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Valuing Socioeconomic Factors of Farmers´ Households and Economic Effects of Agroforestry System

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Abstract

The paper contains results of research realized in the rural area of Ucayali region in Peru, situated in the tropical zone in the Central East of the country. With the use of data acquired from agroforestry research on the demonstration plots and questionnaire survey on farmers´ households, the objective is to assess the economic effects of designed agroforestry multi-strata system by means of ex-ante approach. It was found out, that unfavorable financial results in first two years of the system, long production cycle of timber trees and low price of timber represent the principal challenges for adoption of agroforestry systems. The results drawn from the LP modeling described in this paper provided useful insight into the household's economy which is based on agroforestry production system. The results were elaborated within the research intention IVZ MSM 6046070906.

Key words

Agroforestry System; Linear Programming Model; Ucayali.

Anotace

Tento článek obsahuje výsledky výzkumu realizovaného v rurální části regionu Ucayali v Peru, který je situován v tropické zóně v centrální části země. Data byla získána z demonstračních parcel z agrolesnického výzkumu a provedeného terénního šetření u zemědělských domácností. Hlavním cílem tohoto příspěvku je zhodnotit ekonomické efekty navrženého agrolesnického systému zvaného multi-strata a to pomocí ex-ante přístupu.

Bylo zjištěno, že finanční ztráta v prvních dvou letech systému, dlouhý produkční cyklus dřevin a nízké ceny dřeva představují hlavní překážky pro přijetí agrolesnických systémův oblasti. Výsledky modelu lineárního programování popsaných v tomto článku poskytnou detailnější pohled na ekonomiku zemědělských domácností, která je založena na agrolesnickém produkčním cyklu. Poznatky prezentované v článku jsou výsledkem řešení IVZ MSM 6046070906.

Klíčová slova

Agrolesnický system, Model lineárního programování, Ucayali.

Introduction

Traditional slash-and-burn[1] (or shifting cultivation) systems1 with prolonged fallow periods are no longer feasible in most parts of the tropics, due to excessive growth of population placing greater demands on soil and forest resources (Fujisaka and White, 1998; pp.1). Farming systems, that imitate the structure and processes of natural forest vegetation, such as agroforestry systems, have high potential to increase the productivity of farming systems and sustain continuous crop production (Stark, 2000; Fagerström, 2000; cit. in Lojka, 2005; pp.3).

Leakey (1997; pp.5-7) defines agroforestry as "a dynamic, ecologically based, natural resources management system that, through the integration of trees in farmland and rangeland, diversifies and sustains production for increased social, economic and environmental benefits".

It is now generally acknowledged that practices which can be qualified as agroforestry are common among many Amazonian tribal and non-tribal farmers (Padoch and de Jong, 1995; pp. 226-237). Indigenous systems are found to provide subsistence and cash income while conserving soil, water and forest resources. For these reasons, indigenous agroforestry systems are being promoted as alternate models for rural development (Coomes and Burt, 1997; pp.27).

Agroforestry can improve productivity by increased output of tree products, improved yields of associated crops, reduction of cropping system inputs, and increasing labor efficiency (Nair, 1993; cit. in Lojka, 2005; pp.13). However, positive effects of agroforestry systems refer mainly to humid tropical conditions, and optimum conditions for fast decomposition are found under high average temperatures and continuous water supply. Tree biomass accumulation and nutritional contribution is generally less pronounced in arid, semi-arid and highland areas and available data are scarce (Anthofer et al., 1998, pp. 1). On the other hand, with increase in density of trees, their size, and/or ability to capture resources, they can exert strong competition for light, water and nutrients, and reduce annual crop yields beyond the interests of farmers if improperly selected and managed (García-Barrios and Ong, 2004, pp. 222).

Sustainability is achieved by conserving the production potential of the resource base, mainly through the beneficial effects of woody perennials on soils. However, the improved or new agroforestry technologies that are introduced into new areas should also conform to local farming practices. According to the research focused on feedback from farmers regarding their perceptions of technology it was found out that the benefits of sustainability are not always perceived by farmers. Especially resource-poor farmers may make sustainability a secondary consideration and thus may be more reluctant to adopt agroforestry technologies (Loker, Verab and Reitegui, 1997; pp.405).

