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Agroforestry: What Matters - Today or Tomorrow?

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Abstract

This paper[1] investigates the determinants and impact of agroforestry for smallholders in rural Tanzania. Two questions are addressed: (1) Do these factors drive farmers to grow trees? (2) To what extent does tree cultivation contribute to income generation of households? The empirical results show households with higher environmental awareness, property rights, and less yield losses cultivate more trees per acre. Also the future evaluation plays an important significant role. Here, suitable measures to increase future expectations and environmental awareness need to be developed to increase tree cultivation. However, the impact assessment shows that only trees up to a certain income level influence income positively. For more prosperous households other income sources such as cash crop production play a more important role; here trees per acre influence the income per capita negatively. This leads to the conclusion that trees may be more important for the poorer households compared to the more prosperous ones.

Keywords: agroforestry, time preference, quantile regression, Tanzania

1. Introduction

The poor living in rural areas derive a high share of their income from forest and soil resources such as timber, firewood, fruits, or vegetables (Holden et al., 1998). In the course of environmental degradation and an increasing global awareness of scarce environmental resources, special emphasis is given to the protection of high-valued areas such forests.

Uluguru Mountains (UM) - part of the Eastern Arc Mountains in Tanzania (EAM) – are an ecosystem of global importance belonging to the 25 "biodiversity hotspots in the world". The UM are threatened by high degradation and hence according to the Tanzania Forest Act of 2002 covered by the highest level of habitat protection. This formation of the Uluguru Nature Reserve (24,115 ha) in November 2008 had huge implications on the livelihoods of the village population as they are regulated to extract only a few forest products from the forest reserve (Doggert et al. 2004). Limiting rural communities from access to forest resources without adequate alternative income and energy sources is a major challenge to livelihoods of conservation programs. Tandai, a village within the Uluguru Nature Reserve and Kitumbatu forests margins represents the case described above. Since cutting trees for firewood and charcoal production is only possible to a limited extent, a shortage esp. in terms of energy supply occurs.

As a consequence, agroforestry increasingly became part of the production portfolio of small-scale farmers. Agroforestry includes tree planting next to crop growing on the same plot, and thus provides new income possibilities, substituting the extraction of firewood, timber, and wild fruits or vegetables from forests. In addition, it is a promising solution to

[1] The paper has been written in the context of the project "Strategies to use Biofuel Value Chain Potential in Sub-Saharan Africa to respond to Global Change - Enhancing low-productivity Farming in Tanzania and linking to SMEs" (http://www.better-is.com/). The project was funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) under the umbrella of the GIZ (former GTZ) project "Advisory Service on Agricultural Research for Development" (BEAF). This work is a further development of a diploma thesis, executed at the Institute for Environmental Economics and World Trade, Leibniz University of Hannover.

alleviate soil erosion on agricultural plots and hence helps stabilizing or even improving yields. Thus, tree cultivation implies an environmental long-term farm investment. The individual evaluation of the future - defined as time preference - plays an important role in the investment decision. The rural poor often have high time preferences which are correlated with a decreasing probability of investing in natural resources, because they value consumption today more than in the future. In the case of agroforestry, benefits from agroforestry accrue in the future, but seedlings and fertilizers have to be bought in the present.

Many studies analyzed determinants of tree cultivation on agricultural plots (e.g. Caveness and Kurtz, 1993; Current et al., 1995; Benin et al., 2003). However, no socioeconomic study is known to the authors, which tried to quantify the influence of today's needs and future evaluation of small-scale farmers on the adoption and utilization of tree cultivation. This paper aims to analyse the impact of today's needs and consumption behaviour from agroforestry and the future evaluation including individual time preferences on the intensity of tree cultivation and its importance for income generation. The paper is structured as follow: In chapter 2 a literature review is given on agroforestry. In chapter 3, the methodology is described in chapter 4. The data collection and a short description of the study area are presented as the basis for the results included in chapter 5. Finally, this paper concludes in chapter 6.

2. Literature Review

Agroforestry characterizes the intentional use of trees and other woody perennials at the same unit of productive land where agricultural crops are grown or which is used for pasture or animal keeping to benefit from the resulting ecological and economic interaction (Nair, 1985). Growing crops and trees on the same unit of productive land is defined as agrisilviculture. The outcome is a mixed spatial arrangement of different land uses at the same place and (Current et al., 1995). The smallholders themselves tend to adapt agroforestry to their personal needs, their production possibilities and resource constraints (Adesina and Chianu, 2002).

