

Tchale, Hardwick; Sauer, Johannes; Wobst, Peter

Working Paper

Impact of alternative soil fertility management options on maize productivity in Malawi's smallholder farming system

ZEF Discussion Papers on Development Policy, No. 98

Provided in Cooperation with:

Zentrum für Entwicklungsforschung / Center for Development Research (ZEF), University of Bonn

Suggested Citation: Tchale, Hardwick; Sauer, Johannes; Wobst, Peter (2005) : Impact of alternative soil fertility management options on maize productivity in Malawi's smallholder farming system, ZEF Discussion Papers on Development Policy, No. 98, University of Bonn, Center for Development Research (ZEF), Bonn

This Version is available at:

<https://hdl.handle.net/10419/32307>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



ZEF Bonn
Zentrum für Entwicklungsforschung
Center for Development Research
Universität Bonn

Hardwick Tchale, Johannes Sauer,
Peter Wobst

Number
98

**Impact of Alternative Soil
Fertility Management Options
on Maize Productivity in
Malawi's Smallholder
Farming System**

ZEF – Discussion Papers on Development Policy
Bonn, August 2005

The CENTER FOR DEVELOPMENT RESEARCH (ZEF) was established in 1995 as an international, interdisciplinary research institute at the University of Bonn. Research and teaching at ZEF aims to contribute to resolving political, economic and ecological development problems. ZEF closely cooperates with national and international partners in research and development organizations. For information, see: <http://www.zef.de>.

ZEF – DISCUSSION PAPERS ON DEVELOPMENT POLICY are intended to stimulate discussion among researchers, practitioners and policy makers on current and emerging development issues. Each paper has been exposed to an internal discussion within the Center for Development Research (ZEF) and an external review. The papers mostly reflect work in progress.

Hardwick Tchale, Johannes Sauer, Peter Wobst: Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System, ZEF – Discussion Papers On Development Policy No. 98, Center for Development Research, Bonn, August 2005, pp. 29.

ISSN: 1436-9931

Published by:

Zentrum für Entwicklungsforschung (ZEF)

Center for Development Research

Walter-Flex-Strasse 3

D – 53113 Bonn

Germany

Phone: +49-228-73-1861

Fax: +49-228-73-1869

E-Mail: zef@uni-bonn.de

<http://www.zef.de>

The authors:

Hardwick Tchale, Center for Development Research (ZEF), Bonn, Germany
(contact: htchale@yahoo.co.uk).

Johannes Sauer, Center for Development Research (ZEF), Bonn, Germany
(contact: jsauer@uni-bonn.de).

Peter Wobst, Center for Development Research (ZEF), Bonn, Germany
(contact: peter.wobst@cec.eu.int).

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

Contents

Acknowledgements

Abstract	1
Kurzfassung	2
1 Introduction	3
2 Review of smallholder maize productivity in Malawi	5
3 Theoretical Review	7
4 The empirical model	9
5 Data	14
6 Discussion of the results	16
7 Conclusions and policy implications	22
References	24
Appendix	29

List of Tables

Table 1: Descriptive statistics	15
Table 2: Estimation results	16
Table 3: Mean output elasticities	17
Table 4: Returns to scale by soil fertility management option	18
Table 5: The economics of maize production under alternative soil fertility management	21

List of Figures

Figure 1: Maize productivity in Malawi	5
Figure 2: Average and marginal products under alternative soil fertility management	19
Figure 3: Average cost of maize production under alternative soil fertility management	20

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

List of Abbreviations

ADD:	Agricultural Development Division
AP:	Average Product
BH:	Bordered Hessian Matrix
EPA:	Extension Planning Area
FAOSTAT:	Food and Agricultural Organization Agricultural Statistical Database
IFPRI:	International Food Policy Research Institute
ISFM:	Integrated Soil Fertility Management
MB:	Mitscherlich Baule Production Function
MP:	Marginal Product
MPTF:	Maize Productivity Task Force
NGO:	Non-Governmental Organization
PASAD:	Policy Analysis for Sustainable Agricultural Development Project
RTS:	Returns to Scale

Acknowledgements

This research was made possible through funding by the Robert Bosch Foundation to the Policy Analysis for Sustainable Agricultural Development (PASAD) Project at the Center for Development Research, University of Bonn. The authors sincerely acknowledge the funding. The Authors also extend their appreciation to Dr. Todd Benson at IFPRI who provided the on-farm trials data. However, the opinions expressed in this paper are those of the authors and do not reflect the views of PASAD, Center for Development Research or University of Bonn. These organizations do not guarantee the accuracy of the results of this study and will accept no responsibility for any consequences of their use.

