AN ECONOMETRIC ANALYSIS OF AGRICULTURAL SUSTAINABILITY IN A MONTAINOUS VILLAGE OF WEST JAVA: Use of the Multinomial Logit Model to Soil Fertility Perception

Hiroshi Tsujii *

要約
途上諸国の農村での持続的農業発展に商業的農業をいかに取り入れるかは重要な問題である．本研究対象の西ジャワの一山間農村では、谷底の集落を取り巻く傾斜地でのアグロフォレストリーが村民の主たる所得源となり、谷底の小面積の自給的水田作がある。この村のアグロフォレストリーにおいて、インドネシアで食べ物の包装や加工に広く使用されているバナナ葉の傾斜地での栽培面積と販売が、過去5年ほどの期間年率30％という速い速度で伸び現在村域面積の半分程度を占めるまでになっている。バナナ葉の収穫が1年間に平均18回も行われ、肥料もほとんど使用されないから、村の傾斜地の土壌肥沃度低下が大きな問題になっている。本稿ではこの土壌肥沃度の低下問題を、以下のような計量経済学的方法で分析した．（1）農家の筆ごとの肥沃度認識関数をマルティノミアル・ロジット・モデルで計測し、この推定値をバナナ葉生産関数の一つの説明変数として推計した．（2）農家の葉バナナ作付面積決定関数を計測する．（3）農家のバナナ葉所得の農家諸所得に対する比率を推計する。この分析によって、（1）研究対象村における葉バナナ面積と生産の急激な拡大は、葉バナナ生産筆の土壌肥沃度を大きく低下さていること、しかし（2）バナナ葉は短期的に農家所得を大きく増加させ、それが葉バナナの研究対象村での急拡大の理由である．（3）ここに短期的農家所得の増加と長期的土壌肥沃度の低下のトレード・オフ問題が存在し、この問題を解決することが重要な問題である。農家の中には葉バナナの筆に豆科の潅木を植えそれを定期的に刈って葉を肥料にし、葉バナナ筆の雑草を緑肥にしたりしているものもあるが、この点の研究が必要である。

1. Introduction

Java is the most populated island in Indonesia, having around 59 percent of the total population of 210 million in 1999, although it occupies only seven percent of the total area of Indonesia (CBS, 1999). Population density of Java is 915 people per sq km in 1999 and is the highest in Indonesia. Indonesian average population density is 107. It is said that in Java there are about 50 million people in mountainous areas while the total population of Java is about 118 million in 1997 (Lie, 1999). It is also said that the number of villages in mountainous areas in Java is about seven thousand while the total number of villages in Java is about fifteen thousand (Hutabarat, 1990). These figures indicate the importance of the mountainous areas in Java.

The area used for agroforestry has been increasing rapidly for the past 20 years. Agroforestry in Java is done in the land classifications such as dry land and woodland. Percentage of those two land

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* The village survey and analysis of its data are assisted intensively by *Mr. Ageng Herianto, a Ph. D. student of Graduate School of Agriculture, Kyoto University*

classifications in total land use in Java has increased from 27 percent in 1980 to 29 percent in 1997, and this 29 percent is considered to be the maximum land use share for agroforestry. (CBS, 1999) As the share of those land use categories has increased, share of national forest in total land use has declined from 25 percent to 22 percent during the same period. These two sets of data seem to suggest that agroforestry has been spreading into forestland in Java, as we can frequently observe when we travel in rural Java.

Since the maximum share of land use for agroforestry in Java is now about 29 percent, which is greater than the share of land use for wet paddy field (28%) in 1997, we can say that agroforestry can be as important or more important than wet paddy production.

As agroforestry has spread into forest and mountainous areas where land slope is steeper than paddy area in Java, soil fertility there has a high probability of being depleted because of potentially high soil erosion and the application of soil-fertility-mining technologies pushed by population explosion. Long run change in arable land soil fertility in Java can be shown by the long run change in the ratio between yield of a crop to the input of chemical fertilizers to the crop. This ratio for dry land paddy that is usually grown in the first stage of agroforestry cycles in Java has declined by five percent from 1988 to 1996 as shown in Figure 1. This ratio for cassava and sweet potato, both of which have also been widely grown in the agroforestry systems of Java, has declined by about 20 percent during the same period as shown in the same figure (CBS, 1988-1999)

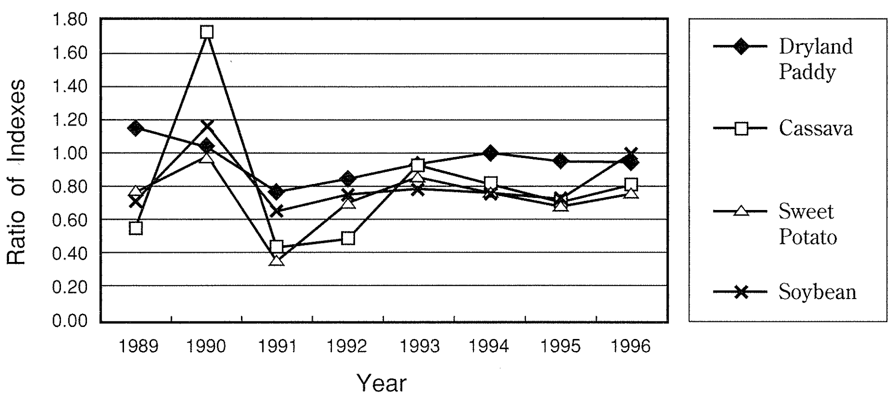

Figure 1 Yield changes of dryland paddy, cassava, sweet potato and soybean adjusted for chemical fertilizers application in Java(1988=1)

While population has been exploding both in mountainous and non-mountainous areas, the expansion possibility of wet rice area in mountainous area of Java is limited because of the topographical reasons. Thus, agroforestry has expanded and will expand more into forest and slopelands. Consequently, it is very important to study about sustainability of agricultural production in mountainous areas of Java.