Benefits from agroforestry accrue from a positive influence on the environment, and hence a reduction of risk exposure for smallholders, and the availability of construction material, fodder and fuelwood. A significant environmental advantage results from trees and shrubs due to effects against soil erosion (Gebreegziabher et al., 2010). Benin et al. (2003) surveyed Ethiopian smallholders who reported less erosion problems and higher fertility-levels on plots where trees were planted. In addition, smallholders in Honduras depended for 100% of their tree products on natural forests and meet now the majority of their needs for tree products from trees they planted on their farms (Current et al., 1995). Hence, agroforestry schemes can lower the pressure on ecosystems. Other benefits such as planting trees for fruits or timber is a benefit due to the provision of food and building material (Gebreegziabher et al., 2010), but also trees which are not needed for the own consumption can serve as a source to generate income (Shively, 1999). In stressful periods, farmers who cultivate trees can bridge the time gap by selling tree products on the market to generate cash income (Nibbering, 1999).

Despite the highlighted positive effects, there are some aspects that might prevent smallholders from agroforestry. One of the reasons is that initial investments - e.g.

seedlings, young trees – are required for agroforestry and further occupy some of the cultivable area. Little or no savings may result in limited access to credits. Hence, the decision to invest in soil conservation incorporates tensions between the objectives to protect yields in the long run and avoid a shortfall of liquidity in the short run (Shively, 2001). Credit markets often function poorly in developing countries; and the interest rates for loans to establish agroforestry may be very high (Hoff and Stiglitz, 1990). This circumstance even increases the opportunity costs for smallholders who borrow money to establish agroforestry. Moreover, opportunity costs of land, labor as well as agricultural inputs such as water and fertilizers accrue to the smallholders. Besides monetary and opportunity costs, the potential competition of crops and trees or shrubs on the cultivable plots has to be taken into account when evaluating the costs and benefits of agroforestry. A positive example is given by a study conducted in Indonesia where cassava was cultivated below trees. The cassava tolerates shade better than cereal crops and therewith the trees were less competitive to the crops grown beyond (Nibbering, 1999). However, before agroforestry can actually alleviate soil erosion, the awareness of having yield losses due to soil erosion is important together with the knowledge that agroforestry has a positive impact on soil quality and thus on the yields in the long run. The perception of soil conserving technology again depends on the information which is available to the smallholder (Caveness and Kurtz, 1993). Information on the options against soil erosion can be provided by extension services.

Individual future evaluation can be measured applying the time preference approach. Holden et al. (1998) claimed that poverty may lead to short planning horizons, which may prevent poor farm households from investing in conservation to protect their natural resource base. Yet there have been only a few empirical studies assessing the rates of time preference among rural poor in the nexus with environmental conservation measures. Holden et al. (1998) assessed the impact of individual discount rates on the soil conservation behavior and deriving the difference between the social and private costs in agricultural production.

The pure rate of time preference is the rate at which individuals discount future utility (Holden et al., 1998) representing the amount of consumption a person is willing to give up in the future consuming now. A high rate of time preference stands for a high value that is attributed to consumption now compared to consumption in the future. Since the adoption of agroforestry is an individual decision, it is based on the expected utility. Hence, the smallholders' pure rate of time preference is meaningful to be examined on its impact on the application of agroforestry. The assumption that each person's discount rate is equal to the market rate of interest holds solely if the neoclassical conditions of perfect functioning markets, perfect information and no externalities are fulfilled (Fisher, 1930, Holden et al., 1998). Within developing countries, like the study area, imperfect information and high transaction costs lead often to market imperfections. This is in particular true for credit markets in rural areas, where interest rates above 75 percent can be observed and sometimes credit is not available at all (Hoff and Stiglitz, 1990). Thus, instead of choosing the market interest rate as the discount rate, the time preference of the rural population in the study region was included in the survey.

Future evaluations as well as investment decisions are always influenced by the income level of households. Thus, not only the reasons impacting tree cultivations are important to assess but also the relevance of trees on income generation. The poor are proved to be more dependent on natural resources than wealthier households. In the theoretical energy stacking model, the energy consumption per capita and day increases with rising income and in addition the energy portfolio becomes more diverse (Kowsari and Zerriffi, 2011).

Based on the literature review, the decision to invest in agroforestry depends on various influencing factors resulting from personal and resource based constraints of a smallholder. In this study the focus is on two questions:

(1) Which determinants influence sustainability of agroforestry?

(2) To what extent does tree cultivation contribute to income generation of households?