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

Abstract

This paper focuses on smallholder maize production in Malawi by investigating the link between productivity and soil fertility management. Many studies conducted in Malawi indicate declining levels of maize productivity thereby posing food security concerns, since maize is the staple crop for most areas of the country. This analysis focuses on the factors influencing productivity of maize among smallholder farmers, especially given the fears that unfavorable output and input market conditions throughout the 1990s may have compelled smallholder farmers into unsustainable agricultural intensification. Farm-household survey data is thus used to compare the productivity of smallholder maize production under integrated soil fertility (ISFM) and chemical-based soil fertility management. A normalized translog yield response model is estimated by imposing monotonicity and curvature correctness at the sample mean. The results indicate higher maize yield responses for integrated soil fertility management options, after controlling for the intensity of fertilizer application, labour intensity, seed rate, land husbandry practices and policy factors such as market access, extension and credit access. The estimated model is highly consistent with theoretical regularity conditions. Thus, the findings indicate that the use of ISFM increases maize productivity in comparison to the use of inorganic fertilizers. Since most farmers in the maize-based farming systems are crowded out of the agricultural input market and can hardly afford optimal quantities of inorganic fertilizer, enhancement of ISFM provides scope for enhancing maize productivity and food security especially where inorganic fertilizer is highly unaffordable and risky to use. Thus there is need for policy interventions to promote smallholder uptake of ISFM options. Finally areas of policy support in crop output and input market development, credit access and extension service provision are identified to enhance ISFM uptake in smallholder maize-based farming systems.

Kurzfassung

Dieser Beitrag betrachtet die kleinbäuerliche Maisproduktion in Malawi indem die Beziehung zwischen Produktivität und Bodenfertilitätsmanagement untersucht wird. Viele der in Malawi durchgeführten Studien berichten von einer rückläufigen Produktivität des Maisanbaus. Da Mais die zentrale Nahrungsmittelpflanze für die meisten Regionen des Landes ist, führt dies zu Problemen im Hinblick auf die Nahrungsmittelsicherheit. Die nachfolgende Analyse fokussiert daher die Faktoren, welche die Produktivität des kleinbäuerlichen Maisanbaus beeinflussen. Dies geschieht vor dem Hintergrund der unvorteilhaften sektoralen Bedingungen im Verlauf der 90er Jahre, welche bei den Kleinbauern eine Intensivierung der Produktion veranlasst haben könnten. Haushaltsdaten werden genutzt um die Produktivität der kleinbäuerlichen Maisproduktion mit einem integrierten Bodenfertilitätsmanagement (ISFM) und diejenige auf der Basis eines chemikalischen Bodenfertilitätsmanagements zu vergleichen. Es wird ein normalisiertes translog Ertragsmodell geschätzt indem Monotonie- und funktionale Krümmungserfordernisse auferlegt werden. Unter Berücksichtigung der Düngemittel- und der Arbeitsintensität sowie der Aussaatbedingungen, der Bodenbearbeitungspraxis und institutioneller sowie politischer Faktoren zeigen die Resultate höhere Ertragsraten für die Produktion mit integriertem Bodenfertilitätsmanagement. Das Schätzmodell weist eine sehr hohe Konsistenz mit den theoretischen Regularitätsbedingungen auf. Die Ergebnisse legen nahe, dass im Vergleich zu inorganischem Düngemiteleinsatz der Einsatz von ISFM die Produktivität der Maisproduktion erhöht. Da viele der maisproduzierenden Kleinbauern nur schwerlich Zugang zu den traditionellen Inputmärkten haben, könnte die Ausweitung des integrierten Bodenfertilitätsmanagements Raum für eine Steigerung der Produktivität des Maisanbaus und der Nahrungssicherheit geben. Dies gilt insbesondere für Gebiete, in denen inorganische Düngemittel nicht erschwinglich sind und risikoreich in der Anwendung erscheinen. Folglich besteht Bedarf für politische Interventionen, um die Akzeptanz von ISFM unter Kleinbauern zu erhöhen. Schließlich identifiziert die vorliegende Studie Ansatzpunkte für potentielle politische Maßnahmen um die Ausweitung des integrierten Bodenfertilitätsmanagements in kleinbäuerlichen maisbasierten Agrarsystemen nachhaltig zu fördern.

