ZEF Bonn
Zentrum für Entwicklungsforschung
Center for Development Research
Universität Bonn

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Efficiency and Biodiversity – Empirical Evidence from Tanzania

Number
100

ZEF – Discussion Papers on Development Policy
Bonn, November 2005

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Jumanne Abdallah, Johannes Sauer: Efficiency and Biodiversity – Empirical Evidence from Tanzania, ZEF – Discussion Papers On Development Policy No. 100, Center for Development Research, Bonn, November 2005, pp. 34.

ISSN: 1436-9931

Published by:
Zentrum für Entwicklungsforschung (ZEF)
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Abstract

This paper aims to deliver empirical evidence on the links between production efficiency, biodiversity, and resource management by analysing a case study on small-scale tobacco production in the Miombo woodlands in Tanzania. The subsistence nature of tobacco production in Tanzania suggests that most power driven equipments, fertilizers and sustainable crop processing technologies are beyond the reach of most small-scale tobacco growers. The consequence is that in order to expand their production tobacco farmers heavily substitute such inputs by an increasing use of wood. Hence an increasing amount of forest land is cleared by the farmers resulting in forest degradation and a loss of biodiversity. This study determines in a first step the efficiency of tobacco production bordering the Miombo woodlands in Tanzania as well as investigates factors for the relative inefficiency on farm level. In a second step the relation between forest species diversity in the surrounding woodlands and tobacco production efficiency as well as between diversity and the type of institutional arrangement with respect to forest management are empirically analysed. The results indicate that the different efficiency measures vary widely over the sample, showing a significant positive effect of the curing technology – i.e. the design of the barn - and the source of the firewood. The majority of farmers produce with increasing returns to scale. A strong positive correlation between the tobacco production efficiency and forest diversity as well as between community based arrangements and forest diversity is revealed. This finally suggests that agricultural production efficiency is conducive for environmental sustainability with respect to tobacco in Tanzania as well as supports property rights based institutional arrangements for forest resource management.

Kurzfassung

Dieser Forschungsbeitrag versucht empirische Evidenz zur Verbindung zwischen Produktionseffizienz, Biodiversität und Resourcenmanagement zu liefern indem eine Fallstudie zur kleinbäuerlichen Tabakproduktion in den Miombo Waldgebieten Tansanias analysiert wird. Die Subsistenzorientierung der Tabakproduktion in Tansania legt nahe, dass Energiegetriebene Geräte, Dünger sowie Technologien zur nachhaltigen Getreidebewirtschaftung nicht von den kleinbäuerlichen Tabakproduzenten genutzt werden. Die Konsequenz ist, dass die Kleinbauern im Hinblick auf eine Ausweitung der Tabakproduktion solche Produktionsfaktoren in großem Umfang durch eine verstärkte Holznutzung substituieren. Dies resultiert in einer zunehmenden Rodung von Waldland und folglich eines Rückgangs von Wald und entsprechender Biodiversität. Die vorliegende Studie bestimmt in einem ersten Schritt die Effizienz der Tabakproduktion in den Gebieten, welche an die Miombo Wälder angrenzen und identifiziert Faktoren für die relative Effizienz auf Farmebene. In einem zweiten Schritt wird die Beziehung zwischen der Diversität der Waldspezies in den umgebenden Wäldern und der relativen Effizienz der Tabakproduktion sowie diejenige zwischen Diversität und der Art des institutionellen Arrangements in Bezug auf das Waldmanagement empirisch analysiert. Die Resultate belegen, dass die verschiedenen Effizienzmaße über das Sample hinweg stark variieren, wobei ein signifikanter positiver Effekt der Räuchertechnik – d.h. dem Design der Räucherscheune – und der Quelle des Feuerholzes festgestellt wurde. Die Mehrheit der Kleinbauern produziert mit steigenden Skalenerträgen. Eine stark positive Korrelation zwischen der Effizienz der Tabakproduktion und der Walddiversität als auch zwischen letzterer und kommunal basierenden Arrangements konnte festgestellt werden. Dies legt nahe, dass in Bezug auf Tabak in Tansania landwirtschaftliche Produktionseffizienz zuträglich für eine nachhaltige Umweltentwicklung ist und unterstützt schließlich die These einer Überlegenheit von auf Eigentumsrechten basierenden institutionellen Arrangements im Hinblick auf das Waldmanagement.

1 Introduction

The agricultural sector in Tanzania contributes to about 50% of the national GDP, to 70% of the foreign exchange earnings and engages over 80% of the rural population. Increasing productivity of agricultural production, hence, is one of the primary policy objectives. Beside tea, coffee, cashew nuts and cotton, tobacco is one of the main export crops. Albeit some foreign direct investment by private companies as e.g. DIMON Inc. or TLTC took place during the last decade, tobacco production in Tanzania is still dominated by subsistence farming highly dependent on family labour, hand tools, natural resources as e.g. wood as well as animal drawn farming implements. More advanced inputs as e.g. power driven equipments, fertilizers and sustainable crop processing technologies are beyond the reach of the majority of those small-scale tobacco growers. Hence, farmers can only expand their production by clearing more land. Moreover, uncoordinated sectoral policies, high agricultural input prices and ineffective market reforms resulted in environmental degradation and a loss of biodiversity by encouraging the production of resource intensive crops.

Tobacco production in Tanzania is largely characterised by traditional technology with regard to plant growing and curing. Consequently, tobacco has remained one of the most input intensive agricultural activity which seems to contrast the fundamental goal of sustainable rural development. Despite a growing awareness of the need for agricultural research to increase the efficiency of tobacco farming (Rowena, 2000) in many developing countries, very little has been done in Tanzania so far. Efforts to quantify the relative efficiency of tobacco production as well as to identify the various sources of inefficiency are still rare. The same holds with respect to the influences of tobacco production on forest diversity: Is there really an environmental benefit in the form of forest quality by increasing the efficiency of agricultural input usage? Is there on the other side a link between the institutional forest management and the efficiency of tobacco production via the quantity and quality of the wood input? Empirical evidence on these questions is needed to adequately address and channel structural changes in the tobacco sector by designing public policies with the aim of increasing the efficiency and sustainability of resources use in the medium and long term. To achieve this a cross-sectional data set for 110 tobacco plots in the Iringa region of Tanzania for the year 2003 was collected. In addition the species diversity of the affected forests which are part of the Miombo woodlands was determined.

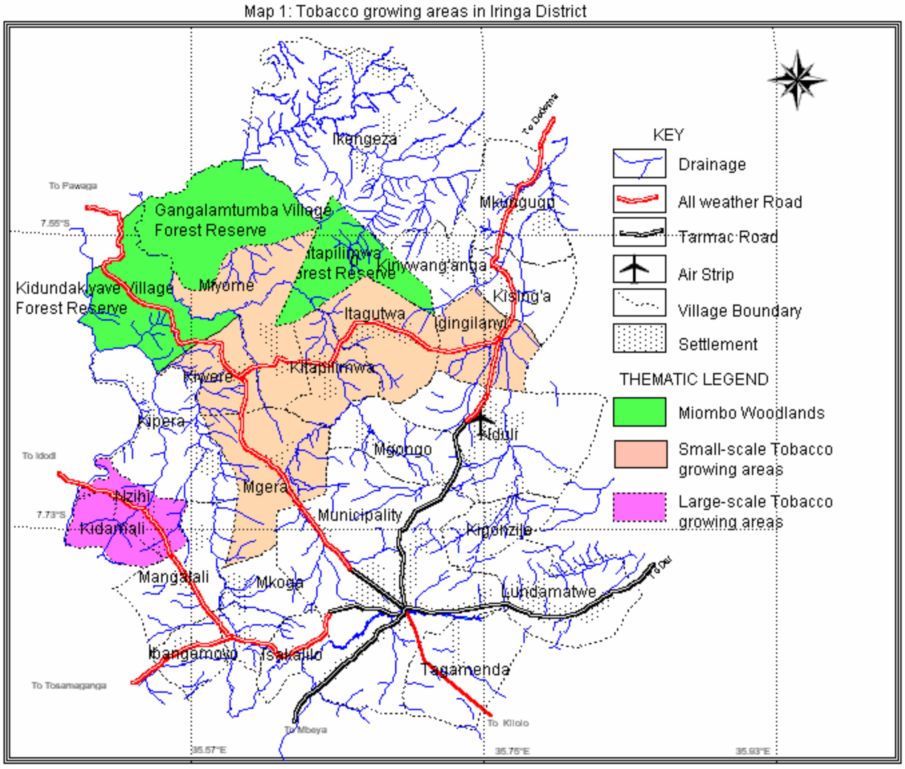
Hence, the objectives of this paper are (1) to assess the relative efficiency of tobacco production in the Miombo woodlands and (2) to identify the different factors for a variation in the farmers' relative efficiency. Further (3) the correlation between the efficiency of tobacco production and the species diversity of the affected forests as well as (4) the correlation between the type of institutional arrangement for the forest management, forest diversity and tobacco production efficiency should be quantitatively investigated. We apply a non-parametric data envelopment analysis (DEA), a censored regression approach (Tobit model) as well as a two stage least square regression procedure (2SLS) to explore these objectives. The rest of this paper is organized as follows: section 2 describes the tobacco production in the Iringa region in Tanzania, whereas section 3 is devoted to the biological diversity with respect to the regional forest and section 4 tries to highlight the links between production efficiency and forest diversity. Section 5 outlines the methodology used and section 6 gives a brief overview of the data and the sampling process. Section 7 reports the different results and finally section 8 concludes.