3. Methodology

The factors influencing the intensity of agroforestry on smallholders' plots will be analyzed by a binomial logistic regression. The tree density observed for each smallholder measures the number of trees grown on one acre (=4,046 m^2) of cultivable land. Tree cultivation usually aims at satisfying a number of purposes. Two major purposes will be included in the model: Trees planted to mitigate soil erosion and as a source for firewood. Additionally, environmental awareness is captured by using the participation in forest protection as a proxy. Land security also is assumed to positively influence the intensity of tree cultivation and according to the literature review, credit access is included. To control for socio-demographic and geographical factors we include household characteristics and distances (to the market, forest reserve and own agricultural plots). The present value as an indicator for the rate of time preference will be included in the model, too. It is hypothesized to positively influence the intensity of cultivation.

In order to get a comprehensive picture of tree intensity influencing income per capita per day, quantile regression is applied. Quantile regression is based on minimizing asymmetrically weighted absolute residuals and estimate conditional quantile functions (Buhai, 2005). The stochastic relationship between the response and explanatory variables can be assessed much better and with more accuracy (Buhai, 2005). Quantile regression shows the relation between predicting variables and defined percentiles of the response variable (Koenker 2005). Thereby, the scientist can specify different percentiles of tree cultivation intensities and thus assess different sizes of the effects of the predicting variables on the response percentiles. This is especially interesting for the estimation on income as a response variable. Without splitting the data set, the effects on poorer and more prosperous farmer households can be assessed and quantified. The quantile coefficient estimates the change in the defined quantile variable of the response caused by a one unit change in the explanatory variable (Koenker, 2005). This allows for the comparison of how some percentiles of tree intensity and income may be more influenced by certain farm characteristics than other percentiles. To show the robustness of the model, an ordinary least square regression will also be applied with all common tests on heteroscedasticity, multicollinearity, and equation specification error test. In addition, each variable will be plotted against its distribution over the estimated quantiles. For comparison, an ordinary least square regression will be performed.

The information on the time preference was elicited by asking the respondent hypothetical questions: "*Which amount of money do you prefer to obtain today instead of*

TZS 100,000 in one year" (Faße and Hoffmann, 2011). The methodology was adapted from Holden et al. 1998. The 100,000 TZS is referred to as future value, whereas the value stated by the respondent is named present value. The question was asked stepwise beginning with a present value of TZS 90,000 which could be obtained immediately instead of TZS 100,000 in one year. If the respondent was not willing to accept TZS 90,000, a present value of TZS 100,000 was noted for that household and no additional question on the time preference was asked. If the respondent agreed on receiving TZS 90,000 today instead of TZS 100,000 in one year the interviewer proceeded with asking for the next lower present value. This kind of questioning was continued until the respondent denied accepting the next lower present value instead of the future value of TZS 100,000. The lowest present value, the respondent accepted to obtain today instead of the future value, was noted as the present value for that household. The intention of asking for the present value in this manner is to ensure data quality, since this kind of questioning is assumed to encourage them to consider their response carefully (Bolt et al., 2005).

4. Data Collection

The study site for the household survey is the village Tandai located in the Uluguru Mountains, Tanzania. Tandai comprises 1055 households in total and is subdivided into seven subvillages. The altitude of the subvillages varies between 314m and 1128m above sea-level implying different types of soils and slopes and thus farming conditions. One sub-village (Nyange) neighbors the natural forest which is part of the Uluguru Nature Reserve. Nyange is characterized by highly fertile soil on the one hand and the risk of soil erosion on the other. The circumstance that Tandai is situated within a valley surrounded by protected forests let environmental resources – particularly arable land and firewood – become scarce (Faße and Hoffmann, 2011). In Tandai, tree planting is widespread and trees are grown by the majority of the inhabitants.

To ensure that all different farming types are included in the survey sample, its frame was divided into strata accounting for different livelihood strategies (Faße and Hoffmann, 2011). Nearly one third (n=314) of all households of Tandai were selected randomly; of each sub-village, 30% of the households were surveyed (see table 1).

	Doga	**Kisambwa**	**Lukenge**	**Lusegwa**	**Nyange**	**Tandai**	**Tonya**	Σ
number	32	50	34	42	30	95	31	314
%	10.2	15.9	10.8	13.4	9.6	30.3	9.8	100

Table 1: Distribution of sub-villages in the sample

Source: Own calculations, data 2010

Data on energy consumption and production patterns were in the focus of attention; in particular in terms of firewood. For that reason, information on the number of trees cultivated by the farmers, its species, average age and purpose was collected; additionally, the quantity of firewood collection and consumption. This data set was then augmented by information on household and farm characteristics as well as income and expenditure data.