Concern over adoption rates of agroforestry systems has highlighted importance of integrating socioeconomic elements into traditional biophysical agroforestry research (Nair, 1998; cit. in Alavalapati and Mercer; 2004, pp.1). The socioeconomic research[2] carried out by Thangata and Alavalapati (2003; pp. 68) find out that younger farmers are more likely to adopt agroforestry. They also state, that farmers with larger families are more likely to adopt agroforestry technology when compare to farmers with smaller families. For resource poor farmers, who cannot afford to apply fertilizers in their farming, agroforestry practices are thought to provide best alternatives. As the findings confirm, "better off households can afford to use high cost fertilizers. As such there is less necessity for them to adopt this technology.

Various research studies focused on the sustainability of production systems in the region of Ucayali have been carried out (e.g. Fujisaka and White, 1998; Fujisaka, Escobar and Veneklass, 2000; Loker, Verab and Reitegui, 1997; Kobayashi, 2004; Fujisaka et al., 1999; Smith et al., 1999).

Fujisaka and White (1998; pp. 1-15) analyze the role of agroforestry as a land use option in region Ucayali. It is suggested that analyzing the adoption of agroforestry systems the attention should be paid also to the conditions and trends in demand. Due to limited land and closeness to the urban market, the designed agroforestry systems developed in the Ucayali region should contribute to intensification and diversification of crop production including the establishment of perennial crops.

The need for proper agroforestry systems is supported in research made by Fujisaka, Escobar and Veneklass (2000). The findings show that the slash-and-burn agriculture reduces diversity of forest plants and increase weeds that lead farmers to more forest clearing. Reduced biodiversity in Pucallpa is due to disappearance of genuine primary forest, expansion of pasture area and pressure to hard wood trees as substitute to cocoa production. The research on land use systems and dynamics (Fujisaka et al., 1999; pp. 23) revealed that most of the farmers using slash-and-burn agriculture techniques arrived to the region Ucayali within 1990-1995. Migratory agriculture in Pucallpa leads to the fact that a high proportion of farmers´ lands is under fallow or secondary regrowth. Thus, the need to work with farmers on new agroforestry technologies such as multi-strata[3] systems is supported.

Based on this evidence, agroforestry dissemination is the main topic of the official development project of Ministry of Agriculture of the Czech Republic carried out by Institute of Tropics and Subtropics of the Czech University of Life Sciences from 2003. One of the main objectives of this project is development of agroforestry systems and technologies for improvement of soil quality of agricultural plots and design of sustainable production systems of agricultural households in the region Ucayali. Since 2004, demonstration plots where multi-strata systems are implemented have been established.

The paper deals with economic assessment of the designed multi-strata systems in the region Ucayali. Ex-post assessment of agroforestry adoption after the technology has been disseminated is useful to evaluate how the resources were used to extend the technologies. However, in this case, the demonstration plots with implemented multi-strata systems do not provide with economic results yet. Therefore, the assessment is based on ex-ante approach which assesses possible adoption before the technologies are disseminated (Mudhara and Hildebrand; cit. in Alavalapati, 2004; pp. 202).On basis of ex-ante assessment, this paper presents the use of dynamic linear programming (LP) model for simulating different situations of farmers´ households adopting multi-strata agroforestry system in the agricultural area of region Ucayali, Peru. The objective is to assess the economic effects of designed agroforestry multi-strata system and to evaluate socioeconomic factors of farmer households with the use of data acquired from agroforestry research on the demonstration plots and questionnaire survey on farmers´ households. The results will provide better understanding of household's economy in relation to agroforestry production cycle and thus will contribute to the process of agroforestry implementation, leading to greater sustainability of the production systems in the region Ucayali.