2 Tobacco Production

TOBACCO

The three major types of tobacco grown in Tanzania are Flue Cured Virginia (FCV), Fire Cured Tobacco (FCT) and Burley Tobacco (BT). Flue Cured Virginia accounts for 80% of the total tobacco grown in the country, it is mainly produced in the Iringa and Tabora region. Fire Cured Tobacco accounts for 15%, whereas 99% of the FCT comes from the Ruvuma region in the district of Songea. Compared to FCV the technology to produce FCT is less firewood intensive. Burley Tobacco is only of minor commercial importance and its national production volume is relatively small. Historically, Greek settlers as well as some religious missionaries were the first to grow FCV tobacco in the 1940s in the Iringa region. Here tobacco production remained the business of settling farmers until national independence in 1961. With respect to the Tabora region the production of FCV has been started by small-scale farmers in 1951. Tobacco production in the Iringa region is characterised by a dual structure: beside the small-scale farms large-scale farms grow about 75% of the regional tobacco (10% of the national tobacco). Whereas the latter obtain about 70% of the firewood for curing purposes from exotic plantations (eucalyptus trees) small-scale tobacco growers mainly depend on the Miombo woodlands (see Sosovele/Ngwale, 2002). Subsistence tobacco production still remains a significant component of regional economic activity (see Map 1).

Map 1: Tobacco growing areas in Iringa District



TOBACCO GROWING HOUSEHOLD FARMS

The cross-sectional sample was collected for 5 villages in the Iringa region for the year 2003 (see also section 6). According to this sample the average household size was 6.2 household members ranging from 4.8 to 8 over the villages selected and compared to a regional household average of 4.3 (URT, 2001). More than 80% of these households were male headed with an average experience in tobacco growing of approximately 18 years. More than the half of all farmers have received primary education (7 years) whereas only 4.8 percent have received college education (13 years). The majority of tobacco growers in the sample belong to the Hehe ethnic group (about 67%), nearly 30% of them have been migrated to the villages with the aim of participating in tobacco related activities. The size of the average land holding was about 10.6 acres ranging from 8.4 to 12.8 acres. At average nearly 23% of the total area is allocated to tobacco (2.4 acres). The smallest tobacco acreages were found in Itagutwa, the largest ones in Kiwere and Mgera. The majority of land for the production of tobacco is inherited (more than 50%) but at average more than 10% has been former forest land ('encroached forest'). Table 1 summarizes these characteristics.

TABLE 1 Tobacco Growing Farmers in the Iringa Region

VILLAGE	MGERA	KIWERE	MYOME	KITAPILIMWA	ITAGUTWA	AVERAGE
SEX OF THE FARMER (%)						
-female	9.5	24	7.4	20	33.3	18.8
-male	90.5	76	92.6	80	66.7	81.2
HH SIZE (#)	8	4.8	7.3	5.7	5.2	6.2
GROWING EXPERIENCE (YEARS)	16.8	13.4	26.8	17.8	15.5	18.1
EDUCATION LEVEL (%)						
-primary school (7 years)	61.9	75	40.7	40	55.6	54.6
-adult education (2 years)	19.0	4.2	25.9	5	11.1	13
-secondary (11 years)	0.0	8.3	7.4	25	5.6	9.3
-college (13 years)	4.8	4.2	14.8	-	-	4.8
-nil (0 years)	14.3	8.3	11.1	30	27.8	18.3
ETHNIC GROUP (%)						
-Hehe	90.5	66.7	63	65	50	67
-Bena	4.8	4.2	25.9	20	33.3	17.6
-Kinga	4.8	8.3	11.1	5	11.1	8.1
-Nyamwezi	-	16.7		-	5.6	4.5
-Mwanji	-	4.2		5	-	1.8
-Ndamba	-	-	-	5	-	1
LAND						
-average acres owned	12.8	10.2	8.4	11.7	10.1	10.6
-% under tobacco	18.8	33.7	23.0	15.3	23.7	22.9
LAND OWNERSHIP (%)						
-inherited	47.6	62.5	29.6	60	61.1	52.2
-bought	4.8		3.7	5	5.6	3.8
-encroached forest	4.8	4.2	29.6	10	5.6	10.8
-allocated by village authority and inherited	14.3	-	14.8	5	11	9
-borrowed	4.8	-	-	5	-	2
-rented	23.7	25	14.9	15	16.7	19.1
-bought and inherited	-	8.3	-	-	-	1.7
-bought and rented	-	-	7.4	-	-	1.5

HH = household

3 Forest Diversity

SPECIES DIVERSITY

In general biodiversity can be considered at different levels: genetic diversity, species diversity as well as ecosystem diversity. Whereas genetic diversity refers to the diversity between and within populations (Norse et al., 1986), species diversity focuses the variety of species found, i.e. the number of different species found in a biome, taxonomic grouping or a geographically defined area (Magurran, 1988). Ecosystem diversity finally refers to the diversity between and within ecosystems. The following considerations solely focus on species diversity with respect to trees in the Miombo woodlands. The question of how many different species exist in a particular environment is central to the understanding of why it is important to promote and preserve species diversity. A uniform population of a single species of plants adapted to a particular environment is more at risk if environmental changes occur. A more diverse population consisting of many species of plants has a better chance of including individuals that might be able to adapt to changes in the environment. Hence, species diversity identifies and characterizes the biological community and the functional conditions of a habitat as well as the overall ecosystem (Kenchington et al., 2003). However, estimates of precise loss rates with respect to biological diversity are hampered by the absence of any baseline measurement (Pearce/Moran, 1994c).

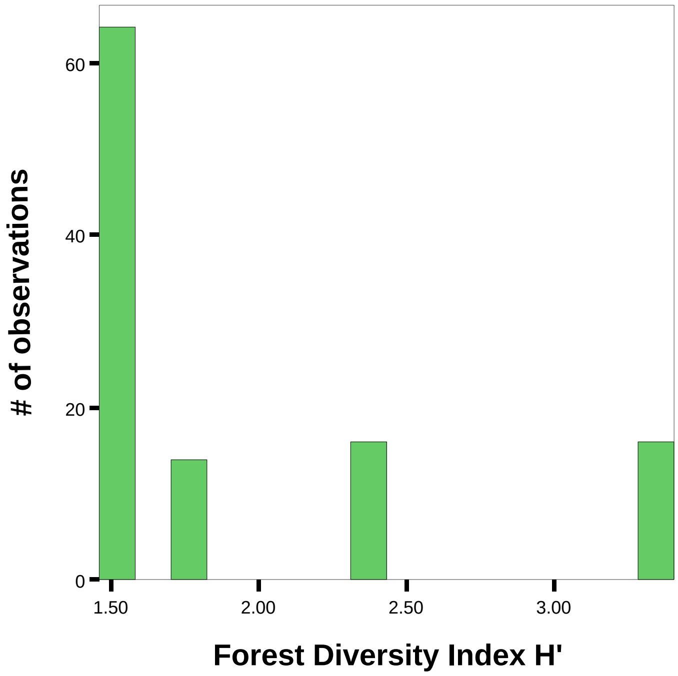
Different biodiversity indices - Simpson’s Diversity Index, Species Richness Index, Shannon Weaver Diversity Index, Patil and Taillie Index, Modified Hill’s Ratio - have been applied to mathematically combine the effects of species’ richness and eveness. Each has its merits putting more or less emphasis upon richness or eveness. The Shannon Weaver Diversity Index (H′) as the most widely used shows the relative advantage of correcting for the "abundance" of species and can be mathematically described as follows:

$$H' = -\sum_{i=1}^{s} \rho_i \log_e \rho_i \qquad [1]$$

where p_i as the proportion of each species in the sample (relative abundance), log_e as the natural log of p_i, and s denotes the number of species in the community (species richness). The minimum value of 0 for H′ denotes a community consisting of only one species and is increasing as the number of species increases and the relative abundance becomes more even.

