Shade-grown coffee under fruit trees in highland forests as part of an environmental village restoration

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Abstract. Highland forest areas upstream of the Ciliwung watershed are part of the Bogor Regency. Land use change is a serious issue which needs to be addressed. Community Based Forest Management was initiated by the Forestry State Enterprise to benefit highland agroforestry. The program aims to reduce forest degradation and provide economic opportunities for communities around the forest to be involved in the management system. The program was implemented in Kampung Cibulao, Tugu Utara Village, Bogor Regency. It has involved the management of village forests by forest farmer groups since 2009. This study aims to determine the impacts of the program on improvement of the local economy and land productivity. Field observations and interviews with forest farmer groups were conducted to collect primary data. The aspects analysed were : 1) the economic impact ; and 2) the positive impact of the shade-grown coffee in supporting forest restoration and land conservation. The study indicates that there has been a significant revenue increase of between 63.0% from cherry production (IDR630,000/hectare/month) to 127.5% from green bean production (IDR 1,275,000/hectare/month) through shade-grown coffee management. Furthermore, the direct benefits of forest management can aid community understanding and encourage collective action in forest restoration and land conservation.

1 Introduction

Goals number 6 (clean water and sanitation), 7 (affordable and clean energy), 13 (climate action), 15 (life and land) of Sustainable Development Goals (SDGs) will be very related to environmental footprint, carbon footprint, and water footprint. In the IPCC's fourth assessment report, 89% of agricultural-based climate change mitigation potentially absorbs carbon [1]. Selection of plants that have supporting roots will reduce the risk of landslides, increase land productivity, and improve water infiltration. Sustainable agriculture is based on the principles of being ecologically sound, economically viable, social justice [2]. In relation to technology, the main components of sustainable agriculture are (1) cultivation techniques

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and plant breeding, (2) soil and water management, (3) non-chemical control of pests and weeds, (4) integration of crop and livestock production systems, and (5) nutrient recycling [3-4] Sustainable agriculture combined with agroforestry systems is one of the many ways to reduce greenhouse gas (GHG) emissions, and to contribute to carbon sequestration.

Agroforestry systems, which combine seasonal crops with timber crops, can increase carbon storage, and even reduce the carbon losses caused by erosion. At present, shade-grown coffee is being developed in an effort to implement an agroforestry system in Indonesia, especially by highland smallholders.

Coffee (*Coffea* sp) is one of the plantation commodities that plays an important role in generating foreign exchange. In 1981, Indonesia earned US $ 347.8 million from coffee exports of 210,800 tons, a value which continues to increase from year to year. In 2001, coffee commodities generated foreign exchange amounting to US $ 595.7 million, ranking them first in the export commodities of the plantation sub-sector. However, Indonesia's coffee production fell from 390,000 tons in 2001 to 300,000 tons in 2004 [6]. Current climate change is influenced by the large amount of GHG emissions from forest conversion, drainage of peatlands into agricultural land, the use of fossil fuels, and industry. Climate change will lead to changes in temperature and rainfall, which will reduce the rate of growth, flowering and fertilization in cultivated plants, including coffee [7-9].

Climate change and coffee plantations are closely related. High rainfall due to climate change can increase cases of coffee plant disease, such as the fungus, rust or La Rolla leaves, a fall in the persarian process, and fruit fall. If the temperature reaches 30^{o}C, it can cause abnormal plant growth, such as yellowing of leaves and falling flowers. Flower growth requires a sufficient dry period of 2-3 month [10-14]. At present, the landscape in the Puncak area is experiencing rapid changes. Floods and damage impacts have increased, with almost area floods in Jakarta in January 1996, February 2002, February 2007, January 2013, and January and February 2014 [15].

Due to the importance of this area, the President of Indonesia assigned it as a national strategic area. Presidential Regulation No. 54 of 2008 on Spatial Planning Jakarta Bogor Depok Tangerang Bekasi Puncak Cianjur (Jabodetabekpunjur) seeks to regulate land use for land and water conservation purposes, including in Puncak, Bogor. Furthermore, a higher regulation was issued, Law No. 37 of 2014 on Soil and Water Conservation. This shows that sustainable development and management are of great importance in preserving the area.

Finally, this paper studies the economic impact, i.e the revenue to total household incomes, and the positive impact of shade-grown coffee managed by forest farmer groups to support forest restoration and conservation.

2 Study area and method

2.1 Study area

The study was conducted in the Kampung Cibulao, Tugu Utara Village, Bogor Regency. The Cibulao area is the most upstream area of the Ciliwung watershed, and is commonly known as Puncak Bogor, a famous tourist destination in the Bogor regency. Located at an altitude of 1,000-1,300 a.s.l, the land cover around Kampung Cibulao is dominated by tea plantations, pine production forests, secondary natural forests and natural forests with natural reserve status.

2.2 Method

A quantitative research method with case studies is used, to measure income revenue. A case

study is a research design that develops in-depth analysis [16]. In this context, a survey was conducted in May-October 2018. Participants were selected and in-depth interviews conducted to collect information about household income and income generated from coffee cultivation.

Revenue from coffee cultivation activities was calculated from the total revenues from total sell and production costs, including raw materials, labour, overheads, and social costs [17]. The equation employed is as follows:

$$I = \sum_{i=1}^{n} piyi - \sum_{j=1}^{m} qjvj \quad (1)$$

Description :
I = Nett Revenue
*p*i = Product price n years – *i*
yi = Product quantity n years – *i*
n = Types of coffee products
m = Types of production input
*q*i = Price of production input m to variable *j*
*v*i = Quantity of production input m to variable *j*

Focus group discussions were also conducted with farmer groups to gather information about the impact of shade-grown coffee on the environment.

