# THE INFLUENCE OF THE HOUSEHOLD AND FARM ATTRIBUTES ON ADOPTION OF SMALLHOLDER TIMBER PRODUCTION SYSTEMS IN THE GUNUNGKIDUL REGION, INDONESIA

Gerhard Sabastian[1,3], Peter Kanowski[1], Digby Race[1], Emlyn Williams[2], James Roshetko[3]

[1] Fenner School of Environment & Society

[2] Statistical Consulting Unit

The Australian National University, Canberra 0200, ACT, Australia

[3]World Agroforestry Centre (ICRAF), Bogor, Indonesia

Email: *gerhard.sabastian@anu.edu.au*

## Abstract

Agroforestry systems have been recognized as valuable for integrating local economic needs and environmental conservation; however, study on the socio-economic household and biophysical farm factors affecting management adoption of agroforestry by smallholders have not been closely examined in Indonesia, particularly in Gunungkidul region. This paper investigates the key determinants and the magnitude of the socio-economic household and biophysical farm factors influence for farmers on land and timber tree management; and provide opportunities for farmers to identify management options for their timber-based production systems which enhance household livelihoods. The household condition and composite models only selected the gross income of the on-farm and off-income variables as the determining factor affecting the likelihood of managing land and timber trees; while the farm characteristic model confirms total area managed as the significant variable. Treatments combining wide initial tree spacing at 4.0 x 4.0 m, light pruning of 40% and heavy thinning 75% produced the largest diameter and highest timber volume per stem for teak, and also highest net profits and returns to labour under conditions of increased interest rates and reduced log prices.

## Introduction

Discussions of tree growing practices in most Asia regions refer to the growing of trees near dwellings that provide products for subsistence and home consumption (Snelder and Lasco, 2008). These practices have had implications for spontaneous forest product diversification through the implementation of tree growing on farms (agroforestry) by smallholders who have limited access to nearby forest resources. Meyfroidt and Lambin (2011) argued that as implications of human population growth, the forest transition model has shifted from net deforestation to tree planting practices. Tree species have been re-located from their native habitats to tree-farm systems, through various forms and levels of domestication, to meet the diverse needs of smallholders for timber and non-timber forest products, water and soil protection and socio-economic services.

In the livelihood strategies theory, small-scale tree growing farmers are assumed to be “profit-maximisers”, means that the efforts of farmers to maximise their welfare by achieving their multiple household objectives, including secure provision of food and essential of subsistence goods, cash for purchase of outside goods and services, savings to meet future planned or emergencies, and social security to access the subsistence goods and productive resources. By selecting their livelihood strategies, farmers may pursue these household objectives to maximise the expected utility of lands, trees, labour, cash and other constraints, while at the same time they attempt to reduce the critical risk factors (Scherr, 1995; Ellis, 2000). Scherr (1995) and Foster and Rosenzweig (1995) added that agroforestry practise objectives for each farmer varies; determined by both their overall livelihood strategies and experience in a long-term experiment. The experiences vary from knowledge incentive assets for farmers to free-ride on the learning of others.

The choice of tree species is one of the most important decisions when an agroforestry system is initiated, influencing the multiple household objectives. Smallholders have often found the information regarding management and end-uses of candidate tree species to be very limited. Smallholders’ choice of tree species depends on four determining factors: (i) the purpose of the planned agroforestry planting, (ii) the availability of the prospec-


**Figure 1**. *Seven sub-districts as the research sites (♣).*

tive tree species for planting (iii) the growth of species on the available sites and compatible with crops, and (iv) the availability of the allocating households' assets (land labour, capital, and knowledge) (Evans and Turnbull, 2004). Therefore, whether the species is economically viable, socially acceptable and ecologically sustainable are the essential factors that need to be considered by smallholders in matching tree species and sites.