In a survey conducted by the authors of this paper (Abdallah/Sauer) in 2003 97 species have been found for the Miombo woodlands’ forest: *Brachystegia boehmii Taub.* contributed about 10% to the total number of stems *Brachystegia spiciformis Benth.* about 7% and *Vitex* *payos (lour.) Merr.* about 5%. With respect to the family managed forests (see next subsection) the most dominant species were found to be *Combretum zeyheri Sond* (about 20%), *Vitex paro (lour.) Merr.* (19%) *Markhamia obtusifolia (Bak.) Sprague* (18%) and *Lannea humilis (Oliv.) Engl.* (8%). With respect to the forest reserves the main dominant species are *Brachystegia boehmii Taub.* (12%), *Diplorhynchus condylocarpon (Muell. Arg.) Pichon* (8%), *Acacia tortilis (Forsk.) Hayne* (7%). 90% of the tobacco farmers interviewed named these species as being normally used for tobacco curing. Figure 1 shows a histogramm for the species diversity index in the sample.

Figure 1 Forest Species Diversity (Shannon-Weaver Index)



FOREST RESOURCE MANAGEMENT

The Miombo woodlands are managed as general land forests, family forests, forest reserves under central government management and local authority reserves which are under the local districts' authority (Village Forest Reserves formulated under the Community Based Forest Management approach). General land forest basically denotes an open access resource with no tenure structure or formally guaranteed user rights and hence no incentive for systematic and sustainable forest management (FAO, 1999). Open access resources are available to anyone and therefore unlikely to elicit investment in maintenance or sustainable utilization (Bromley, 1992). Ongoing forest harvesting without taking into account its replacement capacity leads to the depletion as well as complete disappearance of the forest. A village land forest reserve (VLFR) refers to a forest, which falls within the village area and is owned by the community as a whole. This forest is declared as a reserved forest area by the village council acting on the recommendation of the village assembly. VLFR is the the major arrangement by which the Community Forest Management (CBFM) is exercised and can be mainly found in the Mgera and Kiwere districts. These forest areas are designated by the village government with respect to agricultural production ('utilization zones') and/or resource protection due to sustainable management objectives defined for each forest reserve based on forest management plans mandated by the 2002 Tanzanian Forest Act ('protection zones'). Family forests (lungulas) are mainly found in the villages of Itagutwa and Kitapilimwa. These forest areas are under family control and there is no incentive for effective resource conservation. Table 2 summarizes the different characteristics.

TABLE 2 Forests and Arrangements

VILLAGE	FOREST NAME	MANAGEMENT REGIME	AREA (ACRE)	USE	SPECIES DIVERSITY INDEX H'
Kiwere	Kidundakyave Village Forest Reserve	VLFR	4,904	Two zones: 1) zone of utilization (firewood for tobacco and home use, charcoal, timber, etc.) 2) protection zone.	3.41
Itagutwa	Mlima Mosi Village Forest Reserve	VLFR	651	Reserved forest, closed to allow for regeneration.	n.a.
	Total of 63 family based forests	Family management	1,727	1,003 acres used for cultivation (10% of this is used for tobacco production; the remaining is used for maize, sunflower, pigeon peas, beans etc.) 713 acres are reserved.	1.73
Kitapi-limwa	Igundalimwi Village Forest Reserve	VLFR	2,108	Forest is closed to allow for regeneration.	n.a.
	Total of 17 family forests	Family management	1,076	300 acres are used for cultivation (25% of this is used for tobacco production; the remaining is used for maize, sunflower, pigeon peas, beans etc.) 776 acres are reserved.	1.50
Mfyome	Mfyome Village Forest Reserve	VLFR	6,065	Two zones: 1) zone of utilization (firewood for tobacco and home use, charcoal, timber, etc.) 2. reserved zone.	2.43
Mgera	A total of 30 family forests	Family management	4,400	200 acres are used for cultivation (10% of this is used for tobacco production; the remaining is for maize, sunflower, pigeon peas, beans etc.) 4,200 acres are not under utilization.	1.46

n.a. = no forest inventory as the forests are not under utilization.

The average wood volume and basal area were 17.48 m^3ha^{-1} and 3.76 m^2ha^{-1} respectively. Family forests showed a lower volume and basal area (11.14 m^3ha^{-1} and 2.52 m^2ha^{-1} respectively) compared to the forest reserves (20.01 m^3ha^{-1} and 4.25 m^2ha^{-1} respectively). Moreover, about 80% of all trees outside the forest reserves fall in diameter classes of 4 to 10 cm (46%) as well as 10.1 to 20 cm (35%). Most of the firewood used in the villages of Mgera, Kitapilimwa and Itagutwa were of small in diameter compared to those used on farms located in Kiwere and Mfyome.

TOBACCO CURING

Curing is the process that causes the destruction of the plants' chlorophyll giving the tobacco leaves a yellow appearance by converting starch into sugar and removing the moisture. By the tobacco curing the aroma and flavor of each variety of tobacco is brought out. After the curing cycle is complete - which takes about 7 to 10 days - there is essentially no water left in the leaves. Many factors have an effect on the curing schedule as e.g. the position of the leaf at the stalk and the prevailing climatic conditions. The number of curing cycles varies between 5 and 7 whereas the mid cycles (#3, #4 and #5) consume the highest volumes of wood.[1] Table 3 shows the main sources of the firewood used in the process of tobacco curing. Nearly 60% is obtained from forest reserves' utilization zones, followed by about 26% from family forests.

TABLE 3 Firewood Sources

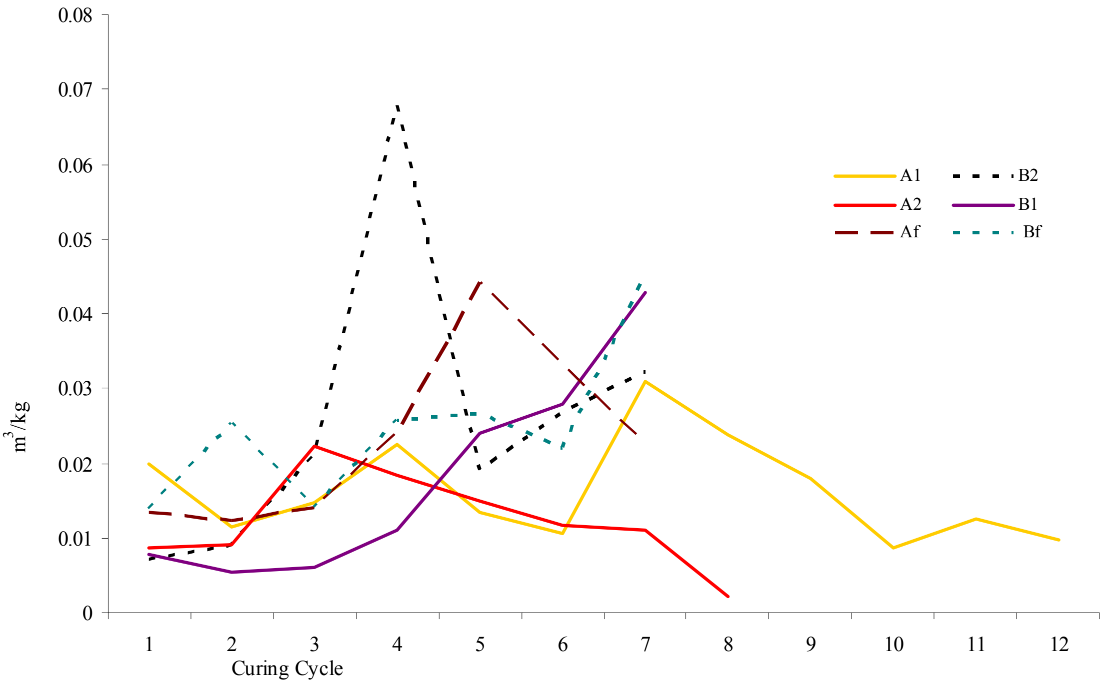
	VILLAGE	MGERA	KIWERE	MYOME	KITAPI-LIMWA	ITAGUTWA	*AVERAGE*
Sources of wood for tobacco curing (%)	Forest reserves (utilization zone)	76.2	93.8	80.5	5	41.2	59.3
	Open forests	-	-	1	5	5.9	2.4
	Exotic trees and forest reserve (utilization zone)	20.8	4.2	14.8	5	-	9
	Family forests	3	-	-	85	41.2	25.8
	Family forests and forest reserves (utilization zone)	-	2	3.7		11.8	3.5