In this paper, we try to analyze agricultural sustainability regarding soil fertility of a village in West Java by econometric methods using farm household and plot-wise agro-economic and agro-ecological data collected by our farm survey in the village in 2002. The name of the village is Kemang and it is located in a mountainous area in the eastern end of a valley of Bojong Picung sub-district of Cianjur, West Java. It lies about 25 km southeast of the district capital. The village area is 2,400 hectares, and there are 22 hamlets in it. Wet rice production is conducted in bottoms of the small valley of the village, mainly for self-consumption purposes, and occupies about 4% of the total village area. Agroforestry area and national forest land account for 37% and 44% of the total village area respectively. Agroforestry production has been done on the sloping land surrounding paddy fields in the village and on the national forest land surrounding the village area. Its commercialized activities yield more cash income to the villagers than paddy production. Banana *(Musa spp)* leaves (BLs, henceforth) sold for food wrapping purposes in big cities, sugar palms *(Arrena piñnata)*, Sengon *(Albizzia falcata)* trees, peppers *(Piper nigrum)*, red rice *(Oryza sativa)*, maize *(Zea mays)*, cassava *(Manihot esculenta)*, vegetables, and fruits trees are grown there.

BL area in the agroforestry of Kemang has been growing at an extremely fast rate of 30 percent per year during past 5 years and now covers about 50% of the total slope area. The BLs produced in Kemang are considered to have good quality by their urban markets because of Kemang's topographical condition at the tip of a valley with less wind to create less cuts on BLs, appropriate spacing of BL trees compared with adjacent villages, better variety of BL trees, and probably good marketing strategy by the forest farmers'cooperatives.

As BLs in each BL plot are harvested about eighteen times a year using about a week each time, extraction of soil fertility by banana leaf harvesting is extremely high. Consequently, extremely fast expansion banana leaf area in Kemang is a serious problem for sustainable agricultural development in Kemang. The purpose of this article is to analyze the impact of very fast BL area expansion to soil fertility in BL plots on the slopeland, and to the agroforester's household economy, and the reasons for the fast expansion of BL area and BL income based on the plot-wise and household data collected in our farm survey in January 2002 following previous short farm surveys in 1998, 1999, and 2000 of Kemang.

2. Problems and Research Methodology

2.1. The Problems and Research Objectives

As stated in section 1, the main research objective of this paper is to analyze the impact of very fast BL area expansion to soil fertility in the BL plots on the slopeland plots and to the agroforester's household economy, and the reasons for the fast expansion of BL area and BL income based on the plot-wise and household data collected in our farm survey in January, 2002. We would like to pursue this objective through three routes, i.e., (1) description of the interactions between plot-wise BL production and agroforesters'perception of the BL plot soil fertility. We intend to capture the negative effect of banana leaf area expansion to the agroforesters'perception of BL plots soil fertility and possibly to the slopeland soil fertility. (2) identification of factors by which the surveyed agroforesters decide the sizes of their managed BL area. (3) description of factors by which the surveyed agroforesters determine the shares of BL income in the total slopeland income (IBL/ISL), in the total agricultural and agroforestry income (IBL/IA), and in the total household income (IBL/IFM).

As we have discussed in section 1 of this paper, banana leaf area has been growing very rapidly in

Kemang during the past five years. Figure 2 shows the number of major trees managed by the surveyed agroforesters in the two hamlets, called Bebeur and Cikupa in Kemang (adjusted for changes in the sample size over time) during the past four decades. This figure reveals a very rapid increase in the number of banana leaf trees managed by the agroforesters. Because of the reason stated in section 1, this very fast expansion of BL area in Kemang could cause serious soil fertility depletion in BL pots and slopeland in general in Kemang. There are some coping technologies against this soil-mining problem used by the Kemang agroforesters. One method is weeding of BL plots and leaving the cut grass on the plot as green manure, second method called a pillowing *(babantal, Sundanese)* is putting cut logs on contours of the slope of agroforestry plots. Third method is planting leguminous trees with BL trees, such as Dadap Negeri *(Erythrina sp)* and *Calliandra calothyrsus.*

We would like to analyze the interaction between soil fertility and BL production, but we do not have direct soil fertility data. Instead we have asked the agroforesters their perception of soil fertility for the plots they manage. Thus the interactions between plot-wise BL production and agroforesters' perception of the BL plot soil fertility is done in the first route of our analysis, especially taking into account such factors as land use and soil fertility conservation measures, include these described just above in the perception function based on the plot-wise and household data collected by our farm survey.

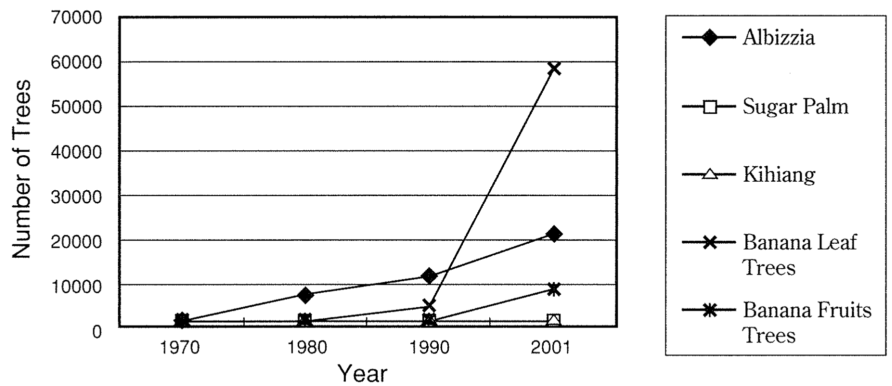

Figure 2 Numbers of dominant trees managed by the surveyed agroforesters adjusted for the changes in the number of surveyed households during past three decades

The main reasons why the BL area have expanded very rapidly in Kemang are (1) relatively high monthly cash income to the BL growers, (2) six months maturing period of BL trees before leaf harvest in comparison with 15 years of maturing period before sap can be harvested for sugar palm trees; i.e. a competitive tree crop in the agroforestry on sloped land in Kemang, and possibly (3) fast development of Kemang sales cooperatives of BL and banana fruits. But we think that when agroforesters decide the sizes of their BL areas, they also consider the risk of future due to BL price declines and preparation for large and irregular household expenditures such as education and marriage, etc. Considering these and other factors, we build a model that identifies the factors by which the surveyed agroforesters decide the sizes of BL area managed by them.