The district of Gunungkidul, situated in the southeast of the Special Province of Yogyakarta, Java, was chosen as a study area because of the occurrence of small-scale tree planting activities to address critical deforestation and soil erosion, which contributed to famines even (Van Der Poel and Van Dijk, 1987; Soerianegara and Mansuri, 1994; and Nibbering 1999). In the last 50 years, this depressing view of the Gunungkidul landscapes has diminished, since individual households have established farm forestry systems to regenerate soil productive capacity after prior degradation by planting timber, fruit and fodder tree species, such as teak (*Tectona grandis*), sonokeling (*Dalbergia latifolia*), coconut (*Cocos nucifera*) mango (*Mangifera indica*) and melinjo (*Gnetum gnemon*), as well as annual crops, on their own land (Nibbering, 1991a). There were 191,064 households and the average household size was 4 persons. Based on the age groups of the population, approximately 59.2% of the population were in the productive age (15 – 60 years) (Statistics of Gunungkidul Regency, 2009). Most farmers (63%) occupy less than 1 ha of land that consists of farmers with land holding less than 0.5 ha (37%) and those with 0.5 to 1.0 ha (26%). Only about 12% of farmers manage their land areas more than 2.0 ha. They were categorized as smallholder teak growers. Farmers with limited land ownership (< 0.5 ha) allocate around 10% of their land for growing timber trees in a woodlot (Rohadi et al., 2011).

Typical silvicultural practices of farmers of Gunungkidul are a barrier to improving the profitability of smallholder teak-based production systems, because they lead to a low quality of logs. According to Sabastian et al. (2009), only 12% of farmers have started to use improved seedlings for the plantations. Many farmers practising tree spacing of less than 2 x 2 m. Farmers assume that they can anticipate losses due to mortality and poor growth of some trees by using this tree density; however, in practice, this high initial stocking limits trees reaching more commercially-valuable sizes. Both teak and other timber species were typically managed at low intensity by farmers, who seldom thin, weed or fertilise their trees, or prune them properly. The trees gained the benefits of fertilisation and weed control only during the intercropping phase, viz. twice a year for the period for which intercropping was practised. Thinning was more likely to be practised when farmers needed cash urgently, viz. to generate income rather than to improve stand quality. Pruning was applied by 65% of farmers; however, the purpose of pruning mainly to collect fuel wood from branches, rather than controlling timber quality. Branches were cut using a machete, leaving 15 – 20 cm long-branch stubs, which impact adversely on timber quality.

Study on the socio-economic household and biophysical farm factors affecting management adoption of agroforestry by smallholders have not been closely examined in Indonesia, particularly in Gunungkidul region, and are often poorly understood. This paper investigates the key determinants and the magnitude of the socio-economic household and biophysical farm factors influence for farmers on land and timber tree management; and also the opportunities for farmers to identify management options for their timber-based production systems which enhance household livelihoods. The management options include the matching of timber tree growth on the available sites and to adopt agroforestry technologies by implementing silvicultural management and intercropping. The research questions of this study are formulated as follows:

1. How have household and farm circumstances influenced smallholders on adoption of timber tree-land management?
2. How have timber trees grown in effects of sites quality across the agricultural landscape?
3. What are possible management options and financial outcomes for enhancing the sustainability of timber-based production systems?

## Methods

### *Research Question 1*

Since the household is the decision-making unit regarding management of land and timber trees on farmer's own land, primary data were collected through face to face interviews with the 267 household heads from seven villages (Katongan, Candirejo, Bejiharjo, Karangduwet, Dadapayu, Giripurwo, and Giripanggung) in seven sub-districts (Figure 1). All data of the questionnaire were collected between May to September 2007 under the 2007 ACIAR Household Socioeconomic study, while data on land biophysical attributes was collected during October 2009 (Nuryartono et al., 2008). This research compared household that participated in land and timber tree management (152 farmers) those that did not participate in timber management (115 farmers). Eighteen explanatory variables representing information on household conditions and farm characteristics and the dependent variable that represented by Land-Timber Management was a binary or categorical (0: no management farmers, 1: management farmers) were utilized to develop models in the Logistic Regression analysis. The Logistic Regression models have been used in agroforestry adoption studies for analysing the quantitative importance of each explanatory variable in the models which driving the adoption of agricultural innovations by the households. In Logistic Regression analysis, nine explanatory variables (Number of Household Members, Household Head Age, Household Head Literacy Skills, Timber Tree Planting Experience, Working Household Members, On-Farm Working Members, Gross Income of On-Farm, Gross Income of Off-Farm and Timber Product Specification) were used to develop the household conditions model; while other nine explanatory variables (Total Area Managed, Number of Parcels, Area Owned, Soil Fertility, Farm Surface, Soil Thickness, Land Position, Distance to Nearest Timber Trader and Distance to Farmer House) were employed to develop the farm characteristics model. Then, all explanatory variables were combined to develop a composited logistic regression model.