Tobacco farmers in the sample area used at average about $1m^3$ firewood to cure 57 kg of tobacco.[2] However the actual amount of firewood used varies with the design of the barn: The

1 The curing cycles follow the leaves' position. The mid curing cycles mostly cure tobacco leaves, which are in the middle of the plant stalk. These leaves have bigger laminas and midribs to that of top and lower leaves, hence higher moisture content. Also, the volume of green tobacco harvested in the middle of the plant stalk is higher because the farmer is expected to harvest 3 to 4 leaves per plant compared when harvesting top and lower leaves.
2 Previous studies revealed inconsistent results: e.g. Temu (1979) reported that $20m^3$ of Miombo woodlands is used to cure 1ha of tobacco, while Wahid (1984) revealed that $15m^3$ is used to cure 500 kg.

4.8m x 4.8m barn design demands a relatively lower amount of firewood for curing than the rest especially when the firewood used comes from a mixture of species (Eucalyptus and Miombo woodlands species). The 4.8m x 7.7m barn design (B2 in Figure 2) was found to demand the highest amount of firewood which especially holds for firewood from family forest reserves. The majority of tobacco farm households (about 60%) use the latter barn design for curing which could be an important source for inefficiency. Figure 2 shows the average firewood consumption per kg tobacco produced as well as per barn design.

FIGURE 2 Average Firewood Consumption



Barn Design: A1 = 4.8m x 4.8m (4x4 rafters) pure, B1 = 4.8m x 7.7m (4x5 rafters) mixed, A2 = 4.8m x 4.8m (4x4 rafters) mixed, Bf = 4.8m x 7.7m (4x4 rafters) family forest, B2 = 4.8m x 7.7m (4x5 rafters) pure; Af = 4.8m x 4.8m (4x4 rafters) family forest.

4 Forest Diversity, Tobacco Production Efficiency and Forest Management

According to FAO (2002) Tanzania loses approximately 91,200 ha of forests each year. URT (1998) cited the region of Iringa as one of those seriously threatened by desertification. Excessive use of wood during tobacco curing as well as unsustainable tobacco cultivation including uncontrolled land clearing coupled with the practice of burning farm residuals (to control nematodes, fungi and pests) are crucial factors for deforestation and eventually desertification. There are currently no alternative sources of energy for tobacco curing and afforestation efforts with respect to wood diversification for tobacco curing are still at an early stage of development. Perrings et al. (1992) note, the loss of biodiversity threatens the functions of the ecosystem infrastructure as well as its resilience, and hence the ability to provide the range of ecological services needed for economic activity and human welfare. The fundamental challenge faced by the small-scale agricultural sector is therefore the development of conservation approaches to integrate the maximization of natural resources use as well as the minimization of resource degrading effects emanating from their use. The conservation of forests, habitats, and biodiversity by increasing the productivity and efficiency of natural resource utilization in the different agricultural production activities hence represents a sensible alternative to enhance sustainable development. However, empirical evidence on the relative efficiency of natural resource intensive small-scale agricultural production as e.g. tobacco cultivation is still lacking for Tanzania. Quantitative analyses should basically focus on the determination of farm-specific efficiency and of factors for the variation of efficiency over different farms as well as the empirical description of the link between farm-specific efficiency and possibly affected forest diversity.

Beside the efficiency of resource intensive agricultural production systems the loss of forest diversity has been attributed to a set of causes varying with respect to the (formal and informal) institutional arrangements in place for the forest resource management at the different administrative levels: national, district and community. White/Martin (2002) e.g. postulated that community forest ownership might be an accurate property framework to develop effective organisational arrangements for forest diversity management. Nevertheless others emphasised that tangible economic benefits have to be realised for the local communities to motivate forest species diversity conservation (Castrén, 2005). However, serious doubts have been raised with respect to its efficacy: At worst the concept of community managed forests is criticised as an empty nut shell as government officials retain a strong controlling power over these forest areas and the land remains the property of the state (see e.g. van den Berg, 1998). National (state level) and local by-laws can act as a disincentive to forest species diversity conservation if they do not support community use rights. By applying game theory based analysis Sumaila (2000) found the highest biodiversity index for forests managed by cooperative arrangements (e.g. community management) the lowest for non-cooperative regimes (e.g. open access resources; see also Kirby, 2001). Weak institutional arrangements such as open access induces various types of nonorthogonal free-riding behavior aggravating biodiversity loss. As is the case for tobacco production efficiency no empirical investigation exists so far with respect to the relative efficacy of different forest management systems in Tanzania.

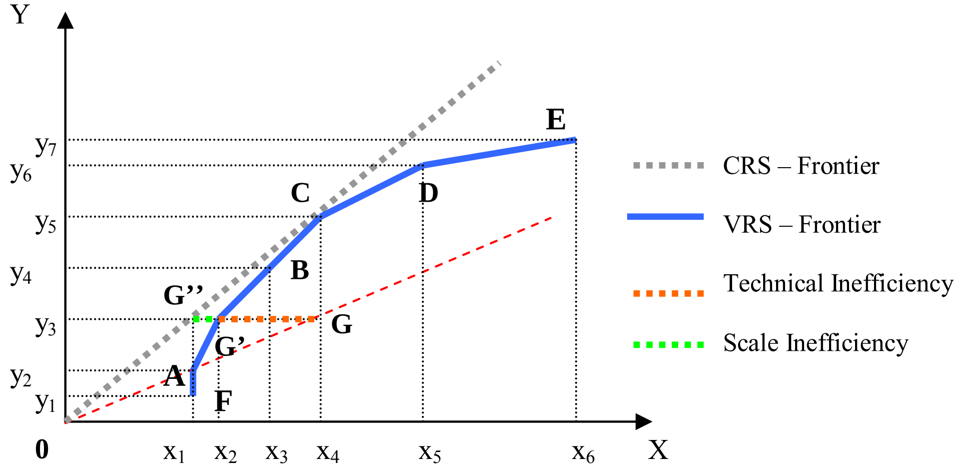
5 Methodology

DATA ENVELOPMENT ANALYSIS – DETERMINING RELATIVE EFFICIENCY

According to the traditional theory of production economics, productive efficiency derives from technical (locus with respect to the isoquant(s)) as well as allocative efficiency (locus with respect to the isosost line(s)). Whereas technical efficiency reflects the ability of the production unit to maximize its output for a given set of inputs (output-orientation), allocative efficiency reflects the ability to utilize the inputs at its disposal in optimal proportions given their relative prices as well as the underlying production technology. Economic (or cost) efficiency is reached as the production unit is both allocatively as well as technically efficient and hence is located at the tangency of the isoquant(s) and the isocost line(s). Finally scale efficiency is related to the optimal input/output mix at a given stage of production. Based on these efficiency concepts different approaches for the measurement of efficiency have been proposed and applied (see e.g. Khumbhakar/Lovell, 2000 or Charnes et al., 1994). In contrast to non-parametric approaches, parametric approaches use statistical estimation techniques to identify and quantify the extent of inefficiency by the use of, or in the form of estimated parameter values. Stochastic approaches consider the existence of statistical noise beside inefficiency, however, as any statistical measurement of production problems such approaches require the specification of a particular functional form adhering to theoretical consistency, global curvature correctness as well as flexibility (see Sauer et al., 2004). In addition the selection of a distributional form for the inefficiency effects may be arbitrary (see Kumbhakar/Lovell, 2000).

Data envelopment analysis as a non-parametric approach uses linear programming methods to construct a non-parametric piece-wise frontier over the data (see Figure 3). It is deterministic as it does not account for statistical noise. Individual efficiency measures are then calculated relative to this frontier. Charnes et al. (1978) proposed a model with an input orientation by assuming constant returns to scale (CRS). Subsequently Banker et al. (1984) considered a variable returns to scale (VRS) model.