Since BL income has recently increased very rapidly in Kemang, it is interesting to identify how the surveyed agroforesters determine the shares of BL income in the total slopeland income (IBL/ISL), in the total agricultural and agroforestry income (IBL/IA), and in the total household income (IBL/IFM). This is done in the third route of our analysis. We will define share functions with appropriate input shares, a relative price, household head age and experience in BL production, and cooperatives membership as their explanatory variables.

2.2. Research Methodology

2.2.1. Research methodology

An econometric analysis of the cross-section and time-series data collected by our farm survey in Kemang in January 2002 was done. Standard multiple regression analysis, 2SLS approach, and multinomial logit analysis were applied in this paper. Hiroshi Tsujii assisted by Ageng S Herianto prepared a farm survey questionnaire that was used for conducting their farm and plot survey of agricultural sustainability in a village of Yogyakarta Province in September, 2001. A revised questionnaire was used for our Kemang survey, by which we collected farm household and plot data and short run and long run data on agricultural-agroforestry production, consumption, sales, and storages, agricultural-agroforestry inputs, yields and soil fertility sustainability, changes in natural conditions such as rain fall and temperature, etc.

2.2.2. Research sites and survey of the agroforesters' household economy and plots

Our survey was done in two adjacent hamlets, Bebeur and Cikupa of Kemang village. These hamlets were very similar regarding their agroecology, economy, and social factors. These two hamlets are in the central part of Kemang where the public service facilities, such as a primary school, a forest farmer cooperative, the village office, etc are located. The population of Kemang was 4,346 in 1999. Agriculture and agroforestry in Kemang were briefly described in section 1 above. The numbers of households were 107 in Bebeur and 55 in Cikupa respectively.

It is important to note that Kemang is one of the Social Forestry Program target areas that have been implemented by the Forestry Department *(Perum Perhutani* III*)*, West Java during the past decade. This program has let people who live near the national forest land cultivate food and other crops including bananas on the lands, and to take care of young trees at the early stage of the tree growth. In our survey, we first conducted short farm surveys and interviewed of three key informants concerning the agroforestry system and their activities in 1998, 1999, and 2000. Second, we conducted an intensive survey of 41 and 21 agroforester households out of the totals of 107 and 55 households in each of the surveyed hamlets in January 2002. The survey households were selected using a stratified purposive sampling technique. The stratification was done based on three criteria, i.e., (1) the ownership size of slopeland, (2) ownership size of paddy field, and (3) household income size, which was identified by Inoue, et al. (2000: 3-4) for the villagers' perception study for the concept of importance of households in the village. The survey households were selected from these three stratifications with weights consisting of the number of households in these stratifications. We also conducted agroforestry and sustainability surveys of all the plots managed by the surveyed agroforesters. The number of the plots surveyed turned out to be 104 in Bebeur and 39 in Cikupa

3. Theoretical Framework

Since our main hypothesis is that very fast expansion of BL area is the main factor that undermines sustainability or soil fertility in the slopeland in Kemang, our model focuses on the agroforesters' behaviors and perceptions regarding banana leaf economy and their relationship with soil fertility and their household economies in the village. [1)]

3.1 The BL plot soil fertility perception and BL production sub-model

Our theoretical model is separated into three interrelated sub-models. The first sub-model is named as the BL plot soil fertility and BL production sub-model that describes the interactions between BL production and agroforesters' perception of soil fertility using plot-wise data collected in our farm survey. We intend to capture the negative effect of banana leaf area expansion to agroforesters' perception of soil fertility and possibly to the real soil fertility.

The plot-wise soil fertility is usually known to the agroforesters but not known to the economists who use economic data. [2)]. Thus, a plot's soil fertility is usually excluded from the explanatory variables of the multiple regression estimation of the BL production function, and included unintentionally in the error term. Agroforesters determine input levels into each plot duly considering the soil fertility of each plot, thus causing the interdependence among independent variables and the error term that leads to biased estimates.

We collected plot-wise soil fertility perception, agroforestry and economic data from agroforesters' households, but we did not measure soil fertility directly in each plot. The agroforesters' plot-wise perception of soil fertility (SFBLA) was introduced into our BL production function as a proxy explanatory variable of plot soil fertility, and into our soil fertility perception function as the dependent variable. The introduction of the soil fertility perception variable to the BL production function is done in order to avoid the problem of interdependence among independent variables and an error term that was described just above. But this introduction causes simultaneous equation problems in the perception function and BL production function, and this problem is partly coped with in this paper by the 2SLS approach using the predicted value of the perception variable as an explanatory variable of the BL production function. The BL plot soil fertility perception and BL production functions are expressed in the next section.