### *Research Question 2*

Farmer collaborators and sites for this research were selected from those described in Research question 1. The total number of sites sampled was 48. At each of these, a circular plot of 10 m radius, corresponding to an area of 314 $m^2$, was established. A nested sampling technique was employed to select a sample representing each of:

- The three principle timber tree species – teak (*Tectona grandis*), mahogany (*Swietenia macrophylla*), and acacia (*Acacia auriculiformis*) - that are grown in the agroforestry systems;
- The three slope classes represented in the district, namely (i) 0 – 15%, (ii) 16 – 30%, and (iii) > 30%); and
- The two different soil types (Vertisols and Alfisols) represented in the district.

Tree biometric information (species, diameter at breast height–DBH, and age), farmland characteristics (slope and elevation), climate conditions (annual rainfall) and soil properties data (clay, sand, silt, pH H2O, C-organic, N, P, K, and Cation Exchange Capacity-CEC) were gathered from the circular plots during a series of field surveys. The process of data analysis and model building was addressed into two steps. The first step identified the individual and interaction effects of slope class, soil type, and average tree age variables on DBH growth of each tree species using the Two-way ANCOVA analysis. In this analysis, the average tree age was employed as covariate to other independent variables. The third step used Multiple Regression analysis to build a model for each tree species to estimate the contribution of both site variables (elevation, slope, bulk density, pH H2O, C-organic, N, P, K, CEC, and annual rainfall) and tree density variables (average tree age and tree density) on diameter growth of the trees.

### *Research Question 3*

In research question 3, the research aims to evaluate the effects of a various silvicultural regimes (initial spacing, pruning and thinning for teak; initial spacing and thinning only for acacia) on tree growth and volume production and to estimate the costs and benefits of silvicultural practices for farmers.

Models are widely used in assessing options for management of agroforestry and forestry systems. The modelling of agroforestry systems has also to contend with the interaction between trees and the other elements of the system. Van Noordwijk et al. (2004) describe key features of the WaNuLCAS (W*ater,* Nu*trient and* L*ight* C*apture in* A*groforestry* S*ystems*) model, formulated in the STELLA research modelling environment. The model is structured to represent a four-layer soil profile with four spatial zones, a water, nitrogen, phosphorus balance and uptake by a crop (or weed) and up to three types of tree(s). For this research, the WaNuLCAS core module requires a minimum set of input parameters: (i) climate conditions (climate and temperature), (ii) soil profiles (texture, C-organic, bulk density, pH H2O, Cation Exchange Capacity-CEC, nitrogen and phosphorus), (iii) tree functional parameters (biomass equation, phenology, canopy and other support structures), (iv) crop functional parameters (potential growth rates and allocation to harvested organs), and (v) management options (tree species and initial spacing – 2.5 x 2.5 m, 3.0 x 3.0 m, 4.0 x. 4.0 m; timber tree pruning intensities – 40%, 60%, 80% of the total bole height; timber tree thinning intensities – no-thinning, moderate thinning of 50%, and heavy thinning of 75%; crop types and planting schedules; crops harvesting events; use of fertilizer for crops). Data to parameterise the model were available from previous work in the Gunungkidul region, where on-farm trials conducted by ICRAF-Indonesia from 2008 to 2010 in Karangmojo sub-district, Gunungkidul, provided empirical field measurement data of diameter and height growth of teak and acacia trees for validation test purposes.