FIGURE 3 DEA VRS-Production Frontier



Whereas farmer C in Figure 3 is technically as well as scale efficient, farmer G is both technically and scale inefficient. At point G'' he would be on the CRS-frontier but inefficient with respect to the scale of operations. At point G' the farmer would be on the VRS-frontier as well as scale efficient. The general linear optimization problem which has to be solved (here as the envelopment form) can be derived by using duality in linear programming:

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ &\text{subject to} \quad -y_i + Y\lambda \geq 0, \\ &\qquad \theta x_i - X\lambda \geq 0, \\ &\qquad N1'\lambda = 1 \\ &\qquad \lambda \geq 0 \end{aligned} \qquad [2]$$

where y_i and x_i denote output and input of the i-th production unit and Y as well as X are the corresponding vectors. θ is a scalar and λ is a Nx1 vector of constants. The value of θ obtained will be the efficiency score for the i-th firm and will satisfy $\theta \leq 1$ with a value of 1 indicating a point on the frontier and hence a technically efficient firm. The linear programming problem in [2] must be solved N times, once for each firm in the sample and a value of θ is finally obtained for each firm. $N1'\lambda = 1$ is the constraint assuring the formation of a concave hull of intersecting planes enveloping the data points more tightly than the CRS conical hull. Measures of scale efficiency (SE) for each firm are obtained by conducting both a CRS analysis and a VRS analysis. Then possible scale inefficiency is calculated from the difference between the VRS and CRS TE scores following [3]:

$$\begin{aligned} &TE_{CRSi} = TE_{VRSi} * SE_i \\ &\rightarrow SE = TE_{CRSi} / TE_{VRSi} \end{aligned} \qquad [3]$$

Hence the CRS technical efficiency measure is decomposed into 'pure' technical efficiency and scale efficiency. With respect to the case of VRS cost minimisation, the input-oriented DEA model in [2] is conducted to obtain values of technical efficiencies (TE). Additionally the solution of the cost minimisation DEA model in [4] is required:

$$\begin{aligned} &\min_{\lambda,x_i} w_i' x_i^* \\ &\text{subject to} \quad -y_i + Y\lambda \geq 0, \\ &\qquad x_i^* - X\lambda \geq 0, \\ &\qquad N1'\lambda = 1 \\ &\qquad \lambda \geq 0 \end{aligned} \qquad [4]$$

where w_i is a vector of input prices for the i-th firm and x_i^* is the cost-minimising vector of input quantities for the i-th firm, given the input prices w_i and the output levels y_i. The total cost efficiency (CE) or economic efficiency of the i-th firm is then obtained by

$$CE = w_i' x_i^* / w_i' x_i \qquad [5]$$

whereas allocative efficiency (AE) is obtained by

$$AE = CE / TE \qquad [6]$$

Hence the deterministic and non-parametric DEA approach is applied to obtain technical as well as cost efficiency measures by a one-stage model using linear programming techniques. Measures of allocative efficiency are obtained by calculation. A two-stage approach is applied here whereas the second stage of analysis uses a censored regression to determine the influences of exogenous variables (inefficiency effects) on the poduction units' efficiency obtained by the DEA analysis in the first stage. Recalling our tobacco production problem the following variables are used in the first stage of analysis to determine the relative technical efficiency: tobacco produced as the output variable, and land, labour (family and hired), fertilizer applied, firewood as the input variables. To determine the relative allocative efficiency beside tobacco output the total costs of tobacco production as well as the prices of the inputs are used.

Tobit Model – Factors for Inefficiency

In order to reveal the sources of efficiency variation over the production units – here tobacco farms – a censored regression model (or Tobit model, see Greene, 2003) was applied. The reason for using a censored model is simply that the dependent variable – the relative technical or cost efficiency values - are by definition bounded by 0 and 1 violating the basic assumptions of the linear regression model. This can be generally formulated in terms of an index function:

$$EFF^*_i = z'_i \beta + \varepsilon_i \qquad [7]$$

where $EFF_i = 0$ if $u^*_i \leq 0$ and $u_i = u^*_i$ if $u^*_i > 0$ and $\varepsilon_i \sim N(0, \sigma^2_\varepsilon)$, z_i as the vector of exogenous variables (inefficiency effects) and β as a vector for unknown parameters, respectively. Eff^*_i denotes the latent variable and Eff_i as the DEA relative (technical or cost) efficiency score. The likelihood function [8] is maximised to solve for β and σ based on the observations in the sample:

$$\ln L = \Sigma_{ui>0} -1/2[\log(2\pi) + \ln\sigma^2 + (u_i - z'_i\, \beta)^2 / \sigma^2] + \Sigma_{yi=0} \ln[1 - \Phi(z'_i\, \beta / \sigma)] \quad [8]$$

where the two parts correspond to the classical regression for the nonlimit observation and the relevant probabilities for the limit observations. This likelihood is a mixture of discrete and continuous distributions. Applied to our tobacco production problem the censored regression model for our second stage analysis is:

$$EFF^*_i = \beta_1 + \beta_2 TLAND + \beta_3 EXPERIE + \beta_4 BDESIGN + \beta_5 LEDUCATI + \beta_6 DFOREST + \beta_7 SFIREWOOD + \varepsilon_i \quad [9]$$

where tland denotes a dummy for the type of land used: cleared forest land or land previously used for tobacco growing. Newly cleared forest land shows a higher fertility and less nematode infects but requires a higher labour input. experie reflects the farming experience of the household head defined in number of years involved in farming. Hence a positive effect on efficiency is expected. bdesign represents different barn designs in the sample. Tobacco curing is currently done by locally constructed barn furnaces which require an excessive amount of firewood (see also Misana et al., 1996). A negative effect on tobacco production efficiency can be expected. leducati as the level of formal education of the household head proxied by the number of years for formal schooling. It is expected that the level of education has a positive impact on the sustainable use of inputs and hence on production efficiency. dforest denotes the distance from the tobacco farm to the nearest forest area, whereas it is expected that the closer the farm is located at the forest the less effort has to be put in obtaining appropriate firewood. The binary dummy sfirewood finally reflects the origin of the firewood obtained: Miombo woodlands managed under community control or open access forests and family managed forests. It is expected that tobacco growers using firewood from community managed forests would reveal higher efficiency scores compared to those using firewood from open areas or family owned areas. This reflects the widespread experience that sustainable forest management is positively correlated with the support of the management arrangement by local populations close to the resource (see e.g. Magurran, 1988, Sosovele/Ngwale, 2002). The role of legitimate forest users contributes to a sustainable use of the resource.

CORRELATION ANALYSIS – EFFICIENCY, DIVERSITY AND ARRANGEMENTS

Correlation analysis can be used to measure the degree of association between two variables. The Pearson product moment coefficient of correlation (or simply, the coefficient of correlation) r is a measure of the strength of the linear relationship between two variables x and y. It is computed (for a sample of n measurements on x and y) as follows

$$r = \frac{SS_{xy}}{\sqrt{SS_{xx}SS_{yy}}} \qquad [10]$$

where

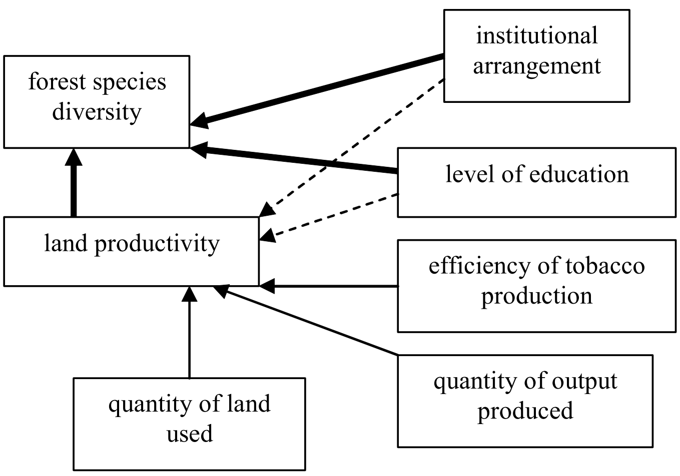
$$SS_{xy} = \sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y}), \quad SS_{xx} = \sum_{i=1}^{n}(x_i - \overline{x})^2, \quad SS_{yy} = \sum_{i=1}^{n}(y_i - \overline{y})^2, \quad \overline{x} = \frac{1}{n}\sum_{i=1}^{n}x_i, \quad \overline{y} = \frac{1}{n}\sum_{i=1}^{n}y_i,$$

$-1 \leq r \leq 1$, r and b (as the slope of the least squares line) have the same sign. A value of r near or equal to 0 implies little or no linear relationship between x and y. The closer r is to 1 or to –1, the stronger the linear relationship between x and y. The statistical significance of r can be tested by a simple t-test: H_0: rho = 0; H_a: rho <> 0. Correlation analysis was applied to investigate the following associations: relative efficiency scores and Miombo woodlands species diversity indices, species diversity indices and institutional arrangements for forest management.