1 Introduction

Maize is the dominant crop in most smallholder farming systems in Africa south of the Sahara. In Malawi, it is the main staple crop, estimated to be grown on over 70% of the arable land and nearly 90% of the cereal area, making Malawi one of the world's highest consumer of maize at 148 kg per capita per year (Smale and Jayne 2003). Thus, maize remains a central crop in the food security equation of Malawi even if the agricultural economy is diversified. The dominance of maize as a staple crop mainly emanates from self-sufficiency policy which the Government adopted after independence in the mid 1960s. This resulted from the need to produce enough food to feed the growing rural population as well as keep staple food prices low.

Many studies conducted in Malawi indicate declining levels of maize productivity that poses serious food security concerns, since maize is the staple crop for most of the country (Kydd 1989; Smale and Jayne 1995; Chirwa 2003). The paper analyzes the factors that influence productivity of maize among smallholder farmers, given that unfavorable output and input market conditions throughout the 1990s have compelled smallholder farmers into unsustainable agricultural intensification. Currently, the most comprehensive studies of smallholder productivity in Malawi have been conducted by Chirwa (1996), Chirwa (2003) and Edriss et al. (2004). The first two studies have used data collected from a sample of farmers from Machinga Agricultural Development Division (ADD). Edriss et al. (2004) used national level data to analyze the levels of maize productivity given the labour market liberalization. All these studies used parametric approaches to estimate the efficiency of Malawian smallholder farmers in maize production. This paper complements these studies in a number of ways. First, the first two studies have been restricted to only one agro-ecological zone and their results may not be applicable to other agro-ecological zones, whereas the sample used for the analysis in this paper is drawn from three agro-ecological zones and thus accounts for agro-ecological variations. Secondly, both studies did not account for the theoretical regularity conditions in their analysis. Therefore it is highly likely that policy conclusions drawn from these studies may have been flawed due to lacking regularity of the estimated functions. Thirdly, this paper considers the productivity effect of alternative soil fertility management options available to smallholder farmers. This is important because while many alternative soil fertility management options have been developed for smallholder farmers, very little is known about their impact on improving smallholder farmers' productivity. The obvious weakness of the study by Edriss et al. (2004) is the use of national level data that masks the farm-level variations. This is improved upon through the use of farm-level data.

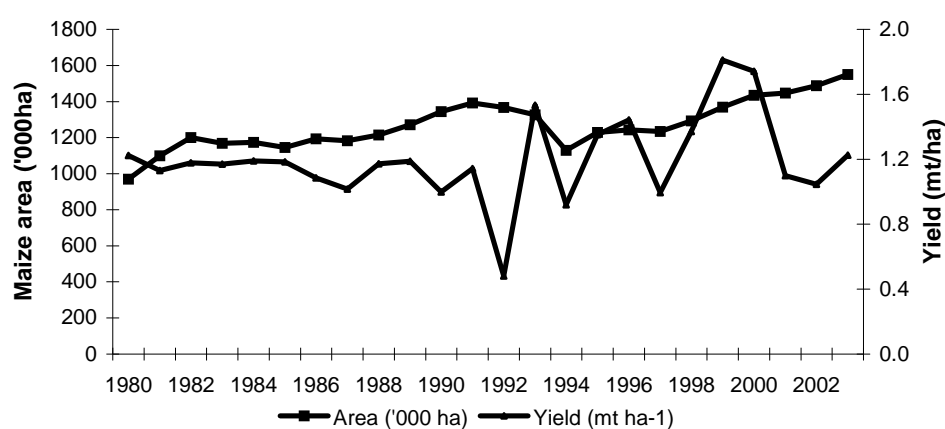
The rest of the paper is arranged as follows: the next section presents a review of maize productivity, drawing from previous studies conducted on Malawi, with specific reference to the smallholder sector. This is followed by the discussion of the theoretical model on which the analytical model presented in section four is based. Section five describes the data and the analysis. Section six concludes with main findings and their policy implications.