The data collected were then analyzed by descriptive and narrative methods. The strength of the descriptive method, with emphasis on the discussion of cases, provides thorough understanding of the context of the actual situation [18].

3 Result and discussion

3.1 The spread of coffee cultivation

Indonesia is the fourth largest coffee producer after Brazil, Vietnam and Columbia, with a production area of approximately 1.3 million hectares, spread across Sumatra, Java, Sulawesi, Bali and NTT [19-20]. Robusta coffee can grow and be produced well in lowland environments with altitudes of 0-800 m above sea level, an average air temperature of 23ºC-26ºC, and rainfall of 2,000-3,000 mm/year, distributed over a 9-10 months period [21-23]. In addition to leading to crop damage and declining crop production, climate change in the tropics can also lead to soil erosion and land degradation due to high rainfall during the rainy season. Conversely, during the dry season, there is a danger of drought [24].

Table 1. A family with the initiative to introduce coffee into Cibulao.

No	Species	Area (Ha)	Culture period	Owners
1.	*Coffea robusta*	0.88	20 years, and 6 years	Partinah (mother)
2	*Coffea robusta*	0.48	10 years	Jumpono (her son)
3	*Coffea robusta*	0.48	10 years	Yono (her son)

In the period 1998-2002 the Cibulao village environmental group started to campaign to save nature by planting native forests of rasamala (*Altingia excelsa*), puspa (*Schina wallichii*), pasang (*Lithocarpus indicus*), jenitri (*Eleocarpus sphaericus*) and TB (*Panicum brevifolium*). This activity was considered to be not very successful, because when the trees had grown to about 20 cm in diameter they were felled by the community. Coffee has a taproot, so that it can be an alternative crop which can withstand the threat of landslides.

3.3 Community-based forest management

The history of Community-Based Forest Management (PHBM) in Indonesia started from a social forestry program organized by Perum Perhutani in Java at the beginning of 1972, before the 8th World Forestry Congress (KKD) in Jakarta in 1978, with the theme of forests for people. After the congress, Perum Perhutani also developed a PMDH (Pembinaan Masyarakat Desa Hutan) program in 1984, an MA-LU program (Mantri-Lurah), a social forestry program in 1986, and Community-Based Forest Management (PHBM) in 2000. The involvement of the village community is important for generating collective participation and action aimed at producing a better life, across the boundaries of the discipline, using knowledge from within and outside the community [25-27]. In Cibulao, Tugu Utara Village, PHBM started in 2009 through an MoU between KPH Bogor and LMDH Puncak Lestari. Subsequently, the forest farmer group of the Cibulao hamlet has added 1,000 new robusta coffee seedlings.

3.4 Cultivation of coffee under shade

Coffee plants can be developed using the agroforestry system, because they are physiologically classified as C3 plants, so do not require full sunlight to grow optimally. With irradiation of 60%, they can already photosynthesize well. The presence of surrounding shade trees can encourage an optimal fruit ripening process, compared with no shade. Excessive sunlight can accelerate the maturation of the coffee fruit, because it is light. In addition, shade also provides benefits in the form of improved product quality, especially flavor [28 - 31]. The agroforestry system is one of the cultivation technologies applied to coffee plants as a precaution against global warming, and aims to maintain coffee production [9, 13, 25, 28].

The agroforestry system can also have a mitigation aspect, because it can increase carbon uptake by 10-15 mg/ha, even reaching 19 mg/ha. In addition, it can be used to increase the organic matter soil content from the deciduous leaves [9, 13, 25, 28]. From experience, people in Cibulao prefer to plant jackfruit and avocado for coffee plant shade, in addition to other plants. Petai (*Parkia speciosa*) and durian (*Durio zibenthinus*) have not been able to bear fruit. Coffee is harvested once period a year, with additional harvests of other fruit in other months, such as banana (*Musa sp*.), jackfruit (*Artocarpus integra*) and avocado (*Persea americana*).

3.5 Household income and revenue from coffee cultivation

Robusta coffee in Cibulao produces fruit once a year. Farmers harvest the ripe coffee fruit for approximately 2 weeks in July. Currently farmers prefer to try to sell the best quality coffee to obtain a better profit; they sell green beans. To calculate the level of increased income for farmers, the main household income of tea workers was used as a baseline, namely IDR 1,000,000/month/household.

The result is an increase in farmers' income by IDR 630,000/month/hectare or 63.0%, if the coffee is processed to cherries. A significant increase in revenue occurs if the coffee is processed in the form of green beans by 1,275,000/month/hectare or 127.5%. In the case of three of the respondents, they processed into green bean. Partinah earned IDR 1,122,000/0.88Ha/month, and Yono and Jumpono earned IDR 612,000/048Ha/month.

4 Conclusion

Robusta coffee cultivation under fruit tree shade increases farmers' income by IDR 630,000/month/household if they sell cherries, and by up to IDR 1,275,000/ month/household if they sell green beans.

The types of fruit that are suitable for the altitude of 1,200 a.s.l in Cibulao are banana, jackfruit and avocado, as additional shade trees apart from local species. This is a climate change mitigation and adaptation option, improving for the environment, socioeconomically, and for the robusta coffee itself.

Acknowledgements

We thank the LMDH Puncak Lestari, BKPH Bogor, Indonesia Climate Change Trust Fund (ICCTF). The research grant was funded by PITTA. We also thank Dr. Suyud Warno Utomo, M. Si as chair of reseacher group and Pratita Atinirmala, S. Si for her support.

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