Regression Analysis – Diversity and Land Clearing

The link between forest diversity and tobacco production - i.e. the clearing of forest land for using it as an input for tobacco production as well as the usage of firewood - should be further investigated by multivariate regression analysis. Crucial threats to the internal validity of such an analysis can be expected because of the nature of the data as well as the data sampling (bias because of omitted exogenous variables, a simultaneous causality bias between endo- and exogenous variables, and errors-in-variables bias). By applying an instrumental variables regression (IV) in the form of a two-stage-least-square analysis (2SLS) we aim to eliminate potential bias from these sources (see Greene, 2003). There are two conditions for a valid instrument Z_i: (1) the 'instrument relevance' implies that $corr(Z_i, X_i) \neq 0$, and (2) the 'instrument exogeneity' requires that $corr(Z_i, u_i) = 0$. The basic IV model can therefore be roughly described as follows.

FIGURE 4 IV Model



The species diversity found for the specific forest area is assumed to be a function of the institutional arrangement for the management of the forest (INSTARR), the decision of the farmers to clear new forest land as well as the farmers' level of education (EDU). The farmers' decision to apply land previously used for tobacco growing or to clear new land gained from the local forest can be basically proxied by the relative productivity of the input land compared to other inputs in the production process (OUTLAND). The relative productivity of land is influenced by the instruments: efficiency of the whole production process (TE), the level of output produced (i.e. scale effects, OUT) as well as the quantity of land used (LAND). Hence, the simultaneous-equation problem can be formally described as follows:

$$fdivindex_i = \beta_1 instarr + \beta_2 edu + \beta_3 outland + \varepsilon_{1i} \quad [11]$$

$$outland_i = \beta_4 te + \beta_5 out + \beta_6 land + \varepsilon_{2i} \quad [12]$$

where FDIVINDEX is the species index for the forest, INSTARR denotes the formal arrangement for the forest management, EDU reflects the formal education of the farmer, OUTLAND is the output per land, TE as the technical efficiency, OUT denotes the quantity of tobacco output produced and FIREW as the quantity of firewood used for production. The instrumental problem in [11] and [12] can be mathematically formulated in matrix notation by:

$$\widehat{Y}_i = X\left[\left(X'X\right)^{-1} X'Y_i\right] = X\beta_i \quad [13]$$

where Y = OUTLAND, and X = TE, OUT, LAND. The two-stage least square method consists of using as the instruments for Y_i in equation [11] the predicted values in the regression of Y_i on all the xs in [11] and [12]. Consequently the 2SLS estimator is:

$$\widehat{\delta}_{i,2SLS} = \begin{bmatrix} \widehat{Y}'_i Y_i & \widehat{Y}'_i X_i \\ X'_i Y_i & X'_i X_i \end{bmatrix}^{-1} \begin{bmatrix} \widehat{Y}'_i y_i \\ X'_i y_i \end{bmatrix} \quad [14]$$

where y = FDIVINDEX. Hence, the 2SLS estimator is obtained by ordinary least squares regression of y_i on $\widehat{Y}_i$ and X_i (see e.g. Greene, 2003). In order to test whether the applied 2SLS estimator $\widehat{\delta}_{i,2SLS}$ is consistent and more efficient than an alternative OLS $\widehat{ß}_{i,OLS}$ estimator we finally use Hausman's specification test (i.e. m-statistic):

$$m = \hat{q}'(\hat{V}_1 - \hat{V}_0)^{-1}\hat{q} \qquad [15]$$

where $\hat{V}_1$ and $\hat{V}_0$ represent consistent estimates of the asymptotic covariance matrices of $\hat{\delta}_{i,2SLS}$ and $\hat{ß}_{i,OLS}$, and $q = \hat{\delta}_{i,2SLS} - \hat{ß}_{i,OLS}$.

6 Data and Sampling

SAMPLING

The region of Iringa is one of 7 tobacco growing regions in Tanzania which are heavily affected by forest degradation implying a decrease in soil fertility, water resources and non-timber forest products. The data sampling process focused on 110 randomly selected tobacco farmers as a proportion of the total farmer population identified for the villages Mgera, Kiwere, Myome, Kitapilimwa and Itagutwa on the base of the respective village tobacco household register. The sample villages were selected due to the relative intensity of the tobacco production activities as well as the growing experience on farmers' level. Table 4 shows the general sampling frame:

Table 4 Sampling Frame

VILLAGE	TOTAL HH #	HH GROWING TOBACCO # (%)	HH SURVEYED # (%)
MGERA	733	55 (7)	20 (36)
KIWERE	412	91 (25)	23 (25)
MFYOME	657	70 (11)	26 (37)
KITAPILIMWA	289	90 (31)	20 (22)
ITAGUTWA	443	63 (14)	21 (33)
TOTAL	*2,534*	*306 (12)*	*110 (36)*

HH = household

The preliminary survey and participatory assessment revealed that there are different barn designs normally used in the study area. However, the majority of tobacco growers use the 4.8m x 4.8m barn design (60%), and the 4.8m x 7.7m barn design (15%). Hence, these designs were used for the 'firewood consumption project': By participatory research the owners of the selected barns were trained and employed to measure the volume of firewood used and tobacco cured in each curing cycle (see also section 3 and Figure 1).

DATA

The different steps of analysis used the following variables: total tobacco produced (in kg) as output (out), labour in man-days (lab), firewood in m^3 (firew), land in acre (land) and fertilizer in bags by 50kg (fert) as input quantities. Each tobacco growing household is contractually linked to a so-called leaf dealer by which the inputs for tobacco production are obtained on a credit basis. The filed data records of the leaf dealers were used for cross-checking the collected data on in- and outputs. The quantity of labour used was calculated by summing up the man-days for family and hired labour with respect to the following operations: nursery, land clearing and tilling, transplanting, weeding, fertilizer application, pesticides spraying, topping and desuckering, harvesting, curing, grading and bailing. The price for labour was obtained by applying the opportunity costs of labour equaling the price for labour by the 'second-best' usage. As firewood is freely collected in the forests, the costs for firewood are obtained by considering the acquisition costs with respect to firewood cutting, loading, unloading as well as transport. The price for firewood is simply total costs for firewood divided by the sum of the firewood used in the curing cycles. The price for fertilizer was obtained from the dealers' records. As finally there are no prices for agricultural land in the majority of regions in Tanzania, the opportunity cost approach was again used by considering the rental rate for land with respect to the different villages in the sample. Total costs (tc) of tobacco production are obtained as the sum of all input cost items.

Fdivindex is the species diversity index on the base of the Shannon Weaver formula (see section 3). The decision of the farmers to use already cultivated or newly cleared land is reflected by the binary variable tland denoting the land type used – newly cured forest land or already cultivated tobacco land. Experie denotes the farming experience of the respective household head whereas Bdesign is a binary proxy for the different tobacco curing technologies applied in the form of an improved furnace or a more traditional one. The level of education of the household head is reflected by the proxy variable Leducati as the number of years of formal schooling received. The distance (in km) from the location of the farm to the edge of the next forest is considered by the dforest, sfirewood as a binary dummy variable reflects if the firewood used for tobacco curing was obtained from woodlands managed under community based arrangements or from woodlands managed by other forms of arrangements (i.e. open access or family based management). Outland is the ratio of output produced per unit of land input. Instarr finally shows the different formal institutional settings with respect to the management of the specific forest: woodlands under community forest management or such managed on the base of family rights or open access. Table 5 gives the descriptive statistics for the variables described; the number of cross-sectional observations is 110.