3.1.1. Function for agroforesters plot wise perception of soil fertility

The function is specified as follows:

$$\text{SFBLA} = F1\,(\text{DNBL, MRU, CFN, CFP, WF, SL, HF, NFL}) \quad \text{\_\_\_\_\_\_\_\_} \quad (1)$$

The agroforester's plot wise perception of soil fertility (SFBLA) were categorized into three classes, i.e., low=1, normal=2 and high=3. The multinomial logit regression is an appropriate model used for handling this categorical dependent variable [3)]. A multinomial logit model for agroforesters' soil fertility perception is as follows:

$$\text{Prob (SFBLA= m)} = \frac{e^{\beta m`xi}}{1+\sum_{k=1}^{m} e^{\beta k`xi}} \quad \text{for m =1,2} \cdot\cdot\cdot \text{M}$$

$$\text{Prob (SFBLA= 0)} = \frac{1}{1+\sum_{k=1}^{j} e^{\beta k`xi}}$$

where we normalize our model by making ß3 = 0. The coefficients of this model can be estimated by the maximum likelihood method. We can calculate log odd ratios for our model as follows:

$$\text{Ln}\,\frac{Pi(SFBLA = m)}{Pi(SFBLA = M)} = \text{Xi}^{1}(\beta m - \beta M)$$

Where m takes the values of 1 and 2, and M takes the value of 3. The marginal effects of the explanatory variables on the probabilities are

$$\delta \text{m}\frac{\partial Pm}{\partial Xi} = Pm\left[\beta m - \sum_{k=0}^{M} Pk\beta k\right] = \left[Pm\ \ \beta m - \bar{\beta}\right]$$

The definitions of the dependent and independent variables in the equation are as follows:

SFBLA = Agroforesters' plot-wise soil fertility perception (low=1; normal=2; high=3. [4]).
DNBL = BL plot size/number of BL trees in the plot, m2.
MRU = Green/Home yard manure used for each banana leaf plot (kg).
CFN = Chemical nitrogenous fertilizer used for food crops (kg).
CFP = Chemical phosphate fertilizer used for food crops (kg).
WF = Annual weeding frequency for each banana leaf plot (times).
SL = Land slope for each plot (%).
HF = Frequency of past huma stage in a slopeland plot managed by each household (times).
DNFL = the national forest dummy. If 1, then the plot is in national forest land; =0, then in self-owned.

3.1.2. The BL production function based on the plot-wise data

PRBL = *F2* (P-SFBLA, BLA, LBH, DMFC, DMTR)________________ (2)

We assume log-linear specification for this equation. The definitions of the variables in the equation are as follows:

PRBL = Production of banana leaf from each plot (ponggol) [4]
P-SFBLA = Predicted values of agroforesters' plot-wise soil fertility perception.
BLA = Size of each BL plot (m^2).
LBH = Labor use for harvesting banana leaves for each plot (hours).
DMFC = Dummy variable for BL cropping patterns. If it is e, and DMTR = 0, then the BL trees are mixed with food crops, and its parameter is the difference between intercept for the group

of plots with BL trees mixed with food crops and of the group of plots with BL monoculture.

DMTR = If it is e, and DMFC = 0, then the BL plot is mixed with other trees, and its parameter is the difference between intercepts for the group of plots with BL trees mixed with other trees and of the group of plots with BL monoculture.

The estimated intercept the BL production function is the level of the production function for BL monoculture system.

Introducing SFBLA that is the agroforesters' perception of BL plots soil fertility into the first sub-model we face simultaneous equation problems in equations (1) and (2). In equation (1), i.e., the perception equation, SFBLA, DNBL, MRU, CFN, CFP, WF, and HF can all be endogenous variables. Considering the fact that the estimated cross-section behavior represents a long run behavior of an entity concerned, let us explain the interdependence between DNBL and SFBLA. If an agroforester uses more land per BL tree in one plot then we can think that the plot land is used less intensively, and the soil fertility of the plot will be maintained better, and thus in the long run the agroforester would evaluate the soil fertility of the plot higher. But conversely, we can also assume that the agroforester uses more land per tree because soil fertility of the plot is perceived as being low comparing with the other plots. Based on our information collected in the village, we assumed the latter causal relation is stronger, so that the sign of the estimated coefficients of DNBL is expected to be negative [5]. This negative impact of DNBL to SFBLA indicates a vicious cycle of agroforesters' using more slopeland for each BL tree, as they perceive soil fertility of the BL plot is decreasing because the fertility is increasingly mined by intensive monthly harvest of BLs.

The agroforesters in Kemang have taken some measures to cope with soil fertility depletion in their BL plots, such as weeding grass and leave them on the BL plots' floor as green manure, creating pillows on the plots' slope, and growing leguminous trees in the BL plots. Since all agroforesters conducted weeding, pillows were mainly for soil conservation in the early food crops stage of the Kemang Agroforestry, and leguminous trees were seldom planted in their BL plots we introduced WF as an explanatory variable of SFBLA function. There is also an interdependence relationship between WF and SFBLA in the sense that if more weeding is done, then in the long run the perception of soil fertility becomes higher, and conversely, if perceived soil fertility is high, then weeding frequency is reduced by the agroforester concerned. Based on our information collected in the village, we assumed former causal relation was stronger in this interdependence, so that the sign of the estimated coefficients of WF was expected to be positive. Similar interdependences can also exist between SFBLA and each of MRU, CFN, CFP, and HF. We assumed the signs of the estimated coefficients of MRU, CFN, CFP, and HF could not be theoretically pre-determined. The formal way to solve this interdependence problem is formulating a simultaneous equation model for our perception function. But in this paper we will not pursue this venue.

The signs of the estimated coefficients of SL and HF were expected to be negative. If the BL plot had greater slope and more *huma* frequency, we expected more soil erosion occurs there, and this would lead to lower perception of soil fertility in the plot by the agroforester. The estimated coefficient of DNFL was the difference between intercepts of the group of BL plots in the national forest and the group of plots owned privately and managed by the owner, its sign was expected to be positive.

Kemang villagers considered that national forest land was more fertile than their private slopeland surrounding hamlets and paddy fields at valley bottoms of Kemang, and only a small portion of the national forest land had been used by nearby villagers for BL and food crops production following the social forestry institutions. Thus we expected the estimated coefficient of DNFL to be positive.