Characterization of research site

The Ucayali region is situated in the central part of Peru and forms a part of the Amazon River basin. It borders with the Loreto Department on the North, with Cusco and Madres de Dios on the South, with Brazil on the East and with Huanuco, Pasco and Junín Department on the West. Its surface is 102 410.55 km2 corresponding to 7.97 % of total national territory. Almost the whole region is covered by forests and by extravagant vegetation with the altitudes varying between 150 and 450 meters above see-level. The predominant climate is warm and humid and the precipitations are abundant (in average 2,344 mm annually) but do not exceed the precipitation of the cloud forest reaching 4,000 mm per year. The temperature fluctuates between 19°C and 30.6°C with the annual average of 26.7°C (Gobierno Regional, 2004; pp. 1).

The population of the Ucayali region is estimated to 460,557 inhabitants in 2003 what is 1.7% of the country's population (Instituto nacional de estadística e informatica, 2003) and is represented mostly by the immigrants from the coast and mountain parts of the central Peru and Amazon Basin that colonized especially the neighboring areas on the main road between the capital of the region - Pucallpa and Lima (Gobierno Regional, 2004; pp. 31).

The poverty rate of the Ucayali region is 70.5% and the level of population living in extreme poverty reached 44.9% that places this region to the ninth place of the poorest regions of Peru. The Human Development Index (HDI) of the Ucayali region was 0.55 that corresponds to the average level, reaching the lowest value for the forest parts. The value of HDI reflects differences in the indicators of GDP per capita and the distribution of income (Gobierno Regional, 2004, pp. 32).

In 2001, the Ucayali region contributed to the national GDP with US $ 462 millions that represented 0.85% while GDP per capita was US $ 1,026. The main production activities of the Ucayali region are: agriculture (farming) and forestry, manufacture industry, commerce, restaurants and hotels, fishery and mining (Křístková and Kalabisová, 2006; pp.1).

The region is divided into four provincials Coronel Portillo, Atalaya, Padre Abad and Purús. A study was carried out in the villages of Pimental, Antonio Raimondi and Nueva Belén. All the villages are situated nearby the capital of Pucallpa in the province of Coronel Portillo.

Nueva Belén, a hamlet of approximately 250 inhabitants with a bad access to the main road Federico Basadre especially during the rainy season, is situated 15 km from Pucallpa. The main activity of the farmers is recollection of the widely grown crop-plant and timber. The bad access to Pucallpa's market is a cause of under-developed agriculture. The principal crops are cassava, rice and pineapple. The productive land is in general poor and the main problem is excessive expansion of weed Imperata[4].

Antonio Raimondi lies 19 km from Pucallpa with the population of 300 inhabitants. This solitary village is surrounded by the terrain with the majority of pasture of bad quality caused by the weed of Imperata. Although the village disposes of suitable terrains for the pasture, beef-raising is not very well developed. The principal crops are cassava, raise, corn, citruses and other fruits. Nowadays a majority of the farmers desire to dedicate to the cultivation of sugar cane hoping to get good results.

Pimental is the most developed village of the entire research area with the total population reaching approximately 500 inhabitants and is situated 35 km from the capital of Pucallpa. In the near history, most of the inhabitants dedicated to the cultivation of pepper that was supported by the state subventions. Nevertheless due to the significant decrease of the pepper prices during last few years, the pepper production is not more profitable. Soils are in general poor and beside pepper, that still remains one of the most important crop, the most cultivated crops are citruses, rise and cassava (Lojka and Lojková, 2003).

Data sources

For the construction of linear programming (LP) model, two data sources have been used. Data dealing with designed agroforestry system were provided from demonstration plots and were related to labor requirements, material inputs, yields, producer prices and rotation of crops within a period of 10 years.

A questionnaire with mostly open-ended questions was developed to collect required information of households´ families. This questionnaire was pre-tested on two households and the output was used to make minor modifications in the questionnaire. 34 questions in the final version were divided into three groups, namely the information about:

- Agriculture related activities of the farmer;
- Age, education and occupation of all household members; and
- Detailed financial flows of the household including all sources of incomes and expenditures.

A total of 60 households (farmers' families) were interviewed from 10th July to 8th September 2006. Most of the questionnaires – 43 were obtained in the biggest village, Pimental. The rest, 10 questionnaires were obtained in Nueva Belén and 7 in Antonio Raimondi. The average age of the interviewed farmers was 48 years. Farmers spent in average 8 years at school, corresponding to second year of secondary school (primary education is six years). The average size of farmers´ families was 5 members (considering only permanent members of the household).

