Perception and adaptation of agroforestry farmers in Upper Citarum Watershed to climate change

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Abstract. Agroforestry is a form of an agricultural system that is adaptive to climate change. Based on the institutional form, the farming system developed under the social forestry program is agroforestry. This form of agroforestry is the essential capital for farmers to establish in their cultivated lands further. This study aim to determine agroforestry farmers' perceptions in the Upper Citarum Watershed on climate change and the adaptation activities. The sample farmers are a sub-set of farmer households sample in the socio-economic survey conducted by ICASEPS – ACIAR in the collaborative research in 2019. The reliability of the data on variables that reflect farmers' perceptions of adverse shocks experienced, which directly or indirectly related to climate changes, is tested with Cronbach's Alpha. Data analysis is performed by cross-tabulation, while multiple regressions are used to determine the effect of social forestry cultivated areas on farmers' income. The results show that more than 55 percent of farmers participating in social forestry say that since the last ten years climate patterns are increasingly unpredictable. The most negative impacts of climate change impacts are indirect effects which are pests and diseases. Popular adaptation are reactive ones, namely increasing the use of pesticides and more intensive use of inorganic fertilizers. Farmers adaptation which are more synergistic with mitigation such as organic farming or cultivation of perennial crops are still relatively low. The increase in the arable land area due to social forestry has significantly increased farmer's household income. Referring to this phenomenon, conducive policies to increase farmer participation in these adaptation actions are needed.

1. Introduction
One of the determinants of sustainable development lies on global climate change adaptation and mitigation actions. The main reason is interrelationships in terms of synergies and trade-offs between climate change and sustainable development [1, 2]. Based on theoretical backgound as well as lessons learned from empirical phenomena, many complementary points between adaptation and mitigation actions need to be developed synergistically [3].

In the climate change adaption and mitigation, the role of forestry sector and agricultural sector is very strategic. Forest plays a vital role in carbon sequestration [4]. On the other hand, the core business production process of the agricultural sector – farming - is very vulnerable to climate change, so the determinant of the performance lies in its success in adapting to climate change [5, 6]. Meanwhile, along with the population growth, food needs continue to increase. It implies that to feed the world, it is essential to scale up adaptation and mitigation in a synergistic manner and as much as possible avoid
deforestation [7]. In other words, climate change adaptation applied in food production systems must be based on a comprehensive understanding of the importance of maintaining vegetation ecosystem services. In such a context, agroforestry is one way, a model, and can also be understood as an adaptation strategy that is synergistic with mitigation [8, 9].

Agroforestry is a system of utilizing land resources for farming to simultaneously optimize financial benefits and environmental services by combining in an integrated manner of trees and shrubs with crop or livestock production systems [10]. Several studies have shown that by selecting perennial crops and crops, livestock, and setting the right spacing, a microclimate is formed that would support much to the growth of the plants cultivated on the land. With this condition, pest and plant disease control become more manageable, less farming costs, more efficient water use, and higher agricultural production income and farm income obtained [11, 12].

Although agroforestry can be a promising solution in mitigating climate change, it cannot be denied that its expansion is still very slow now. Meanwhile, the available data to explore the problems and obstacles faced in its development efforts are still inadequate [13].

In Indonesia, agroforestry has been practiced for a long time but usually at small piece of land belong to individual farmers. An example is the use of yard and garden land. On this land, many farmers combine fruit crops with seasonal crops and livestock.

One of the most interesting agroforestry models is the one applied to land owned by Perhutani in a social forestry institution called Community Forest Management (Pengelolaan Hutan Bersama Masyarakat – PHBM). Apart from being a form of adaptation that is synergistic with climate change mitigation, agroforestry on Perhutani land is also conducive to inhibiting the rate of forest encroachment by communities living around the forest. This model can be seen as one of the community-based forest management [14, 15]. The extent to which the effectiveness of this model in the context of climate change adaptation and mitigation is certainly related to farmers' perceptions of climate change and the adaptation practices they apply. This study aims to provide context-specific evidence to help policymakers and researchers and development organizations to gain a better understanding of how smallholder farmers perceive climate change and the potentials of promoting agroforestry systems to enhance their resilience.