The plot-wise BL production function, i.e. equation (2) above was formulated as the standard log-linear form with such explanatory variables as the predicted values of plot-wise soil fertility perception (P-SFBLA), BL plot size (BLA), BL harvesting labor (LBH), and dummy variables for BL cropping systems such as BL mixed with food crops (DMFC) and BL with other trees (DMTR). If we used the soil fertility perception (SFBLA) as its explanatory variable, we would face the simultaneous equation problem where greater SFBLA that was probably consistent with higher plot soil fertility results with greater BL production, but conversely greater BL production in the long run would deplete plot's soil fertility, and results in lower SFBLA. In this paper we utilized the 2SLS approach to cope with this problem. In this approach we estimated equation (1) by the multinomial logit method, then calculated the predicted value of soil fertility perception for each BL plot by the agroforester concerned, (P-SBFLA), using the calculated probabilities of each perception for each plot as explained just above. Then use this predicted perception variable as an explanatory variable of equation (2), i.e. the BL production function.

We expected the signs of the estimated coefficients for P-SBFLA, BLA, and LBH were positive. We expected the signs of the estimated coefficients of the dummy variables, DMFC and DMTR were negative because we assumed BL monoculture plots had the highest productivity comparing with mixed cropping BL systems represented by these dummy variables.

3.2. The sub-model for household decision concerning managed BL area

The second sub-model is the model for household decisions about its managed BL area. We assume that each household decides its BL area to manage based on the size of total slopeland managed, risk aversion and diversification, available resources for management, education and experiences, and a relevant relative price. The sub-model is given as follows:

$$BLA = F3\ (TSA, NPLOT, PFL, EXBL, PREDU, PBLBS_{21}) \qquad (3)$$

BLA = the total BL area managed by the household surveyed (m^2).

TSA = the total slopeland area managed by the household surveyed (m^2)

NPLOT = the total number of slopeland plots managed by each household surveyed (plot).

PFL = Number of productive family laborers who are over 14 years old in each household surveyed (person).

EXBL = Number of traditional agroforestry cycles experienced by the household surveyed (cycles).

PREDU = the period of formal education obtained by the household head surveyed (years).

$PBLBS_{21}$ = Farm gate price ratio between banana leaf and block palm sugar in year 2001.

We assumed that the BL area managed by a household increased as the total size of slopeland managed by each household grew. We also assumed that as NPLOT increased the surveyed household decreased the total size of BL plots managed as the household tried to reduce risk by diversifying the crops planted to the plots managed by it. Kemang agroforesters had tried to diversify their income sources to monthly sources such as BLs and seasonal sources such as Sengon (Albizzia falcata), and to stabilize their agricultural income by diversifying their trees grown on slopeland plots. The signs of the estimated coefficients for PFL, EXBL, and PREDU were expected to be positive, as family labor, experience in agroforestry cycles, and formal education of the household head increase, BLA would increase. By PBLBS21 we would like to capture economic effect of year 2001 relative price between BL and palm sugar, which are competitive crops for slopeland in Kemang. [6] The relative price differs among surveyed households by at most 40 percent because of product quality and markets for these commodities to be sold.

3.3 The sub-model for household BL income shares

3.3.1. Function for household BL income share in total slopeland income

This sub-model describes how household BL income shares in the total slopeland income (IBL/ISL), in the total agricultural income (IBL/IA), and the total family income (IBL/IFM) is determined by the sample households. The share of BL income in the total slopeland income is assumed to be determined by the following function:

$$\text{IBL/ISL} = F4\,(\text{BLA/TSA, LBL/LSL, PBLBS}_{21}\text{, EXBL, RAGE}) \_\_\_\_\_\_\_ (4)$$

The definitions of variables not yet described so far are as follows:

BLA/TSA = the ratio of banana leaf area to the total slopeland area.
LBL/LSL = the ratio of labor allocation between BL production and other slopeland agricultural production activities.
PBLBS21 = the relative farm gate price between BL and block palm sugar in 2001.
RAGE = Household head age (years).

We assume that all coefficients for explanatory variables have positive signs, except for RAGE. The sign for the coefficient of RAGE cannot be predetermined.

3.3.2. Function for the household BL income share to total agricultural and agroforestry income (IBL/IA)

This share is shown by the following equation.

$$\text{IBL/IA} = F5\,(\text{BLA/TFA, LBL/LFA, PBLBS}_{21}\text{, EXBL, RAGE}) \_\_\_\_\_\_\_ (5)$$

The definitions of the variables in equation (5) that were not defined so far are:

BLA/TFA = the ratio of BL area to the total agricultural and agroforestry area.

LBL/LFA = the ratio labor allocation between BL and agricultural and agroforestry activities.

We assume that all coefficients for explanatory variables except RAGE have positive sign. The reasons for it are self-explanatory. We hypothesize that the coefficient for RAGE has a negative sign because as the surveyed household head becomes older, it becomes increasingly difficult for the agroforesters to manage labor-intensive BL production that is usually done on steep BL plots. Thus the old agroforesters diversify their activities to less labor-intensive agroforestry production and rice production.

3.3.3. Function for BL income share to total household income (IBL/IFM)

This share is shown by

The definitions of the variables not yet described are as follows:

LBL/LTO = Labor allocation between BL and the other household economic activities.

COOP = Dummy variable for the membership of the household to the Forest Farmers Cooperatives; member= 1; otherwise = 0.

We expected the signs of the estimated coefficients for LBL/LTO and RAGE are positive and negative, respectively, because of the reasons just described above. The forest farmer cooperative was established in 1995 and has been run by a private farm leader. The cooperative sells BLs and banana fruits for its members and the leader, and sells daily necessities to the villagers. It has been expanding its activities very rapidly in the village during recent years. The sign of the estimated coefficient of the villagers' membership was expected to be positive. The sign is an indicator of the contribution of the cooperatives to the members' BL sales and income, and this will be checked by the sign of the estimated coefficient.