In the research area, the crop production predominates; 29 of the interviewed households noticed as main activity crop production, 10 households claimed as main activity animal production and 13 households obtained their incomes from other activities. Regarding farmers´ revenues, crop production reached in average 50% of total farmers´ revenues while animal production represented only 22%. The rest 28% of revenues originated from other activities such as recollection of the widely grown crop-plant and timber, commerce, hired labor and financial support from other family members.

Rice, cassava and maize represent main source of income from crop production (29% of the total income) followed by citruses with 20% and other fruits with 14%. Total average area of farmers´ plots was 23.8 ha; however the farmers cultivated only minor part reaching 3.7 ha, the rest of the land were pastures and fallows. With respect to the land ownership, 42 farmers claimed themselves as the registered owners, 14 as unregistered owners and only 4 claimed that lived on a hired land. More then 50% of households were producing on their land less then 20 years, whereof 9 farmers lived in the respective area less then 5 years. It was found out that 24 farmers included in the questionnaire survey were involved in the agroforestry project of Institute of Tropics and Subtropics by planting demonstration plots.

In the research area there is limited access to state support and microfinancing tools are not employed in a large extent; only 16 households of all research sample derived benefits from micro credits. Due to insufficient financial capital, the crop production is carried out with low inputs of fertilizers, seeds and machinery. Most farmers claimed that in case of having sufficient financial capital, they would invest to cattle production that is perceived as more stable and profitable.

Pucallpa represents the principal trade outlet for the farmers. Despite of its closeness, the undeveloped infrastructure and non-existing sales cooperatives make the commercialization of agricultural commodities difficult. To assess the economic effects of designed agroforestry multi-strata system, a representative farm household was chosen on basis of following criteria:

- farmer main activity is crop production,
- both the farmer's income and profit meet the average value of the sample, calculated on basis of percentile mean (Hendl, 2006, pp.103).

The characteristics of the selected farmer are given in Table 1.

Description of Agroforestry System

Agroforestry system was designed with respect to the experience gained from the research carried out in demonstration plots. For modeling purposes, the agroforestry system was simplified to final form with the total of five planting activities: cassava, pineapple, Inga edulis[5](Guaba), fruit trees (Annona muricata – Guanabana) and timber tree Bolaina (Guazuma crinita – Bolaina blanca) that represent major crops in the research area.

A dynamic 10-year LP model was chosen to reflect the rotation of the crops taking into account the long production cycle of Bolaina. The designed agroforestry system during a 10-year production cycle on one plot of land is demonstrated in Table 2.

The rotation of crops follows the multi-strata principle of agroforestry system. In the first year, the main cash and food crop (C) that is cassava, is planted on one plot of land together with guaba and other tree species (guanabana and bolaina). In the following year, cassava is grown again on the plot but due to the higher competition with the tree species, the cassava yields are lower. Since cassava cannot be planted more because of the insufficient light and nutrient competition with trees, in the third year it is replaced by pineapple (P). The competition between cassava and tree is also mentioned in work of Agbo et al. (1997). The pineapple is shade tolerant crop and is cultivated until the sixth year, when the tree cultivation prevails. Guaba (IE) is grown on the plot between the first and fifth year of the cycle. It is periodically pruned and thinned to minimize light and nutrient competition. Since the third year, fruit can be harvested. Last four years, only timber trees of bolaina (B) and fruit trees of guanabana (FT) are cultivated on the given unit of land. Guanabana fruit can be harvested since the third year and the trees has to be thinned to the final density of 150 trees of guanabana and 150 trees of bolaina per hectare in the fifth and seventh year. After ten years, the agroforestry cycle is finished, the timber is harvested and the rotation can start again following the described agroforestry practice on the same unit of land.