2. Methodology

Data analysis in this study is a part of farm household survey data of “Agricultural Policy Research to Support Natural Resource Management in Indonesia’s Upland Landscapes”. The policy research is the collaboration of Indonesian Center of Indonesian Center for Agriculture Socio Economic and Policy Studies (ICASEP) with Australian Centre for International Agricultural Research (ACIAR). The survey was conducted on March – June 2019. The research site was at Upper Citarum Watershed located in West Java, Indonesia. There are 499 of farm household sample randomly chosen from 14 and 8 villages which are located in Bandung and Bandung District respectively. Out of the total sample are 129 social forestry farmers.

Descriptive statistical analysis is used to summarize and analyze data gathered through the household survey. Regression analysis is then implemented to examine the contribution of agroforestry on household income generation. The approach is carried out in the following way. The first step, a simple regression is applied estimate the contribution of PHBM cultivated land to the farmers’ total land holding. The prediction results obtained from the regression are then used as explanatory variables from the regression equation with the dependent variable is the total income of the farmer's household:

\[ \ln L_{tot} = \ln a + b \ln L_{PHBM} + e \]  
\[ \ln L_{nat} = \ln \alpha + \beta \ln L_{nat} + \varepsilon \]

Assume contribution of PHBM cultivated land reflected by its elasticity (E), then:

\[ E = \beta \cdot b \]
\[ \ln L_{\text{tot}} : \log \text{of total landholding (hectare)} \]
\[ \ln L_{\text{PHBM}} : \log \text{of PHBM's landholding (hectare)} \]
\[ \ln I_{\text{tot}} : \text{total income of the farmer's family} \]
\[ \ln L_{\text{tot}} : \ln L_{\text{tot}} \text{ predicted} \]
\[ a, \alpha : \text{intercept} \]
\[ b, \beta : \text{coefficient of parameters} \]
\[ E : \text{elasticity of total income subject to PHBM cultivated land} \]

### 3. Results and discussion

#### 3.1. Farmers’ perception

Farmers who are categorized as participants in social forestry in this study are those who work in Perhutani land in the Community Based Forest Management Program (PHBM). Out of the total sample surveyed (499) there are 129 sample that is categorized as social forestry participants. More than half proportion of the farmers who are participating in PHBM are farm workers who rely on their farming activities by working on other parties’ land. As an illustration, of the 129 sample households, only 55 (43%) farmers own their own farming land, and even their area is only 0.285 hectares on average. Of all farmers participating in social forestry, the average area of land cultivated by farmers is 0.96 hectares and of that around 0.86 hectares is land owned by Perhutani in the PHBM program. Thus the social forestry programme is very significant in increasing their land holding.

The choice of commodity type is one of the most important decisions in agroforestry. Considering the prospect of income earned by farmers and its contribution to land conservation, the popularity of coffee as a mainstay commodity in agroforestry occurs in this research location and several other PHBM locations. Based on several studies, coffee-based agroforestry systems are also widely practised in Latin America [16, 17]; Eastern Africa, for example, in Kenya [18], Ethiopia [19], and Uganda [20].

As required in PHBM program, the main commodities that farmers must cultivated are perennial crops. By considering the marketing potential and the expected profit, PERHUTANI and farmers in the research site agree to choose coffee as the main perennial crop. Related to the conditions of the agroecosystem, the coffee plants cultivated by the farmers in Bandung Regency are Arabica, while those in West Bandung Regency are Robusta.

Before deciding the adaptation method to be applied, of course, farmers must first be aware of climate change [21]. In this context, because Indonesia is located at the equator, the climate parameter that farmers most easily recognize is the rainfall pattern. In this study, the outcome variables for perceptions of climate change are (1) whether or not respondents observed changes in rainfall and (2) whether or not respondents observed an increase in temperature. Affirmative responses are assigned the value of “1”, and the rest, assigned to “0”.

To examine the perception, it is questioned to the farmers: “State all extraordinary events that occur, whether in the form of natural or non-natural events, and affect the agricultural activities and daily livelihoods”. There are 17 variables included in the extraordinary events and scale reliability (Cronbach’s Alpha) is 0.8216 which means that the data is consistent and reliable.