4. Results and Discussion

The total number of the surveyed agroforester households was 62, and the number of their agroforestry plots surveyed was 143. Out of the surveyed households, 49 had BL trees. There were three BL cropping systems in Kemang, i.e., (1) BL tree monoculture, (2) BL tree mixed with food crops, and (3) BL trees mixed with other trees. Out of 143 agroforestry plots, 75 had BL trees. Out of these plots, 25 adopted the first cropping system, 13 adopted the second, and 38 adopted the third. Regarding land tenure systems in the BL plots, out of these 75 BL plots, 44 were owned and managed, 19 were rented-out as share rent plots, and 12 were managed as the plots in the Social Forestry Program in the national forest land.

4.1. Estimation results of the sub-model for the BL plot soil fertility and BL production

The estimated parameters of the agroforester's plot-wise perception of soil fertility using the multinomial logit model are shown in Table 1. Chi-square test tells us that the overall model is statistically significant at 1% level. The Mc Fadden's Pseudo R2 was 0.26 and not very high. [7] The estimated marginal effect of dummy variable for being not in the national forest, i. e. DNFL = 0, to odd ratio was more than five times higher for the BL plots soil fertility of which were perceived to be low than the BL plots with normal soil fertility perception. This result is consistent with villagers' recognition that soil fertility in national forest land is much higher than privately owned slopeland near the village. The Wald statistic for β estimates indicated that the estimated coefficients for DNBL, MRU, and WF for the BL plots, soil fertility of which were perceived to be low were significant at normal levels. This significance result was almost consistent with the result for the linear probability estimation. For BL plots soil fertility of which was perceived to be normal, all the estimated coefficients were not significant.

Since the marginal effects for continuous explanatory variables to odd ratio and estimated β coefficients shown in Table 1 do not have any theoretical meanings and are not very useful, [8] we estimated marginal effects of explanatory variables to probabilities for each soil fertility category to be

Table 1 Estimation results of the agroforesters' perception with the multionmial logistic function

Variables	SFBLA=1			SFBLA=1			Performance of the model
	β_{1i}	Marg. Eff.to. Odd-ratio	Wald-statistic	β_{2i}	Marg. Eff.to. Odd-ratio	Wald Statis tic	
Constants	(1.692)			(0.014)			
DNBL	0.093	1.098	2.789*	0.042	1.043	0.651	Chi-quare =35.620***
MRU	(0.193)	0.825	3.809**	(0.052)	0.949	1.705	
CFN	0.170	1.185	2.294	0.060	1.062	0.556	
CFP	(0.488)	0.614	2.405	(0.059)	0.943	0.316	Pseudo R^2 McFadden's =0.26
WF	(0.130)	5.585	0.878**	(0.029)	0.971	1.201	
SL	0.009	1.009	0.031	(0.003)	0.997	0.004	
HF	0.203	1.225	0.154	0.606	1.833	1.793	
DNFL=0	2.932	18.764	1.917	1.141	3.131	0.939	

Notes: ( )=negative sign
*** =1%; ** =5%;and * =10%, significant level

perceived, and these effects are presented in Table 2. Absolute values of the marginal effects were much bigger in the third column comparing to the second column, and absolute values for the second column were near zero. From these results we could expect that if land use per BL tree, (DNBL), increased one unit, the probability of each BL plot to be perceived by agroforesters as normal soil fertility decreased by 0.256, and probably those plots were perceived to belong to low soil fertility category.

As we described in section 3, the sign of estimated coefficient for DNBL in linear probability model was assumed to be negative. We assumed that the agroforesters' soil fertility mining behavior was stronger than soil-conserving behavior in the BL plots surveyed based on our observations in the

Table 2 Estimated values of marginal effect of independent variables to the probability of soil fertility perception

Variables	δ SFBLA=1	δ SFBLA=2
DNBL	0.007	-0.256
MRU	-0.040	-0.321
CFN	0.019	-0.244
CFP	-0.088	-0.326
WF	-0.029	-0.305
SL	-0.010	-0.287
HF	0.025	0.132

surveyed village. The estimated results of multinomial logit model were consistent the asumption of stronger soil mining behovior for agroforesters in Java.

Comparing the other estimates of δ s for MRU, CFN, CFP, WF, and SL between the two columns in Table 2, larger and negative estimates for the second column suggest strong soil mining behavior rather than soil fertility conservation behavior of agroforesters in Kemang. These results suggest that very fast expansion of BL area had contributed to fast decrease of soil fertility in the BL plots and slopeland in general in Kemang.

The estimated parameters for the plot-wise BL production function using predicted value of SFBLA, calculated from estimated perception-category probabilities and the estimated multinomial logit parameters from Table 1, as an explanatory variable are shown in Table 3. The adjusted-R square was 0.43, and this was high. The estimated coefficients for P-SFBLA, BLA, and LBH were positive as expected in section 3 and significant at 1%, 5%, and 5% levels respectively. It is important to note that the estimated coefficient of the P-SFBLA was highly significant at the 1% level. Since P-SFBLA was introduced into the plot-wise BL production function as an explanatory variable following the 2SLS approach, this result indicated that the predicted value of the agroforester's perception of soil fertility in their BL plots calculated from the multinomial logit estimation served as a good independent indicator of the soil fertility.

The signs of estimated coefficients of two dummy variables that represent cropping systems such as BL with food crops (DMFC) and BL with other trees (DMTR) were consistent with the theoretical expectation described in section 3. These estimated coefficients for the dummy variables indicated that BL monoculture had the highest estimated intercept of production function followed by the cropping systems of BL with other trees and BL with food crops. [9]. All the estimated results were very consistent with the estimated results for a comparable linear probability production model.