In the paper, the representative farmer applies designed agroforestry system on five units of land that represents total cultivated agricultural area of the farmer. Within the ten-year cycle, the agroforestry plots are gradually occupied in two years-period. In the last two years, the whole agricultural area is occupied by agroforestry plots. In order to meet farmer auto-consumption requirements, on the unoccupied parts of total agriculture area, the additional cassava mono-cultivation was introduced into the model. Due to the fact, that the additional cassava monoculture is planted without tree species, there is no competition problem and thus the yields do not decrease in the following year. Scheme of the agroforestry system of all the units of total agricultural land within ten-year period is demonstrated in Figure 1.

	Representative Farmer	Sample mean
Age	49	48.15
Education (years)	8	7.9
Number of family members	9	4.6
Total Annual Income [Soles*]	17.620	17.899
Total Annual Profit [Soles]	7.496	6.759

Notes: * US $ 1= 3.1853 Soles (as of March 13, 2007)

Table 1: The representative farmer.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
ALK	c	c	p	p	p					
	IE	IE	IE	IE	IE	IE				
	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT
	B	B	B	B	B	B	B	B	B	B

Notes: ALK- Agroforestry plot, C-cassava, P-pineapple, IE- Inga Edulis, FT-fruit trees, B- Bolaina.

Table 2: Agroforestry production cycle.

Household LP Model

Linear programming is a mathematical technique for determining the most desirable or most profitable course of action for situation where a number of variable are involved, where many possible courses of action are available, and where the problem can be expressed in linear terms. Thus, linear programming is another optimizing technique, however, which is applicable to many types of decision problems (Howel and Teichroew, 1963; pp.103).

Before the presentation of general form of the LP model it is necessarily to specify the specific assumptions, limitations and household behavioral characteristics that determine the design of the model. These assumptions are as follows:

[1] aim of the farmer's agricultural activity is especially to assure own auto consumption,
[2] decision making is presented by whole farmer's household,
[3] there are two kinds of decision processes: strategic ones with long term effects and operational ones with short term effects,
[4] auto consumption is partly provided by monoculture cassava and partly by purchasing local product on the market.

The general form of the LP model is represented by following description:

Maximize $z = cx$

Subject to $Ax \leq b$

$x \geq 0$

where z are revenues of the farmers at the end of the agroforestry cycle using their constrained resources (land and labor). C is row vector of revenues of each activity per hectare and x is a column vector of each activity. A is matrix of technical coefficients driven from demonstration plots and b is a column vector of farm resource endowments represented by household's labor, cash surplus and cassava auto-consumption requirements (including initial capital in the first year of the cycle). The model was processed by means of LP modeling application Linkosa.

The LP model is designed for a ten-year period. The objectives are:

- Determine optimal size of each five agroforestry plots.
- Find out additional area of cassava mono-cultivation to meet the auto-consumption needs of the farmers' households.
- Maximize revenues from sales of the cultivated agroforestry crops at the end of tenth year of the cycle.

The optimal size of agroforestry plots and cassava mono-cultivation is determined by constraints as follows:

- available annual family labor sources (calculated on the base of number of household members that are dedicated to crop production, taking into account the age of the members),
- initial available capital (assuming that all annual profit of the farmer at the beginning is invested into the model activities),
- cash surplus t = annual sales t-1 – annual fixed costs[6] (the sales in one-year period is transferred to following period to meet the future expenses),
- annual auto-consumption requirements (assuming cassava as the principal source of alimentation and considering only the family members permanently living in the farmer's household with respect to their age),
- available agriculture land,
- tree area limit (maintaining the same size of each agroforestry plot within the whole cycle),
- rotation of cassava monoculture (cassava can not be cultivated more than two consequent years on the same unit of land and simultaneously less than two years before the beginning of cultivation of agroforestry crops on the respective unit of land – as described in Figure 1).

In the LP model, the only investment that is carried out from the cash surplus is used to pay for the hired labor that enables to cultivate more crops within the limited household's available land.

Matrix of technical coefficients is formed by variable costs per hectare. In the case of agroforestry plot, variable costs per hectare are defined as sum of labor costs, expenditures on seed and tree plants and transport costs per hectare. According to the crop rotation, the amount of variable costs changes within the agroforestry cycle. In case of cassava monoculture, variable costs comprise labor and transport costs per hectare.