Of the 17 variables included in the shock, which are directly or indirectly related to climate change, the most prominent ones (in order of highest percentage) are: (i) pests and plant diseases, (ii) fluctuations in crop prices, (iii) drought patterns, (iv) rain patterns, (v) wind, (vi) the increase in staple food prices, (vii) scarcity of fertilizers, and (viii) land fertility. The top two shocks, namely pests and plant diseases and fluctuations in crop prices are not directly related to climate change. Comparison between shock variables in upstream and downstream area (Bandung versus West Bandung) shows that the difference is only in three aspects, namely: rainfall patterns, land fertility, and flooding. In Bandung, the percentage of farmers who experienced shocks related to rain patterns and land fertility is higher than farmers in West Bandung, while for shocks related to flooding events was the opposite (Table 1).
Table 1. Farmers’ perception on extraordinary natural or non-natural events affecting agricultural activities and daily livelihoods (%).

| Var | Shocks                           | Bandung | West Bandung | All  |
|-----|----------------------------------|---------|--------------|------|
| a   | farmland erosion                 | 4.7     | 4.6          | 4.7  |
| b   | flood                            | 1.2     | 6.8          | 3.1  |
| c   | landslide                        | 3.5     | 6.8          | 4.7  |
| d   | soil fertility                    | 18.8    | 6.8          | 14.7 |
| e   | rain pattern                      | 35.3    | 15.9         | 28.7 |
| f   | dry pattern                       | 41.2    | 31.8         | 38.0 |
| g   | pest                             | 56.5    | 52.3         | 55.0 |
| h   | fertilizer scarcity               | 17.7    | 13.6         | 16.3 |
| i   | pesticide scarcity                | 7.1     | 4.6          | 6.2  |
| j   | staple food price increase        | 18.8    | 15.9         | 17.8 |
| k   | price fluctuation of agric. commodities | 58.8 | 47.7 | 55.0 |
| l   | ash rain                          | 3.5     | 4.6          | 3.9  |
| m   | ice rain                          | 9.4     | 2.3          | 7.0  |
| n   | wind                              | 28.2    | 15.9         | 24.0 |
| o   | theft                             | 14.1    | 11.4         | 13.2 |
| p   | none                              | 17.7    | 22.7         | 19.4 |
| q   | other                             | 4.7     | 4.6          | 4.7  |
| n   | Number of Farm Household (n)      | 85      | 44           | 129  |

According to the farmers, the shock variable that affected most are fluctuations in harvest prices (26%), attacks of pests and plant diseases (19%), and patterns of seasonal changes, especially in their observations of the duration and beginning of the dry season (7%). On the other hand, there are around 14% of farmers who state that none of the 17 shocks have a real effect on their farming business and daily life. Presumably, the latter phenomenon is experienced by farmers who autonomously have adapted and or the conditions of their farming land are favorable.

More than half (53%) of the farmers say they heard about climate change. The farmers pay more attention to the climate parameter of changes in rainfall patterns, especially the duration and onset of the dry season. Around 56% of the farmers state the rainfall patterns is “unpredictable”, while 42% say that it is still “predictable”. In terms of temperature increase parameters, farmers in Bandung Regency state that there is an increase in temperature, it is around 45%, while in West Bandung Regency it is around 34%.

The impact of negative shocks that are directly or indirectly related to climate change on productivity and quality of agricultural products is very significant. It is about two thirds (66.67%) of the farmers who state that they experience a decrease in farm productivity. In terms of quality, it is about 59% of farmers state that the quality of their harvests is lower. In this context, the conditions that occur among farmers in Bandung are not much different from the farmers in West Bandung. On the other hand, the number of farmers who state that their productivity is not affected is only 22%, while those who state that their quality is still only about 27% (Table 2).

Table 2. Farmers’ perception on the effects of climate change to the productivity and quality of farm outputs.

|                | Bandung Productivity | Quality | West Bandung Productivity | Quality | Total Productivity | Quality |
|----------------|----------------------|---------|---------------------------|---------|--------------------|---------|
| Lower          | 67.1                 | 61.2    | 65.9                      | 54.6    | 66.7               | 58.9    |
| No impact      | 21.2                 | 23.5    | 25.0                      | 34.1    | 22.5               | 27.1    |
| Others*)       | 11.7                 | 15.3    | 9.1                       | 11.3    | 10.8               | 14.0    |
| Total          | 100.0                | 100.0   | 100.0                     | 100.0   | 100.0              | 100.0   |

*) Include “unpredictable, higher, and don’t know”.

3.2. Adaptation practices
To reduce the negative impacts of climate change, the farmers carried out several activities. There are at least 7 activities that the farmers can undertake. It is presented in Table 3.

