of land available to plant trees and the people are willing to support the steps taken by the local governing body. It can be observed that around 60–70 per cent of people would like to plant timber yielding trees irrespective of the sapling's nativity (**Table 2**). Around 50% of people also like to have fruit trees. Many of them would like to plant both native and non-native fruit trees. These results show that timber yielding and fruit-producing trees are preferred by the people. Therefore, providing saplings of these varieties in equal numbers could satisfy the sapling requirement of the people of Meenangadi.

Individuals of Meeanangadi are concerned about the change in climatic conditions. They identify climate change as the increase in the atmospheric temperature and as the reduction in crop yield. They showed good interest in the program and actively participated in the survey. There is a significant number of families in Meenangadi whose main source of income is agriculture (**Figure 1**), and many among them earn less than 25,000 Indian Rupees annually (**Figure 3**). When there is a reduction in crop yield due to climate change, their annual income diminishes. This makes it harder for them to find the money and resources for day-to-day living. When approached for the survey, most of them were very much interested in participating. They believe that this project's successful implementation will help to mitigate climate change and provide them with suitable conditions for profitable agriculture.

Exploratory data analysis is performed between the critical variables in the study, namely the acceptance of afforestation, landholding, and income range, to check whether there is any visible correlation between these variables. The survey shows a slightly inverse relationship between income and interest in tree planting (**Figure 4**). Respondents in the lower-income category

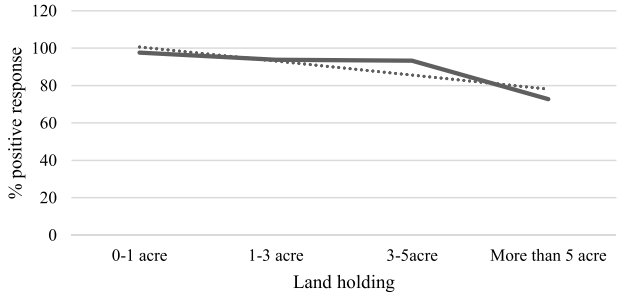

FIGURE 5 | Land Holding vs. Outlook towards afforestation.

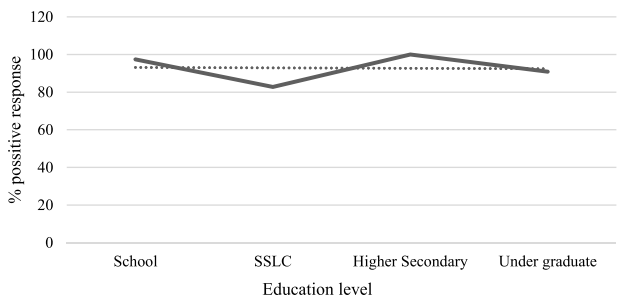

FIGURE 6 | Education Level vs. Outlook towards afforestation.

expressed more interest in tree planting, and interest in tree planting declined along with an increase in income.

The individuals who consider agriculture as a secondary or tertiary source of income were even reluctant to participate in the survey. The reduction in crop yield is not affecting their annual income significantly. Hence, they are less concerned about the effect of climate change on agriculture and crop yield. They also showed less interest in the project and seemed to be less optimistic about the steps taken by the Government towards climate change mitigation. It is also important to note that small-scale farmers are ready to plant trees. They show interest in planting medicinal trees as well. However, individuals whose primary income was not agriculture were primarily interested in planting timber-yielding varieties.

Similar trends are observed in the case of landholding and interest in tree planting (**Figure 5**). Medium [3–5 acres (1.21–2.02 ha)] and large holders [above 5 acres (2.02 ha)] expressed less interest in tree planting compared to smallholders. Farming is the primary source of income for the medium and smallholders, and they derive a large chunk of their income from the annual coffee harvest. The long gestation period of trees does not attract them, and planting trees might affect income from coffee. These results are not surprising as it is evident that individuals holding larger amounts of land have a higher annual income (**Supplementary Appendix S4**).