Analysis of LP model results

The described dynamic LP model was applied on example of the selected representative household family in two scenarios:

Scenario 1 (Model 1) assumes that there are no land and auto-consumption constraints. The results are interesting since they uncover the optimum structure of farmers´ agricultural activities (cultivation of agroforestry crops and cassava monoculture) on basis of available labor source and initial amount of capital. The results indicate optimal sizes of each plot within ten–year period.

Scenario 2 (Model 2) takes into account land and auto-consumption constraints and thus this scenario corresponds to the real situation of the selected farmer.

The results of the two scenarios processed in Linkosa are expressed in the Table 3. In the Table 3 it is evident that agroforestry crops are not cultivated in Model 1 during the first six years of the cycle. Only in the seventh year, the agroforestry plot enters to the cycle (ALK 4). All the activities are focused on production of cassava monoculture, which in the first period occupies 11.3 ha, in the second period 19.5 ha and in the third period 34.8 ha. The tenth year, total area of agroforestry crop reaches 28.1 ha and the area of cassava monoculture 65.6 ha.

Considering Model 2, the results are completely different. Due to the auto-consumption constraint, all agroforestry plots are cultivated within the whole cycle to meet the basic consumption needs of cassava. Total cultivated area (15 ha) corresponds to the household's available agriculture land. Financial flows originating from the results of the two models are expressed in the Figure 2 and 3.

Comparing two agroforestry models, it is apparent that the model with no constraints reaches more profit in the last year of the cycle achieving 104,259 Soles. On contrary to the second model, in the first three periods, the revenues flow only from cassava mono-cultivation. This is due to the fact that in the initial period, the cultivation of agroforestry plot brings the household into the loss. As the revenues from cassava monoculture grow, the farmer is able to cultivate up to 28 ha agroforestry crops in the seventh year that will bring considerable increase of revenues between the ninth and tenth year of the cycle (the fruit trees start to produce).

The problem with exclusion of agroforestry plot in the first periods is due to insufficient revenues from fruit and timber trees. Sensitivity analysis of cost coefficients shows that if the amount of revenues per hectare in the tenth year increased from 4,950 Soles to 6,928 Soles, the agroforestry plots would be included in the cycle from the beginning.

The amount of financial flows in case of Model 2 gradually rises. At the beginning, the farmer is facing a loss that will be recovered in the second period. The peaks in the graph correspond to the increase of revenues when the plots produce in the fourth period of the cycle (the fruit trees start to produce).

Impact of production factors on household's revenues

This chapter deals with the impact of land, capital and labor on revenues in the tenth year of the production cycle. The representative household has fixed amount of available production sources. The designed LP model enables to find out optimal level of revenues with one variable production factor maintaining the other two constant. Estimating the relation between production factor and output is useful to objective finding of the effectiveness of employed factors comparing real yields with their theoretical values (Tvrdoň, 2000; pp.65).

The paper assumes that the farmer employs three production factors: land, labor and capital. With respect to the land, the farmer disposes with limited

Variable	*ALK1*	*ALK2*	*ALK3*	*ALK4*	*ALK5*	*CM31*	*CM41*	*CM42*	*CM51*	*CM52*	*CM53*
Model 1	x	x	x	27.8	0.3	11.3	x	19.5	x	x	34.8
Model 2	5.8	1.1	0.4	7.5	0.1	x	x	x	x	x	x

Notes:"x" – variable is not cultivated in the respective year and plot, all variables are expressed in [ha].

Table 3: Comparison of two scenarios.

available agricultural land. Figure 4 demonstrates dependence of farmers' revenues on variable amount of available agricultural land. As shown in the Figure 4, the revenues increase substantially up to 40 ha of employed land. Afterwards, marginal revenues decrease. The saturation point of revenues is reached at the level of 165,248 Soles that corresponds to 93.6 ha of cultivated land. The regression curve that best estimates the dependency between these two variables is logarithmic regression function (as shown in the Figure 3). The coefficient of determination is close to one that corresponds to high rate of dependency of the respective regression function. In accordance to the economic theory, the estimated relation is of degressive type indicating declining marginal production expressed in Soles. According to the Figure 3, the selected farmer is situated in the first part of the curve, indicating the amount of revenues that could be reached with extending household's agriculture land.