TABLE 5 Descriptive Statistics

VARIABLE (UNIT)	MEAN	STDEV	MIN	MAX
OUT (KG)	935.3	913.9	165	6780
LAB (MAN-DAYS)	353.5	242.2	23	1250
FIREWOOD (M^3)	4.1	2.1	1	12
LAND (ACRE)	2.4	1.9	.5	12
FERT (50KG BAGS)	10.3	8.5	2	60
P_LAB (USD)	1.6	.72	.7	2.7
P_FIREWOOD (USD)	16.1	6.2	2	28.3
P_LAND (USD)	3.1	.56	1.9	3.5
P_FERT (USD)	16.4	.75	15.8	17.3
TC (USD)	782.1	562.9	144.8	4106.4
FDIVINDEX	1.9	.7	1.5	3.4
TLAND	.4	.5	0	1
EXPERIE (YEARS)	21.4	14.1	4	44
BDESIGN	.3	.5	0	1
LEDUCATI (YEARS)	5.7	3.5	0	11
DFOREST (KM)	6.3	3.7	.5	20
SFIREWOOD	.3	.5	0	1
OUTLAND	394.4	142.6	69	1008
INSTARR	.2	.4	0	1

7 Results and Discussion

NON-PARAMETRIC EFFICIENCY SCORES

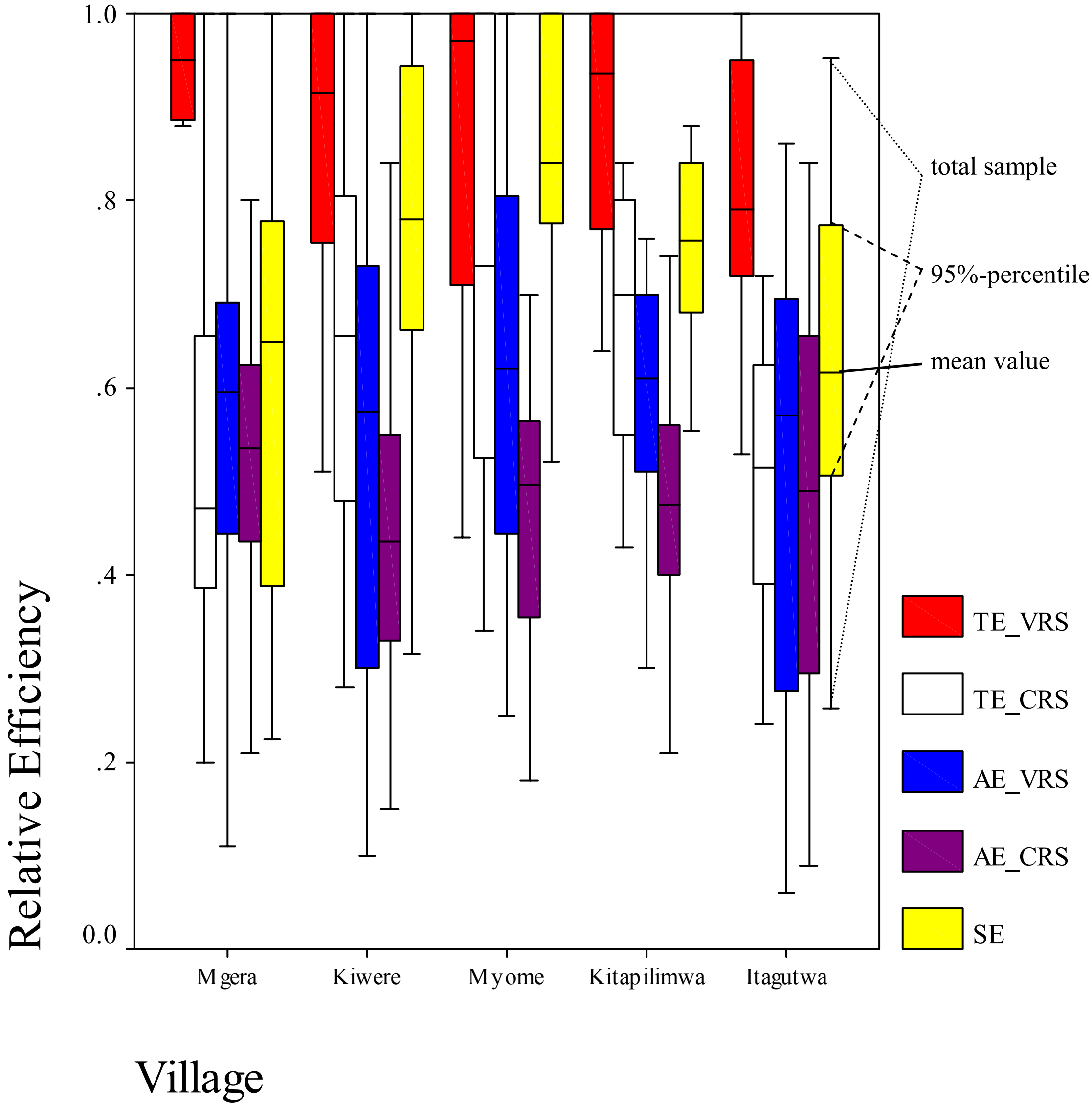
The quantitative efficiency analysis revealed a mean technical efficiency of about 62% (CRS model) and 86% (VRS model) which means that the tobacco growing households need to radially decrease their input usage (i.e. every input by the same relative amount) by 38% and 14% respectively to be on the technical frontier. The technical efficiency in the sample ranges from 20% to 100% (CRS) and 44% to 100% (VRS) respectively. The mean allocative efficiency of the small-scale farms was found at about 49% (CRS) and 56% (VRS), those for the average overall economic or cost efficiency per tobacco farm at about 30% (CRS) and 49% (VRS) respectively. The values for the relative scale efficiency finally vary from 22% to 100% with a mean scale efficiency of about 72%. Hence a relatively large difference in the efficiency of tobacco growing farms has to be stated as Table 6 summarizes.

TABLE 6 Efficiency Scores – Summary

VARIABLE (MODEL)	MEAN	STDEV	MIN	MAX
Technical Efficiency at CRS TE_CRS	62%	21%	20%	100%
Technical Efficiency at VRS TE_VRS	86%	16%	44%	100%
Allocative Efficiency at CRS AE_CRS	49%	18%	9%	100%
Allocative Efficiency at VRS AE_VRS	56%	22%	6%	100%
Cost Efficiency at CRS CE_CRS	30%	15%	4%	100%
Cost Efficiency at VRS CE_VRS	49%	23%	6%	100%
Scale Efficiency SE	72%	20%	22%	100%

It has to be noted that the level of technical efficiency in the sample is higher than the level of allocative efficiency. Further it became clear that inefficient households are distributed over the whole tobacco growing region investigated. Figure 5 illustrates the results for the different villages in the sample.

FIGURE 5 Efficiency Scores per Village



The technically as well as allocatively most efficient farms (VRS specification, mean value) are located in the village of Myome. The same holds with respect to scale efficiency. The latter indicates increasing returns to scale for the majority of small-scale tobacco farmers in the sample ranging from 1.00 to 4.45 with an average of about 1.54 (standard error: 0.794).

FACTORS FOR INEFFICIENCY

To determine relevant factors for tobacco farm efficiency improvements, the variance in inefficiency found was regressed on possible explanatory variables by using a censored Tobit regression model (see [9]). The most significant results are summarized in Table 7.

TABLE 7 Inefficiency Effects

VARIABLE	CONSTANT RETURNS TO SCALE			VARIABLE RETURNS TO SCALE		
	TE	AE	CE	TE	AE	CE
CONST	.352*** (.070)	.652*** (.056)	.282*** (.064)	.509*** (.055)	.573*** (.069)	.460*** (.068)
DFOREST	-.008*** (.003)	-.017*** (.004)	-.014*** (.003)	-.001 (.033)	-.016*** (.005)	-.015*** (.005)
SFIREWOOD	.071 (.024)	.126 (.032)	.097*** (.023)	.049* (.028)	.102** (.040)	.112*** (.039)
EXPERIE	.010*** (.001)	.005*** (.002)	.001 (.001)	.005** (.002)	.0004 (.002)	.002 (.002)
BDESIGN	.11*** (.027)	.022* (.032)	.062** (.026)	.091* (.033)	.146 (.045)	.138** (.044)
TLAND	.003* (.025)	-.071** (.031)	-.005** (.023)	-.031* (0284)	-.048*** (.040)	-.050* (.039)
LEDUCATI	.008** (.003)	.006 (.125)	.006** (.003)	.007* (.004)	.0125** (.005)	.013** (.005)
LL-VALUE	66.9	50.2	83.45	62.71	77.4	68.5