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

2 Review of smallholder maize productivity in Malawi

Despite the central role that maize plays in food security in Malawi, its productivity has not been impressive especially from the early 1990s when stagnation in maize yield led to frequent food security problems. Smale and Jayne (2003) have attributed the decline in maize yield to four main reasons: (i) removal of subsidies; (ii) devaluation of the Malawi Kwacha; (iii) increase in world fertilizer prices; and (iv) low private market development because fertilizer dealers require substantial risk premiums to hold and transport fertilizer in an inflationary economy with uncertain demand (Conroy 1997; Diagne and Zeller 2001; Benson 1997; 1999). The situation is exacerbated because maize price changes follow parity levels while fertilizer price changes reflect full import costs. Since most fertilizer in Malawi is used on maize (and tobacco), the removal of implicit subsidies in the form of over-valued exchange rates had a strong negative effect on fertilizer use. Furthermore, since almost all of Malawi's fertilizer supply is imported, the depreciation of the real exchange rate has also invariably raised the nitrogen to grain price ratios (Minot, Kherallah and Berry 2000; Heisey and Smale 1995). All these factors, along with shifts in relative prices of competing crops, as well as the unfavorable weather patterns may have contributed to the major fluctuations in the maize yield and production through the 1990s as shown in Figure 1.

Figure 1: Maize Productivity in Malawi (1980-2002)



Source: Ministry of Agriculture and Irrigation National Crop Estimates
FAOSTAT (area data)

One critical consequence of the increase in fertilizer prices relative to maize grain prices is that most farmers over the past decade have continued to over-exploit the natural soil fertility. This is because the improved maize varieties released by the National Agricultural Research (i.e. MH17 and MH18) proved to yield more than local maize without fertilizer at the seed prices that prevailed through the early 1990s. This implies that it made economic sense for farmers to grow hybrids even if they could not apply fertilizer (Heisey and Smale 1995; Benson 1999). This has resulted in soil fertility mining, leading to unsustainability, as the inherent soil fertility is no longer capable of supporting crop output at a rate that is required to feed the growing population. This calls for concerted efforts to promote smallholder soil fertility management using relatively more sustainable options such as integrated soil fertility management (ISFM) i.e. involving incorporation of grain legumes and inorganic fertilizer in maize production systems. However, farmers' choice of the available soil fertility management options depends to a large extent on the relative returns of the options.

This study aims at assessing the productivity (and thus profitability) of maize production using ISFM or inorganic fertilizers only. This is important in order to assist farmers to make rational soil fertility management choices, given the options made available through soil fertility and agronomic research.

3 Theoretical Review

A number of functional forms have been used to specify yield response functions, most commonly the Cobb-Douglas, quadratic, square root, translog, Mitscherlich-Baule (or MB) as well as the linear and non-linear Von-Liebig functions. The rationale for choosing a particular functional form depends on the research questions and the underlying production processes to be modeled (Nkonya 1999). Furthermore, the choice of a functional form should be based on the need to ensure rigorous theoretical consistency and factual conformity within a given domain of application as well as flexibility and computational easiness (Lau 1986; Sauer et al., 2004). For example, while the Cobb-Douglas is simpler and easier to estimate, it assumes invariant returns to scale and does not ensure the attainment of a yield response plateau, thereby resulting in an overestimation of the optimal input quantities (Ackello-Ogututu et al. 1985). The polynomial functions (i.e. the quadratic and square root) do allow for the diminishing marginal returns of inputs as well as flexible input substitution, but they are also lacking when it comes to the yield response plateau. The non-linear Von-Liebig and MB functions are the most widely used functions, especially in the field of agronomy. However, because they are highly non-linear, especially when a number of inputs are involved, their estimation is cumbersome and liable to several parametric restrictions. The other weakness of the MB function is that it may not be appropriate for modeling farm production in developing countries because it is only appropriate for stage II production (where marginal product increases at a decreasing rate). But research shows that most constrained farmers in developing countries still largely operate within stage I where marginal product increases at an increasing rate (Franke et al. 1990; Keyser 1998).