Table 3 Estimated plot-wise BL production function

Variables	Standardized β_i	t-value	Significance level	
Constant	0.809			Adjusted
P-SBFLA	0.303	3.145	***	R^2=0.43
BLA	0.210	2.166	**	
LBH	0.216	2.262	**	
DMFC	-0.338	-3.114	***	
DMTR	-0.105	-1.031		

Note: *** =1%; ** =5%;and * =10%, significant level

4.2. Sub-models for household decision concerning BL area

The estimated parameters for this sub-model are presented in Table 4. The adjusted R Square was 0.71 and was very high. The estimated coefficients of TSA, PFL, EXBL, PREDU, and PBLBS21 were all positive as expected in the theoretical explanations presented in section 3.2 above. The estimated coefficients of the first three variables of those just discussed were significant. Meanwhile, the estimated coefficient of NPLOT was negative as expected in section 3.2, and significant at the 10% level. The negative coefficient of NPLOT indicates that the surveyed agroforesters averted their risk by diversifying their slopeland plot income sources in order to adapt monthly and seasonal expenditures of their households, and in order to stabilize their income from slopeland crops as we described in section 3.2.

Table 4 Estimated function for the managed BL area by the households surveyed

Variables	Standardized β_i	t-value	Significance level	
Constant	-7059.28			Adjusted
TSA	0.848	7.981	***	R^2=0.714
NPLOT	-0.189	-1.902	*	
PFL	0.140	1.737	*	
EXBL	0.149	1.831	*	
PREDU	0.081	0.932		
$PBLBS_{21}$	0.030	0.357		

Note: *** =1%; ** =5%;and * =10%, significant level

4.3. Sub-models for household' s BL income shares

4.3.1. Function of BL income shares in total slopeland income

The estimated parameters of the function are presented in Table 5. The adjusted-R square was 0.27. We found that all the explanatory variable's signs were positive as we expected in the theoretical framework above. The estimated coefficient of PBLBS21 was positive but not significant. This indicates that the change in relative price between BL and block palm sugar did not significantly influence BL income share.

Table 5 Estimated function of BL income shares in total slopeland income

Variables	Standardized β_i	t-value	Significance level	
Constant	-0.203			Adjusted
BLATSA	0.341	2.508	**	R^2=0.269
LBLLSL	0.350	2.667	**	
$PBLBS_{21}$	0.055	0.428		
EXBL	0.061	0.469		
RAGE	0.055	0.428		

Note: *** =1%; ** =5%;and * =10%, significant level

4.3.2. Function of BL income share to total agricultural and agroforestry income

The estimated parameters of the function are presented in Table 6. The adjusted R Square was 0.47. The signs of estimated coefficients were positive, except RAGE. The negative sign for the estimated coefficient of RAGE means that as the surveyed household head became older, the agroforesters faced more difficulties to produce BLs on steep plots and diversified their agricultural and agroforestry income away from BL as discussed in section 3.3.2.

Table 6 Estimated function of BL income share to total agricultural and agroforestry income

Variables	Standardized β_i	t-value	Significance level	
Constant	-0.224			Adjusted
BLATFA	0.343	3.107	***	R^2=0.472
LBLLFA	0.523	4.886	***	
$PBLBS_{21}$	0.094	0.877		
EXBL	0.003	0.026		
RAGE	-0.164	-1.522		

Note: *** =1%; ** =5%;and * =10%, significant level

4.3.3. Estimation results for the function of BL income share to total family income

The estimated coefficients of the share function are shown in Table 7. The adjusted R Square was 0.53. The signs for the estimated coefficients for LBLLTO and RAGE were positive and negative respectively. The estimated coefficient of the dummy variable, COOP, that differentiates the membership of the surveyed agroforesters, had a negative sign and was significant at the 10% level. This means that the BL income share to the total family income was higher for non-members than members. This result seems to indicate that being a member of the cooperative did not contribute to an increase in total family income through an increase in BL income.

Table 7 Estimated coefficients of the household BL income share to total family income

Variables	Standardized β_i	t-value	Significance level	
Constant	0.234			R^2=0.527
LBLLTO	0.666	5.174	**	
RAGE	-0.094	-0.725	*	
COOP	-0.223	-0.223		

Note: *** =1%; ** =5%;and * =10%, significant level

5. Conclusions

As population explodes and agriculture and agroforestry spread into sloped land and forest in Java, sustainability of natural resources such as soil, water, and forest have become serious problems in the mountainous area. In this paper, sustainability of soil fertility of a village in West Java was analyzed where very rapid expansion of banana leaf area into sloped land had taken place during the last five years by econometric methods using plot-wise and household data collected from our survey conducted in the village in January 2002, following previous short household surveys in 1998, 1999, and 2000.

Banana leaf (BL) area in the village has been expanding at the rate of about 30 percent per year into the private agroforestry area surrounding the small valley bottom paddy fields and hamlets during the last 5 years, and now it covered about 50 percent of the total private agroforestry area. As BLs in each banana leaf plot were harvested about eighteen times a year using about a week each time, extraction of soil fertility by banana leaf harvesting was extremely high. Consequently, extremely fast expansion of BL area in the surveyed village was a serious problem for maintenance of soil fertility there. We analyzed the impacts of very fast BL area expansion to the agroforester's perception of soil fertility in BL plots, BL production and surveyed household economy, and the factors affecting BL area expansion based on the econometric analyses of plot-wise and household data collected in our farm surveys.