Benefit-cost analysis was selected as the method for financial comparisons of various silviculture alternatives in this research, and the Net Present Value (NPV) was used as the benefit-cost criterion of the investment at the interest rate (discount rate) considered. The investment is judged profitable and viable when NPV is greater than zero. The second criterion is that of the net returns to labour. Franzel and Scherr (2002) defined returns to labour as earnings that expressed per unit of labour; Tomich et al. (1998) argued that returns to labour can be viewed as the primary indicator of profitability for smallholder production systems. Sensitivity analysis was used here to assess the responsiveness of each simulation scenario (from no-silviculture management system to silviculture-based timber production systems) in response to the three different levels of interest rates - 5%, 10%, and 15% - and to log market price decreases of 25% and 50%, for both NPV and returns to labour criteria.

## Results and Discussion

### *Research Question 1*

The household condition model shows the performance of only gross incomes of both on-farm and off-farm significantly influenced land and timber tree management when all household condition variables were considered together; while the farm characteristic model confirms total area managed as the significant variable. The composite model only selected the gross income of the on-farm and off-income variables based on the significance of improvement as the determining factor affecting the likelihood of managing land and timber trees. Both the household condition model and the composite model explain that farmers who had on-farm income around 1.8 times more likely to manage their land and timber trees intensively, compared with the farmers who did not manage the land and timber trees. Meanwhile, the probability of applying management principles to land and timber trees increased by enlarging the total area managed for almost two times more.

In Gunungkidul, more intensive management of both agriculture and tree production systems was associated with increasing on-farm and off-farm incomes and greater total farm area. Agroforestry innovations, such as utilizing high quality planting materials and implementing silvicultural practices, can be more easily adopted by farmers when they have greater incomes, from either or both on- and off-farm sources. The total area owned and managed has implications on the proportion of agricultural land devoted to growing timber trees, tree crop production on both an annual and longer term basis, and income generation. The area of land owned and managed by a farmer seems very important in determining farming strategies, influencing productivity, input level, tree densities, and livestock densities.

### *Research Question 2*

The selection of teak, mahogany and acacia trees as the main species for smallholder tree growing and reforestation program in the degraded landscapes of Gunungkidul is appropriate. Long-term tree growing experience demonstrates that these tree species are well-matched to sites, and can be incorporated in various densities and arrangements in existing farm niches and farm crops. The site matching is shown by diameter growth responding differently to the soil type, slope and soil properties of the site. Diameter growth for all species was faster where trees grown in Alfisols than Vertisols. Sungkar (2008) categorized each of the species as drought resistant, since each have satisfactory growth in shallow soils of Gunungkidul. Results of this research shows teak and acacia grew faster on steeper slopes, while mahogany demonstrated the best growth on slight slopes. Lower levels of soil CEC and bulk density improved the diameter growth of acacia; while mahogany and acacia grew better under lower annual rainfall conditions.

### *Research Question 3*

This research investigated the results of simulations of a range of feasible management options of the production of both timber and maize crops under various tree-row intercropping systems. The growth and yield of two timber tree species in the system, teak and acacia, were estimated under management scenarios that ranged from no-silviculture to the most intensive silviculture likely to be practised by farmers.

The results show that, in the timber tree-row intercropping system, the maize yield decreased considerably after three years cropping period, since tree spacing, tree canopy and root system, and tree growth influenced maize growth. Increasing maize yield and the duration of the maize cropping period were possible when the distance between timber trees increased; however, the expected tree wood yield would be reduced as a result.

Initial spacing, pruning and thinning treatments in different intensities and schedules should be combined to manipulate the growth and yield of acacia and teak in the intermediate stages and at the end of rotation. This combination also impacts on the costs and revenues associated with tree growing. In the simulation, there was trade-off between effects of wide spacing at establishment, thinning and pruning. Increasing height of the pruned bole of teak leads to slower diameter and height growth. Within the regimes tested, the wider the initial tree spacing or the heavier the thinning of the initial standing stock, the larger stem diameter and higher timber volume per hectare attained. Therefore, treatments combining wide initial spacing at 4.0 x 4.0 m, light pruning of 40% and heavy thinning 75% produced the largest diameter and highest timber volume per stem for teak, and also highest net profits and returns to labour. This relative advantage remained under conditions of increased interest rates and reduced log prices. The sensitivity analysis of reduced log prices and increased interest rates indicated that the silviculture-based timber production systems are still a viable option for farmers in Gunungkidul.