We maintain the assumption that farmers' choice of a soil fertility management option is based on the desire to increase the profit derived from increased crop yield. As such the underlying problem is that of optimizing profit, given the technology and soil fertility management options available. Thus given the production function:

$$h(q, x, z) = 0 \tag{1}$$

where q is the vector of output, x is the vector of variable inputs and z is a vector of fixed factors. If we let p and c be the output and input prices respectively, the farmer's restricted profit becomes¹:

¹ Profit is restricted because only the variable costs are subtracted from the gross revenue. The restricted profit equation uses p' and c' to denote the transposition of vectors (see Sadoulet and de Janvry 1995).

$$\pi = p'q - c'x \quad [2]$$

The farmer is thus assumed to choose a combination of variable inputs and outputs that will maximize restricted profit subject to the production technology constraint:

$$\underset{x,q}{\text{Max}} p'q - c'x \quad \text{s.t.} \quad h(q, x, z) = 0 \quad [3]$$

The solution to this profit maximization problem becomes a set of input demand and output supply functions of the form:

$$x = x(p, c, z) \quad \text{and} \quad q = q(p, c, z) \quad [4]$$

Substitution of the expressions in [4] into the restricted profit equation given by [2] gives the maximum profit the farmer could obtain given the output and input prices, the availability of fixed factors and the production technology.² Hence it is possible to derive the optimal level of inputs, which when substituted into the corresponding production function yield the optimum level of output which is consistent with the optimal level of restricted profit. The following analysis uses a primal production function rather than the dual profit function as the latter is conditioned on prices. Relevant prices in the study area suffer from a considerable bias of aggregation as it is fairly difficult to capture the variation in prices on household level. Given further the uncertainties in expected agricultural prices and production, it is unlikely that the correspondence between expected prices and production would give a good model fit.

² Due to duality theory a well behaved dual profit function is a “sufficient condition” of the underlying well-behaved production function (see McFadden, 1978). According to economic theory a well-behaved production/profit function has to be non-negative, monotonically increasing (decreasing) in output (input) prices, concave (convex), homogeneous of degree zero in all prices and if the production function displays constant returns to scale, homogeneous of degree one in all fixed factors (Sadoulet and de Janvry 1995).

4 The empirical model

In this analysis, a normalized translog functional form was used because of the assumption that yield response depends on nutrient use efficiency. Such a relationship can be approximated by a second order polynomial function. The normalized translog models have been widely used for describing the crop response to fertilization and tend to statistically perform better than other functional forms. Belanger et al. (2000) compared the performance of three functional forms (quadratic, exponential and square root) and concluded that although the quadratic form is the most favoured in agronomic yield response analysis, it tends to overstate the optimal input level, and thus underestimating the optimal profitability. Other studies that have reached similar conclusions include Bock and Sikora (1990), Angus et al. (1993) and Bullock and Bullock (1994). Our choice of the normalized translog is based on two further reasons: First, it is the best-investigated second order flexible functional form and certainly one with the most applications (Sauer et al. 2004); secondly, this functional form is convenient to estimate and proved to be a statistically significant specification for economic analyses as well as a flexible approximation of the effect of input interactions on yield.