A zig-zag relationship exists between the level of education and interest in tree planting for addressing climate concerns (**Figure 6**). More educated and at the same time, economically well-off categories of people are hesitant to respond positively towards tree banking scheme. This could be due to either lack of trust in the tree banking scheme or the belief that it might not be enough to compensate for the short-term loss in crop productivity.

From the results of the survey, the feasibility of the tree banking scheme introduced by the local governing body with the close support of the Government of Kerala to promote agroforestry in the region is evaluated. By ensuring the interest and participation of farmers and individuals, the initiative aims to develop the tree banking concept as a sustainable income-generating mechanism (**Supplementary Appendix S2** for the income calculations, which also shows how the farmers' income potentially doubles). As a result, the initiative is equally good for both the environment (**Supplementary Appendix S3** for carbon sequestration calculations) and the community that relies on it.

CONCLUSION

We present the results from a study carried out to evaluate the acceptance of afforestation in the form of agroforestry as a climate change mitigation strategy in an area with a significant population of farmers. An important finding from the study is that individuals have a positive outlook towards agroforestry, and the tree banking program is appealing to the farmers. The main findings from the study are:

- The majority of the individuals (93% of the survey participants) residing in the region are interested in supporting the activities for climate change mitigation.
- Incentives from the local governing body or other government institutions increase the interest of farmers in participating in climate change mitigation activities. 89% of the survey participants consider an incentive scheme to be an attractive option, as it can compensate for the short-term loss in crop productivity.
- A significant number of farmers, around 61% of respondents, are ready to plant tree saplings on their farms even if they face a slight decrease in their income from agriculture.
- Calculations (**Supplementary Appendix S2**) show a clear potential for (nearly) doubling the income of farmers with shade coffee conversion (perhaps the farmers are not fully aware of this potential).
- Farmers are very selective in choosing the species of tree to be planted on their farms. Most of them are interested in planting timber-yielding or fruit yielding, long-growing trees.
- Incentivization is expected to help to make sure that a large proportion of the planted saplings will grow into mature trees.
- Afforestation in the form of agroforestry might successfully contribute towards achieving carbon neutrality for Meenangadi.

Even though there have been many climate change mitigation strategies adopted around the globe, one challenge has been the lack of participation from the individuals who are directly affected by such initiatives. In many cases, the expenses exceeding the benefits are also expected as a challenge. Farm forestry appears to be an attractive and sustainable income-generating strategy for farmers in the region. Therefore, this study can be a bellwether for setting up research about incentivizing afforestation in the form of agroforestry. The results show that afforestation in the form of agroforestry could contribute towards the efforts for achieving carbon neutrality in the selected region. This might also be applicable in other tropical regions and hence, further studies are needed. Findings from this study are expected to help in policymaking for meeting ambitious climate targets.

FUTURE WORK AND WAY FORWARD

Till now the tree species have been selected and suggested rather based on the opinions of the stakeholders in Meenangadi. However, several other factors need to be considered while choosing the tree species to be planted, such as the effectiveness of the tree species in sequestering carbon, any potential reduction in crop yield due to the competition between the trees planted and the coffee plants, any additional direct and indirect benefits that the trees might provide the farmer, and the area available for planting the trees. Many of these factors are contradicting each other. Usually, to figure out the best choice in such cases, multi-criteria decision-making techniques could be used. Such an effort is considered as the next step in selecting the suitable tree species to be planted, the optimum amount of incentive that should be provided to the farmer, the optimum time interval for incentivization and the area to be devoted for tree planting.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

PA and GG devised the project, the main conceptual ideas, and the proof outline. TN performed the survey, analysis, and numerical calculations for the suggested study. TN wrote the first draft of the manuscript. AS, VC, GG, and PA revised it critically for important intellectual content and approved the version to be published.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenrg.2022.758372/full#supplementary-material

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