Following production factor that was analyzed was the initial capital. Analogically to the previous case, the relation between revenues and capital was estimated taking into account fixed amount of agriculture land. The results of the analysis are demonstrated in the Figure 5. As shown in this figure, the relation between initial capital and the output, expressed in Soles, can be best estimated by means of quadratic production function with degressive character and a satisfactory high rate of dependence. On basis of the regression function it is possible to conclude that the productivity of initial capital is decreasing within the considered interval.

Situation of the respective farmer, as expressed in the Figure 5, indicates that the farmer's maximum potential revenue reached with a constant amount of employed land is 81,884 Soles, i.e. only 2,318 Soles less then farmers´ actual revenues. It is evident, that increasing of farmer's initial capital would not contribute substantially to growth of revenues. Based on the analysis of RHS (Right-Hand-Side), the maximum value of initial capital would have to be 11, 945.78 Soles to cause additional increase of revenues.

In the last case, relation between labor and revenues was analyzed taking into account only available household labor. The results of regression analysis are expressed in Figure 6. Maximum value of revenues that can be achieved with constant amount of initial capital and available land is reached when the household's labor costs are between 44,000 to 47,000 Soles that corresponds to 25 - 27 members of household. At this point, maximum sales would be 86,630 Soles, which does not represent a big increase in comparison with the actual level. As in case of initial capital, the additional increase of family size does not cause any substantial growth in revenues. The highest productivity of household labor is noticed at the beginning of the respective curve and it declines within the observed interval. From a certain point, with additional amount of household labor, the revenues start to fall down due to excessive cassava auto-consumption that leads to decrease of revenues originating from cassava production.

This analysis showed interesting findings regarding the effectiveness of production factors employed in the agroforestry production system. Comparing the real data of the respective household with the values from regression function it is evident, that having unlimited access to land, the revenues could be increased by 108% to achieve its maximum value. On the other hand, in case of initial capital, the actual value would be increased only by 3% and in case of household's labor only by 7% to reach the maximum revenues. This indicates that the amount of initial capital and household labor does not play essential role for the increase of household's production since the representative farmer employs these production factors in sufficient level. On the other hand it is evident, that the amount of land is limiting factor for production possibilities of the region.

Discussion

It was showed that the designed LP model represents a useful instrument to assess economic effects of multi-strata agroforestry system. However, there are some limitations that should be considered in further modeling stage. A remarkable limitation that is essential to the distribution of model activities is the maximization function that should be extended to include results from all the ten-year period and not only in the tenth year of the cycle.

In order to improve the results of agroforestry plots, it would be useful to extend the model to two agroforestry cycles (i.e. from 10 to 20 years period). The positive effects of agroforestry system are noticed only in the second cycle such as saving of the labor connected with the preparation of the plot and possibility to sell timber every year from the tenth year of the cycle.

Other considerations that would be useful to take into account are the positive effects of agroforestry systems such as improving of soil quality due to increase of nitrogen quantity by cultivation of Inga edulis and mitigation of the problem with weed extension by agroforestry tree species included in the system.

The designed model is a simplified version of the reality including various farmers' activities and range of commodities. Usually, the farmers are involved in many different activities, not only in crop production but also in animal production, recollection of widely grown plant and timber, commerce and so on. However, the model takes into account the real amount of the labor that the householder uses for crop cultivation. With respect to structure of commodities, in reality the crop production is more diversified and besides cassava and fruit trees include especially citruses, rice and maize.