## *Implications of Results for Smallholder Timber-Based Production Systems in Gunungkidul*

The results of research provide a basis for smallholders to move from low-intensity tree growing to more intensified management in Gunungkidul, particularly, and elsewhere in Indonesia where similar systems are practiced. Pattanayak et al. (2003) review of agroforestry adoption globally concluded that there are five indicators of smallholder adoption of agricultural and forestry innovations: preferences, resource endowments, market incentives, biophysical factors, and risk and uncertainty. It is likely that smallholder farmers in Gunungkidul would consider the results of this research in these terms. The results can be discussed in the context of the five indicators, as follows:

1. Preferences
   - Treatments that combine wider initial spacing and different pruning and thinning regimes allow for farmers to intensify their timber tree growing and produce higher yielding trees and less variation in log quality compared to no-silviculture management. This research found that a wide initial spacing at 4.0 x 4.0 m, light pruning to 40% of bole height, and heavy thinning of 75% produced the greatest timber volume per stem for teak, and highest NPV and returns to labour.
   - Planting trees at wider spacing in the timber-based agroforestry system will provide higher economic returns to the farm as a whole because: (i) crops can be planted in the alleys between rows of trees with higher yield, (ii) trees will grow faster because of the more intensive thinning, and (iii) farmers gain more benefits from the lower tree establishment and management costs.
2. Resource endowments (family labour, land, and on- and off-farm income)
   - In the silviculture-based timber production system, farmers with labour constraints will be attracted to the wider spacing of 4.0 x 4.0 m, labour requirements at establishment are reduced by 50% compared to the standard 2.5 x 2.5 m spacing.
   - Silvicultural practices in the systems can maximise land productivity with returns equivalent to a higher wage level.
3. Market incentives
   - Improved product quality resulting from application of wider initial tree spacing and pruning and thinning intensities on teak, and appropriate initial spacing and thinning intensity for acacia, can allow farmers to tap recover higher value and provide more economically attractive returns.
4. Biophysical factors
   - Information on the existing levels of soil nutrient and texture, soil type, elevation and slope, and annual rainfall can be used by farmers or those working with them to evaluate soil fertility levels and land productivity. Lower levels of organic carbon and nitrogen, for example, in the soils are associated with poorer diameter growth of trees and less total above-ground tree biomass. This information should be considered in the application of tree spacing and pruning and thinning intensities. Silvicultural practices in the timber based production systems should optimise impacts on soil fertility, minimise soil erosion, and optimise total above-ground biomass; and ultimately optimise benefits for farmer.
5. Risk and uncertainty
   - The results of sensitivity analysis of log prices and interest rates should reassure farmers of the levels of risk and uncertainty associated with integrated tree-crop systems. The analysis results indicated that silviculture-based timber production systems remain a viable option for farmers in Gunungkidul even when the log price is reduced by 25% to 50%, and under various interest rate scenarios.

- On the basis of the criteria of net present value and returns to labour, silviculture-based timber production systems will benefit individual farmers more than no-silviculture management systems.

## Acknowledgements

We thank other members of the ACIAR Project FST/2005/177 for their assistance in various ways for this work. We thank small-scale farmers who participated in the research.