***, **, * significant at 1, 5 or 10%-level, standard errors in parentheses

The design of the barn (bdesign, see section 3) is positively correlated with all efficiency concepts for the tobacco farms in the sample. This implies positive efficiency effects (energy savings) by improving the curing technology through a ‘modernisation’ of the barn. Export oriented tobacco growing led to a large loss of woodland for firewood used in such traditional and inefficient barns (Moyo et al., 1993). The distance of the farm to the next forest (dforest) is negatively correlated with all efficiency concepts in both model specifications. As the costs of acquiring firewood for the tobacco curing furnaces increase as the distance to the forest increases this seems to be rational. The higher the level of education experienced by the farm head (leducati) the higher the efficiency of tobacco production. This significant positive correlation is only partly supported by the relevant literature (see e.g. Belbase and Grabowski, 1985; Kalirajan and Shand, 1986; Bravo-Ureta and Pinheiro, 1997). Others (see e.g. Kalirajan, 1984; Bravo-Ureta and Eveenson, 1994; Binam, 2003) found an insignificant or significantly negative correlation between formal education and production performance. The farmers’ experience with respect to tobacco production (experie) shows also the expected positive effect on efficiency, the most significant effect on technical and allocative efficiency levels. The type of land used for tobacco production (tland) is negatively correlated with efficiency suggesting that an expected productivity increase by using newly cleared forest land is more than offset by the efficiency loss because of the need for higher labour input to clear the land. Finally a relevant increase in inefficiency as a result of the use of firewood from Miombo woodlands (sfirewood) has to be stated. Those tobacco farmers depending solely on Miombo woodlands as the source for curing tobacco - 86% of our sample farmers – show lower scores of efficiency. More efficient small-scale tobacco farms use firewood on the base of a mixture of Miombo and eucalyptus trees or eucalyptus trees only.

FOREST DIVERSITY, PRODUCTION PERFORMANCE AND INSTITUTIONAL ARRANGEMENTS

The correlation analysis revealed a significant strong correlation between the forest species diversity index (H') and the different efficiency measures in a CRS specification. The same was found for the scale efficiency concept. Moreover the analysis revealed a significant strong correlation between the forest species diversity index (H') and the type of institutional arrangement for the management of the specific forest. Finally the partial correlation analysis delivered evidence on significant positive correlation between the efficiency of small-scale tobacco production and the institutional arrangement in place for the forest resources. The Pearson product moment coefficients of correlation are summarized in Table 8.

TABLE 8 Pearson Correlation Coefficients

	FDIVERSITY	CONSTANT RETURNS TO SCALE			VARIABLE RETURNS TO SCALE			SCALE EFFICIENCY
		TE	AE	CE	TE	AE	CE	
Fdiversity	–	.770** (.018)	.670* (.104)	.559** (.048)	.433 (.366)	.434 (.180)	.390 (.342)	.173** (.070)
Instarr	.515** (.000)	.250*** (.010)	.264*** (.010)	.381*** (.000)	.092 (.338)	.424*** (.000)	.424*** (.000)	.200** (.040)

***, **, * significant at 1, 5 or 10%-level, p-value in parentheses

The correlation coefficients indicate that a relatively higher efficiency of small-scale tobacco production is related to a higher species diversity in the surrounding forest area. As the diversity of species can not be considered as a direct input for tobacco production this suggests that a more efficient use of firewood for tobacco curing as well as a more efficient use of land (i.e. a lower rate of forest land clearing) contributes to a sustainable production by a lower rate of biodiversity loss. The coefficients further indicate that community based forest management has a positive impact on the species diversity of the respective forest resource. Hence community based institutional arrangements significantly contribute to the conservation of the forest in Tanzania implying the need for an enhancement of such arrangements and supporting the view that the government authorities should continue to transfer the control over the woodland resources back to the community level. As Dewees (1994) notes, albeit the danger of resource misuse by local elites for unsustainable immediate short-term political or economic gains local communities are successful in curbing free-riding behaviour and in sustainably managing the resource (Ruttan, 1998; Ostrom, 1999; Trawick, 2001; Milinski et al., 2002). Since areas with lower diversity indices are under open access and family domain management rarely motivating any conservation efforts because of absent or weak property rights, hence, producing tobacco in these areas can be expected to be less efficient. This means in other words that village based forest management in areas with higher species indices is associated with a more sustainable input utilization. This reasoning is finally impressively supported by the empirical results showing a significant positive correlation between the institutional arrangement and the relative efficiency of the tobacco production activities: forest resources (relevant for firewood collection as well land clearing) under community based management contribute to a higher efficiency of tobacco production in the study region.

These findings are confirmed by the instrumental least-square regression results: The type of institutional arrangement has a significant effect on the species diversity found in the respective forest area. Again, it was found that community based forest management has a positive impact on the species diversity of the respective forest resource. The level of education is positively correlated to forest diversity: farmers with a higher education tend to more sustainable forest use with respect to the application of firewood as well as the clearing of new forest land. The partial productivity of the input land showed to be negatively correlated with the species diversity in the affected forest area. The higher the land productivity is, the higher is the incentive for the farmer to increase the quantity of land used by clearing new forest land leading to a loss in species diversity. The statistical results of the 2SLS instrumental regression are shown by Table 9.

TABLE 9 2SLS Regression Results

FIRST-STAGE REGRESSION DEPENDENT VARIABLE : OUTLAND (LAND PRODUCTIVITY) F-VALUE : 46.68 (0.000), N = 110		
VARIABLE	COEFFICIENT	STANDARD ERROR
CONSTANT	350.196	27.234***
TE	189.355	44.660***
OUT	0.279	0.022***
LAND	-140.121	10.551***
INSTARR	18.812	21.362
EDU	-0.353	2.270
INSTRUMENTAL VARIABLES (2SLS) REGRESSION DEPENDENT VARIABLE : FDIVINDEX (FOREST SPECIES DIVERSITY) F-VALUE : 4.72 (0.004), N = 110		
VARIABLE	COEFFICIENT	STANDARD ERROR
CONSTANT	2.258	0.234***
OUTLAND	-0.001	0.000***
INSTARR	0.458	0.171***
EDU	0.032	0.018*
HAUSMAN SPECIFICATION TEST H_0: DIFFERENCE IN COEFFICIENTS NOT SYSTEMATIC (2SLS SUPERIOR TO OLS) $CHI^2(2) = 6.43$, P-VALUE = 0.040		

***, **, * significant at 1, 5 or 10%-level

The results of the Hausman specification test confirmed the underlying model assumption: the use of a 2SLS instrumental variables regression in favour of an ordinary least square regression (OLS) is consistent and efficient.

8 Conclusions and Implications

This analysis determines the efficiency of small-scale tobacco production in the Iringa region of Tanzania as well as empirically explores linkages between tobacco farmers' economic performance, forest species diversity, and institutional arrangements for forest resource management. The revealed efficiency levels largely vary over the sample of 110 tobacco farmers, with the average technical efficiency being higher than the average allocative efficiency in the sample. The scale efficiency scores indicate increasing returns to scale for the majority of the tobacco farmers. The most important factors to increase the level of farm efficiency are the design of the barn representing the tobacco curing technology applied as well as the source of the firewood used in this curing process. The empirical findings strongly suggest that agricultural policy measures should be focused on fostering the introduction of improved barns in the region by which considerable savings could be realised. Further the area-wide use of a mixture of firewood sources should be recommended. However, having said this it has to be kept in mind that such monoculture plantations of non-indigenous species like eucalyptus draw heavily on underground water (Calder, 1992). Finally, efficiency could also be enhanced by forming bigger production units exploiting economies of scale.

The theoretically well established links between efficiency and sustainability of resource use as well as between community based resource management and sustainability of resource use could be highlighted by the empirical material. By focusing on improving tobacco farmers' efficiency, policy measures indirectly contribute to the goal of resource use sustainability and biodiversity conservation in the Miombo woodlands of Tanzania. The same holds with respect to the institutional arrangements of forest resource management: Community based institutional arrangements significantly contribute to the conservation of forest in Tanzania implying the need for an enhancement of such arrangements and supporting the view that government authorities should continue to transfer control over the woodland resources back to the community level. Such arrangements can even contribute to the enhancement of tobacco production efficiency by disseminating of information and experience among small-scale farmers via extension programs or other forms of non-formal education. Hence, this empirical investigation supports the results of earlier findings with respect to the superiority of cooperative arrangements for resource management aiming at tackling the loss of biodiversity.

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