5. Empirical Results

Firewood is the most important energy source for cooking. Almost all (97.5 percent) households use firewood; in addition, 26.5 percent are using charcoal. Crop residuals are used occasionally when available after harvest or after consumption such as coconut husks depending also on the agricultural portfolio. Predominantly, it includes cassava stems and coconut husks. As pointed out in the literature, the dependency on resources is often conditional on the wealth status of a household. Thus, the sample is grouped into quartiles in terms of income per capita and day of the households. Table 2 shows the mean and the median for key variables in the energy consumption differentiated by income quartiles.

Variables: Mean (Median)	Income quartile 0-25%	Income quartile 25-50%	Income quartile 50-75%	Income quartile 75-100%
Income (TSh per day and capita)	147 (175)	365 (349)	733 (713)	2337 (1576)
Firewood consumption (kg per day per capita)	0.82 (0.54)	1.08 (0.80)	1.17 (0.85)	1.16 (1.07)
Charcoal consumption (kg per day per capita)	0.07 (0.00)	0.06 (0.00)	0.09 (0.00)	0.16 (0.00)
Kerosene (l per day per capita)	0.024 (0.02)	0.026 (0.02)	0.031 (0.02)	0.037 (0.03)
Petrol (l per day per capita)	0.012 (0.00)	0.0023 (0.00)	0.013 (0.00)	0.007 (0.00)
Diesel (l per day per capita)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.0014 (0.00)
Energy cons. (MJKG per day per capita)	17.90 (14.57)	18.98 (15.20)	19.87 (14.99)	23.00 (21.21)
Firewood cons. per total energy cons.	0.88 (0.91)	0.87 (0.95)	0.85 (0.93)	0.80 (0.91)
Energy expenditures (TSh per day per capita)	225.40 (164.28)	225.08 (176.19)	253.79 (182.85)	292.97 (244.28)
Energy costs (TSh per MJKG)	11.82 (11.46)	11.84 (11.27)	12.29 (11.60)	12.45 (11.85)

Table 2: Energy consumption patterns in terms of income quartiles

Source: Own calculations

With increasing income per capita and day, firewood consumption rises from 0.59 kg per capita and day to 1.16 per capita and day on average. This quantity is in line with the results of Malimbwi and Zahabou (2009) calculating 0.76-1.07 kg per day and capita. Counter-intuitively, the firewood consumption share of total energy consumption decreases from 0.88 to 0.80 with increasing income. In line with the energy stacking model (Kowsari and Zerriffi, 2011), energy consumption increases with higher income levels (more firewood), but additional energy sources are consumed resulting in a smaller share of firewood in the energy portfolio. This result is observable in the increase of total energy consumption of households calculated in mega joule per kilogram (MJKG) per capita and day. Households in higher income quartiles can afford and consume additional energy sources such as charcoal, petrol, and diesel.

The high dependency of low income households on energy is also shown by the expenditures for energy per capita and day compared to the revenue per capita and day respectively. The first income quartile consumes more energy valued in TSh than they normally could afford when they satisfy their energy demands only from the market;

whereas the upper quartile use only 12% of their income for energy consumption. Hence, the main source of energy is firewood from natural resources for the poorer households since it is free available when collected on farm or forests.

The question inferred from these results is, to what extent firewood dependent households satisfy their needs from own agroforestry? Hence, table 3 shows the key variables for firewood production and sufficiency, again differentiated by the income quartiles.

Variables Mean (Median)	Income quartile 0-25%	Income quartile 25-50%	Income quartile 50-75%	Income quartile 75-100%
Land size (acre) (median)	4.1 (3.0)	6.3 (4.5)	6.1 (5.5)	9.5 (7.5)
Trees (no.)	180 (38)	185 (74)	214 (85)	345 (104)
Trees per acre	28	33	35	34
Self-Sufficiency of firewood	-0.13 (0.00)	0.07 (0.00)	-0.007 (0.00)	-0.06 (0.00)
Present value	27800 (5000)	37200 (20000)	35592 (15000)	40000 (35000)

1) Annual increment per tree and year is 15 kg.

Table 3: Firewood production patterns in terms of income quartiles

Source: Own calculations

Households in lower income quartiles own or rent smaller land sizes with lower number of trees resulting in lower tree densities compared to the upper income quartiles. The sufficiency of own firewood production is slightly negative besides the second quartile, however improving with higher income level. This means that on average the households are not sufficient in own firewood supply but wealthier households are more sufficient compared to the poor. The future evaluation in terms of the present value increases with higher income quartiles, which is in line with the findings of Holden et al. (1998).