## References

*Ellis, F., 2000. Rural livelihoods and diversity in developing countries. Oxford University Press, Oxford*

*Evans, J. and J. Turnbull, 2004. Plantation Forestry in the Tropics. The Role, Silviculture and Use of Planted Forests for Industrial, Social, Environmental, and Agroforestry Purposes. 3rd Edition. Oxford University Press, pp: 107-130*

*Foster, A.D. and M.R. Rosenzweig, (1995). Learning by doing and learning from others: Human capital and technical change in agriculture. Journal of Political Economy, Vol. 103, No. 6, pp: 1176-1209*

*Franzel, S. and S.J. Scherr (Eds), 2002. Trees on the farm: Assessing the adoption potential of agroforestry practices in Africa. CABI Publishing in association with ICRAF, Nairobi, p: 186*

*Meyfroidt, P. and E.F. Lambin, 2011. Global Forest Transition: Prospects for an End to Deforestation. Annual Review of Environment and Resources, 36, pp: 343-371*

*Nibbering, J.W., 1991a. Hoeing in the Hills: Stress and Resilience in an Upland Farming System in Java. Unpublished PhD Thesis, Australian National University, Canberra*

*Nibbering, J.W., 1999. Tree planting on deforested farmlands, Sewu Hills, Java, Indonesia, Impact of economic and institutional changes, Agroforestry Systems, 57, pp: 173-186*

*Nuryartono, N., N. Kusumowardani, J. Effendi, and H Hasanah, 2008. Aspek finansial petani jati Gunungkidul. ACIAR Project Report, Improving Economic Outcomes for Smallholders Growing Teak in Agroforestry Systems in Indonesia, Inter-CAFÉ Bogor Agricultural University, Indonesia*

*Pattanayak, S.K., D.E. Mercer, E. Sills, and J.C. Yang, 2003. Taking stock of agroforestry adoption studies. Agroforestry Systems, 57, pp: 173-186*

*Rohadi, D., J. Roshetko, A. Perdana, M. Blyth, N. Nuryartono, N. Kusumowardani, A.A. Pramono, N. Widyani, A. Fauzi, M.J. Sasono, P. Sumardamto, 2011. Improving economic outcomes for smallholder growing teak in agroforestry systems in Indonesia. Final report of project no. FST.2005/177. Australian Centre for International Agricultural Research (ACIAR), Canberra*

*Sabastian, G.E., J.M. Roshetko, D. Anggakusuma, A.A. Pramono, I. Heriansyah, and A. Fauzi, 2009. Smallholder teak-based farming management in Gunungkidul, Yogyakarta: Current Practice, Obstacles and Improvement Options. ACIAR Project Report, Australian Centre for International Agricultural Research and World Agroforestry Centre*

*Scherr, S.J., 1995. Economic factors in farmer adoption of agroforestry: Patterns observed in Western Kenya. World Development, Vol. 23, No. 5, pp: 787-804*

*Snelder, D.J. and R.D. Lasco, 2008. Smallholder tree growing in South and Southeast Asia. In: Snelder, D.J. and R.D. Lasco, (Eds) Smallholder tree growing for rural development and environmental services, Lessons from Asia, Advances in Agroforestry. Springer, Vol.5, pp: 11-12*

*Soerianegara, I. and Mansuri, 1994. Factors which determine the success of regreening in Gunungkidul, Central Java. Journal of Tropical Forest Science, 7(1), pp: 64-75*

*Statistics of Gunungkidul Regency, 2009. Gunungkidul in Figures 2009, Katalog BPS: 1102001.3403, collaboration between the Regional Development Planning Board of Gunungkidul and Statistics of Gunungkidul regency, Yogyakarta, Indonesia*

*Sunkar, A., 2008. Sustainability in karst resources management: the case of the Gunung Sewu in Java. A thesis submitted in fulfilment of the requirements for the degree of Doctor Philosophy, The University of Aukland, New Zealand*

*Tomich, T.P., M. van Noordwijk, S.A. Vosti, and J. Witcover, 1998. Agricultural development with rainforest conservation methods for seeking best bet alternatives to slash-and-burn, with applications to Brazil and Indonesia. Agricultural Economics, 19, pp: 159-174*

*Van Der Poel, P. and H. Van Dijk, 1987. Household economy and tree growing in upland Central Java, Martinus Nijhoff Publishers, Agroforestry Systems, 5, pp: 169-184*

*Van Noordwijk, M., B. Lusiana, N. Khasanah, 2004. WaNuLCAS 3.01, Background on a model of Water, Nutrient, and Light Capture in Agroforestry Systems. World Agroforestry Centre, Bogor, Indonesia*