Table 3. Percentage of farmers by the actions can possibly take to reduce the impact of climate change.

| Activity                                      | Bandung | West Bandung | Total |
|-----------------------------------------------|---------|--------------|-------|
| Diversify planting pattern                    | 82.4    | 17.7         | 84.5  |
| Add more (an organic) fertilizer              | 88.6    | 11.4         |       |
| Replace chemical with organic fertilizer      | 68.2    | 31.8         | 67.4  |
| Change crop variety                           | 97.7    | 2.3          | 93.8  |
| More intensive pesticide/herbicide utilization| 63.6    | 36.4         | 63.6  |
| More intensive on non-farming activities      | 95.5    | 4.6          | 94.6  |
| Plant more perennial crops                    | 88.6    | 11.4         | 89.2  |
| Don't know                                    | 79.6    | 20.5         | 76.0  |
| Other                                         | 93.2    | 6.8          | 92.3  |

Table 3 shows that the most popular adaptation practices of the farmers are the use more utilization of pesticide/herbicide and/or chemical fertilizer. On the other hand, farmers practicing diversify planting pattern, replace chemical with organic fertilizer, change crop variety, and cultivate more perennial crops are still relatively low. It means that in general the farmers adaptation tend to the short terms problem solving, reactive ones, and relatively have not convergence to mitigation.

Pro-mitigation adaptation actions such as organic farming or planting more perennial crops, although in the long term it can increase the effectiveness of adaptation activities, the benefits felt by farmers are long-term. Meanwhile, in general, farmers in the research site really crave for an income that can be obtained immediately (quick yield farming) because most of the farmers are small holding farmers and it is around a third of them are poor. In such conditions, the additional of land holding from PHBM and the existence of agroforestry in social forestry institutions can contribute significantly in encouraging the development of adaptation actions that are synergistic with climate change mitigation actions.

3.3. Contribution of PHBM cultivated land to income
The total income of farmers in this context does not only include income from farming but also includes income from off-farm activities, even non-agricultural activities. This is done considering the separation between these types of activities is often difficult to do.

In the parameter estimation, all variables are transformed into their logarithmic form so that the parameter coefficients directly show their elasticity. With the coefficient of determination (R-Adjusted 0.91), the estimation results show that the elasticity of the total area arable by farmers to the arable area of PHBM is 0.963 (t=37.76), while the elasticity of income (total) of farmers to the total land holding is 0.282 (t=3.18). In this case, the coefficient of determination is quite low (R-adjusted 0.07) because the total household income of farmers includes income from activities outside of farming, meanwhile farm income is not only determined by the area of cultivation but also the type of commodity cultivated, productivity farming, as well as the prices of inputs and outputs of farming. Using the two elasticities, then could obtain the elasticity of total income subject to PHBM’s land holding that is 0.272 which means that an increase of 10 percent of the PBM land area, total income of the farmers increases by around 2.7 percent.

The main income obtained by farmers from PHBM’s arable land is from coffee farming. The contribution of income from coffee farming to total household income is around 15.3 percent because some of the coffee plantation have not yet produced coffee beans. Especially for farmers whose PHBM lands have performed production, the average contribution is around 19 percent.
4. Conclusion
More than half of the farmers participating in the agroforestry are aware of climate change. The climatic parameters of concern to these farmers are changes in rainfall patterns, especially the onset of the dry season and its duration.

The most significant impact of extraordinary events that occur, whether in the form of natural or non-natural events, and affect the agricultural activities and daily livelihoods felt by the farmers are the sharpening of output price fluctuations and increasing pests and diseases. Also related to those matters, productivity and quality of crop yields decrease.

Popular adaptation actions among farmers are reactive ones, i.e. increasing the use of pesticides/herbicides and more intensive inorganic fertilizers utilization. The participation of farmers in adaptation that is more synergistic with mitigation by diversifying farming, organic farming, and cultivating more perennial crops is still relatively low.

The existence of a coffee-based agroforestry system on PHBM lands cultivated by farmers is one of the adaptation models that is synergistic with mitigation. Its contribution to increasing farmers' income is significant and therefore prospective as a model of a farming system that is adaptive to climate change. The implications are the policies and programs of mainstreaming climate change adaptation through agroforestry system, especially in the upper watershed to be prioritized.

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