It should be noted that the agroforesters' plot-wise perception function of soil fertility was introduced into our model and its predicted value was used as an explanatory variable of our BL production function as a proxy of plot soil fertility, and into our soil fertility perception function as dependent variable. Since soil fertility perception is a multiple choice qualitative dependent variable in the perception function, we used multinomial logit model to estimate its β coefficients. The introduction of the soil fertility perception variable to the BL production function was done in order to avoid the problem of interdependence among the independent variables and the error term of the production function that was caused by the unintentional exclusion of plots' soil fertility from the explanatory variables and including it in the error term. This exclusion was common because plot-wise soil fertility was known to the agroforesters but not known to the economists who usually use survey and statistical data. This introduction however caused the simultaneous equation problem in the perception function and BL production function, and this problem was partially coped with in this paper by the 2SLS approach using the predicted value of the perception variable as an explanatory variable of the BL production function.

Some important findings are as follows:

1. The results of the multinomial logit estimation of the agroforesters' perception function of plot wise soil fertility supported our hypothesis that the agroforesters' soil fertility mining behavior was stronger than soil conserving behavior in the surveyed BL plots and this result was consistent with our personal hearings and observations in the surveyed village. This was shown by negative, significant, and by far the larger estimated marginal effects to the soil-fertility-category probabilities of such explanatory variables as DNBL, MRU, CFN, WF, and SL for the plots, soil fertility of which were perceived as normal comparing with the plots perceived to have low soil fertility. The estimated coefficients of DNBL in the perception function, and this was consistent with our assumption that the BL growers in Kemang tended to use more land per BL tree in a sloped plot as they perceived their plots' soil was becoming less fertile. This suggests that very fast expansion of BL area had contributed to fast decrease of soil fertility in the BL plots and sloped land in general in Kemang.
2. Weeding was the popular BL plot soil conservation activity by Kemang agroforesters. The estimated marginal effects of weeding frequency (WF) by the multinomial logit method indicated that our hypothesis that the negative effect from soil fertility perception to weeding frequency more than offset the positive effect of weeding to soil fertility.
3. The BL area had expanded considerably into the very wide national forest, which has steeper slopes, and surrounds the Kemang private land area as the Forestry Department had allowed agroforesters to use a part of the national forest under the Social Forestry Program. The multinomial logit estimation results for the perception function showed that the estimated marginal effect of dummy variable for being not in the national forest, i. e. DNFL = 0, to odd ratio was more than five times higher for the BL plots, soil fertility of which were perceived to be low than the BL plots with normal soil fertility perception. This result is consistent with villagers' recognition that soil fertility in national forest land is much higher than privately owned slopeland near the village. But we fear soil fertility of the national forest will also be mined if the BL area spreads fast there without proper soil conservation measures.
4. In our plot-wise BL production function, predicted value of the soil fertility perception (P-SBFLA) calculated form the multinomial logit estimation results for soil-fertility perception function replaced SBFLA as an explanatory variable in order to cope with the simultaneous equation problem in the function, and estimated coefficient for this predicted value was positive and highly significant. This indicated that this predicted value of soil fertility perception functioned as a good independent proxy for plot-wise soil fertility after coping with the simultaneous equation problem. In the estimated results regarding the dummy variables of the BL production function, it was shown that the BL monoculture was most productive compared with other BL cropping systems. This indicates that if BL monoculture expanded its area rapidly, as it has been during past five years 6) would increase agroforesters' income in the short run, but it might deplete soil fertility faster in the long run since this monoculture system was a heaviest soil mining one.
5. It was found that each agroforester household decided its size of BL area by the total size of sloped land it owns, the size of household's labor, and experience in BL production. But, the estimated negative and significant coefficients of the number of plots that agroforesters managed indicates that they tried to diversify their income sources from monthly ones like BL production, to 5-10 year cycle sources such as sengon (Albizzia falcata).

6. It was found that the shares of BL income to the total sloped land income, the total agricultural and agroforestry income, and household income were significant in responding to relevant land and labor input shares. The estimated coefficient for the relative price between BL and palm sugar that are competitive crops in sloped land, had the correct positive sign, but was not significant at normal significance levels. The coefficient for household head's age in the share functions for agricultural income and household income was estimated to be negative but not significant. We think this suggests that older household heads try to reduce BL production, which requires hard labor on sloped land. Finally, the role of Kemang agroforestry cooperatives was identified as a negative significant coefficient to the dummy of membership in the share function for the total household income. This suggests that to be a member did not contribute to the increase of the share, and this was not consistent with our observation in Kemang. This result must be checked in future surveys.

Notes

1) Mercer and Miller says biophysical studies continue to dominate agroforestry research. (Mercer and Miller 1998: 177-193).
2) See Varian, Hal (1984: 171-188).
3) See Greene, (2000: 857-879).
4) *Ponggol* is a unit to count BLs, and it is one leaf consists of the two sides of a leaf after removing leaf stem. *Kompet* is a folded and tied bundle of ponggols of about 20kg each, and is a unit used for transaction between BL agroforesters and BL buyers in the village.
5) We could assume that the former causal relation was fixed in the true simultaneous relation, so that the estimated equation is the latter causal relation.
6) Calculating the relative price for the total 49 sample households who sell either BL or palm sugar, we used sample average price for the product that is not sold by the households concerned. Out of 49 households who plant BL trees, 29 households sold BLs as the main income source and sold no palm sugar, 17 households sold both BL and block palm sugar, and only 3 households sold both BLs and powder palm sugar.
7) The adjusted R squared is generally very low for multiple regression researches using micro data. Examples were Tsujii, Hiroshi, et al., (2002: 32-42), Tsujii, Hiroshi, (2000: 34-45), Pender, John, (2002 A: 1-10), Pender, John, at al., (2002 B: 30-40), Pender, John, (2001: 20-30), Place, F., et al., (2002: 35-45), and Swallow, B., et al., (2002: 11-20).
8) See Madalla ,G. S., (1992,p. 332).
9) BL monoculture has spread very rapidly in Kemang during last ten years.

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