It was found out, that in the first two years of the agroforestry cycle; the householder faces financial loss due to elevated labor costs and requirements of initial capital. This is the principal challenge for adoption of the agroforestry systems since the farmers are discouraged by negative financial results at the beginning of the cycle. As described by Mercer, an agroforestry system is likely to take three to six years before benefits begin to be fully realized compared to the few months needed to harvest and evaluate a new annual crop or method (Franzel and Scherr 2002). These characteristics can enhance opportunities for adoption by allowing more farmer experimentation and adaptation but can also complicate analysis of who adopts, what they adopt, and how they modify the system adopted (Vosti et al. 1998). The additional uncertainty inherent in these new input-output mixes is also an important reason for slower adoption rates and suggests that agroforestry projects will require longer time periods before becoming self-sustaining and self-diffusing than the earlier Green Revolution innovations (Amacher et al. 1993).

Another problem represents long production cycle of timber trees, where the benefits originating from selling of the timber are derived after ten years of cultivation (in case of Bolaina). Other timber trees have even longer production period and if included in the agroforestry systems, the agroforestry cycle would be extended. Furthermore, the prices of timber are unfavorable for the farmers and therefore the attractiveness of agroforestry systems is low. The main challenge for the future of the multi-strata agroforestry systems is to improve the commercialization of timber. It was found out that the price of processed timber tree is much higher then of the unprocessed tree.

An important remark is the investment activity of the farmers. The model assumes that the entire cash surplus is used for hiring of the labor and there are no savings incentives. In the reality, the cash-surplus might be spent in other activities such as cattle production, purchase of vehicle or other items increasing the living standard.

The results of the model would be slightly different, if discount factor was included. However, for this purpose of the paper, the discount factor was not considered relevant since the objective was to assess the optimal structure of agroforestry plots.

With respect to the effectiveness of production factors, it is necessary to realize, that the conclusions based on the regression analysis are only derived from the model and not from the real data. It should be taken into account, that the impact of labor might be different in reality because productivity of labor is lower then the model assumes (the real farmers´ yields might be lower then estimated). Also, the analysis does consider impact of hired labor on revenues by the reasons of model form that does not enable such analysis. Regarding the land effectiveness, most of the interviewed farmers cultivate in average only 16% of total available land (corresponding to 3.7 ha).

Conclusion

The paper was elaborated with the use of ex-ante approach. Ex-ante approach is a useful instrument of economic evaluation because it saves time and funds resources both of the farmers' households and the researchers. In addition, ex-ante approach is very helpful especially in case of agroforestry systems evaluation where the results of ex-post analysis are usually derived after a long time period due to prolonged production cycles. However, once the ex-post analysis is made, it can be compared with the results of ex-ante analysis too.

By means of LP model, optimal sizes of agroforestry plots were determined under the maximization criteria and consequently the results were used for evaluation of production factors effectiveness. The designed LP model was found to be proper tool for assessing the economic effects of multi-strata agroforestry systems. In the same light, the constructed model can be utilized for further analysis. Furthermore, the general character of the model enables to be used for agroforestry systems evaluation in different regions of the world. The results drawn from the LP modeling described in this paper provided useful insight to the household economy which is based on agroforestry production system and will serve for the realization of the development project of Institute of Tropics and Subtropics in the Ucayali region. Furthermore, the aim is to introduce the results of the paper to the households´ families.

Footnotes

1 Slash-and-burn agriculture or swidden/fallow system refers to farming or agricultural systems in which land under natural vegetation is cleared, cropped with agricultural crops for a few years, and then left untended while the natural vegetation regenerates (Lojka, 2005; pp. 13)

2 The socioeconomic research is based on exploring the differences between adopters and non-adopters in terms of their age, gender and other socioeconomic variables.

3 Multi-strata system is a combination of annual crops (e.g. maize and cassava), perennial crops and tree species (local fruit and timber species). Farmers begin to cultivate annual crops in combination with tree species at first. Annual crops are gradually replaced by perennial species and within few years tree species prevail in this system (Areaviva, 2007).

4 Imperata is a pandemic genus, found throughout the tropics. It is a rhizomatous perennial grass, with a spreading habit (Menz et al., 1998; pp. 2).

5 Inga edulis, a large genus of leguminous trees native to the American humid tropics, is popular with agroforesters for its rapid growth, tolerance of acid soils and high production of leafy biomass to control weeds and erosion (FACT Net, 2007).

6 Annual fixed costs are formed by living expenditures of the family: consumption goods, health, education, services and transport.

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