This results lead to the second question to what extent does future evaluation influence the tree numbers per acre? Table 4 shows the results of the ordinary least square regression

	Estimate	Std. Error	t-value	p-value
Intercept	0.92	0.78	1.17	0.24
Present Value (TSh)	0.00003	0.00002	2.03	0.04
Area with yield losses (acre)	-0.07	0.02	-3.79	0.000
Participation in Forest Protection	0.54	0.14	3.77	0.000
Firewood Self-Sufficiency (1=yes)	0.53	0.13	3.84	0.000
Land security	0.52	0.23	2.25	0.02
Household size	0.05	0.03	1.66	0.09
Experience	0.0009	0.004	-0.22	0.82
Household head (1=male)	0.23	0.19	1.24	0.21
Credit access (1=yes)	0.22	0.14	1.56	0.12
Distance Forest log(minutes)	0.18	0.12	1.61	0.10
Distance market log(minutes)	0.02	0.07	0.24	0.81

Distance plots log(minutes)	-0.14	0.08	-1.92	0.05
[1)] adjusted R^2: 0.22; Breusch-Pagan Test: p-value: 0.23; vif test: all values > 1.4; Reset Test: 0.13				

Table 4: Determinants of tree cultivation

Source: Own calculations

The present value represents the proxy for the future evaluation in this model. The present value has a significant impact on the tree number per acre. Firewood sufficiency also promotes tree intensity. Households with the awareness of high yield losses cultivate less intensively trees on their agriculture areas then those with lower losses. Land security and environmental awareness both positively influences the cultivation. Regarding distances, only the distance to own plots seem to play a significant role. Those who live closer to own plots cultivate more trees per acre.

These results lead to the last question: To what extent does tree cultivation contribute to income generation of households? The results from the quantile regression and the OLS are shown in table 5.

	Log (Revenue per day per capita)					
	0.05	**0.25**	**0.50**	**0.75**	**0.95**	**OLS[1)]**
Intercept	3.01	4.27***	4.95***	5.76***	4.65***	5.03
Tree density **log**(trees per acre)	0.04	0.10*	0.06	0.05	-0.11*	0.06
cellphone_sum	0.33	0.19	0.06	0.12	0.59***	0.22*
Total_Bana_Pine_Revenu_D	-0.10	0.27*	0.45***	0.33**	0.08	0.28**
Total_Maize_rice_Revenu_D	-0.18	-0.33*	-0.21	-0.06	-0.28	-0.26
Off_farm_dummy	0.15	-0.15	-0.12	-0.13	-0.02	-0.17*
log(cl022001_TP)	0.08	0.08	0.05	0.05	0.21***	0.05
agg2004	0.01	0.005	0.005	0.002	0.01***	0.005
agg2003male	0.02	0.01	0.07	0.07	0.22	0.09
cl17001yes	0.38	0.11	0.19	0.20	0.05	0.18
cl21008_distance_tandai	-0.004	0.0006	0.006**	0.004**	0.005	0.004***
[1)] adjusted R^2: 0.15; Breusch-Pagan Test: p-value: 0.97; vif test: all values > 1.33; Reset Test: 0.14						

Table 5: Impact of tree cultivation on income per capita and day

Source: Own calculations, data 2010

Trees per acre do only have a significantly positive effect on the lowest income quantile 0.05; for the highest income percentile, households achieve a lower income per capita. Here, the income is more driven due to participation banana cultivation. Though, banana cultivation as a cash crop increases per capita income, the production of staple crops such as maize and rice reduces the income respectively. Credit access has no significantly positive effect on income. Education has a significantly positive impact on income. The Households characterized by a low distance to the market achieve more income compared to those households who live in more remote areas. This is in line with findings on transaction costs lowering the market participation.

6. Conclusions and Outlook

The aim of this paper was to analyze the cultivation intensity of agroforestry and the influence of the rate of time preference in Tanzania, Sub-Saharan Africa. The results show that households with higher environmental awareness, property rights and less yield losses cultivate more trees per acre. Also the future evaluation plays an important significant role. Here, suitable measures to increase future expectations and environmental awareness are needed to be developed to increase tree cultivation. However, the impact assessment shows that only trees up to a certain income level influence income positively. For more prosperous households other income sources such as cash crop production play a more important role; here trees per acre influence the income per capita negatively. This leads to the conclusion that trees may be more important for the poorer households compared to the more prosperous ones.

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