The normalized translog maize production model can be expressed as:

$$\ln\left(\frac{q}{q'}\right) = \alpha_0 + \sum_{i=1}^n \alpha_i \ln\left(\frac{x_i}{x_i'}\right) + \frac{1}{2} \sum_{i=1}^{n-1} \sum_{j=i+1}^n \beta_{ij} \ln\left(\frac{x_i}{x_i'}\right) \ln\left(\frac{x_j}{x_j'}\right) + \sum_{k=1}^m \gamma_k z_k + \varepsilon_i \quad \varepsilon_i \sim N(0, \sigma^2) \quad [5]$$

Where q is the yield (kg/ha), x_i are the variable inputs (fertilizer, labour and seed), z is a vector of productivity shifters such as land husbandry practices (i.e. weeding and date of planting) as well as rainfall. All variables are normalized to the sample mean by dividing by the mean value (q' , x_i' , x_j'). We also include a dummy variable for soil fertility management (i.e. integrated management or use of inorganic fertilizer only) in order to assess the impact of soil fertility management choice on yield response as well as other control variables. α_i are the linear input parameters, β_{ij} are the quadratic and interaction parameters, γ_k are the parameters for the productivity shifters and ε_i is the error term assumed to be randomly distributed with zero mean and constant variance σ^2 .

In the case of a (single output) production function monotonicity requires positive marginal products with respect to all inputs and thus non-negative elasticities. With respect to the normalized translog production model the marginal product of input i is obtained by multiplying

the logarithmic marginal product with the average product of input i . Thus the monotonicity condition given holds for our translog specification if the following equation is true for all inputs:

$$\frac{d\left(\frac{q}{q'}\right)}{d\left(\frac{x_i}{x_i'}\right)} = \frac{\left(\frac{q}{q'}\right) d \ln\left(\frac{q}{q'}\right)}{\left(\frac{x_i}{x_i'}\right) d \ln\left(\frac{x_i}{x_i'}\right)} = \frac{\left(\frac{q}{q'}\right)}{\left(\frac{x_i}{x_i'}\right)} \left(\alpha_i + \sum_{j=1}^n \beta_{ij} \ln\left(\frac{x_j}{x_j'}\right) \right) > 0 \quad [6]$$

Since both (q/q') and (x_i/x_i') are positive numbers, monotonicity depends on the sign of the term in parenthesis, i.e. the elasticity of (q/q') with respect to (x_i/x_i') .³ By further adhering to the law of diminishing marginal productivities, marginal products, apart from being positive should be decreasing in inputs implying the fulfillment of the following expression:

$$\frac{d^2\left(\frac{q}{q'}\right)}{d\left(\frac{x_i}{x_i'}\right)^2} = \left[\alpha_{ii} + \left(\alpha_i - 1 + \sum_{j=1}^n \beta_{ij} \ln x_j \right) \left(\alpha_i + \sum_{j=1}^n \beta_{ij} \ln x_j \right) \right] \left[\frac{\left(\frac{q}{q'}\right)}{\left(\frac{x_i}{x_i'}\right)^2} \right] < 0 \quad [7]$$

Again, this depends on the nature of the terms in parenthesis. These should be checked a posteriori by using the estimated parameters for each data point. However, both restrictions (i.e. $[\partial(q/q')/\partial(x_i/x_i')] > 0$ and $[\partial^2(q/q')/\partial(x_i/x_i')^2] < 0$) should hold at least at the point of approximation.

The necessary and sufficient condition for a specific curvature consists in the semi-definiteness of the bordered Hessian matrix as the Jacobian of the derivatives $\partial(q/q')/\partial(x_i/x_i')$ with respect to x_i : if $\nabla^2 Y(x)$ is negatively semi-definite, Y is quasi-concave, where ∇^2 denotes the matrix of second order partial derivatives with respect to the normalized translog production model. The Hessian matrix is negative semi-definite at every unconstrained local maximum⁴. The conditions of quasi-concavity are related to the fact that this property implies a convex input requirement set (see in detail e.g. Chambers, 1988). Hence, a point on the isoquant is tested, i.e. the properties of the corresponding production function are evaluated subject to the condition that the amount of production remains constant. With respect to the

³ If it is assumed that markets are competitive and factors of production are paid their marginal products, the term in parenthesis equals the input i 's share of total output, s_i .

⁴ Hence, the underlying function is quasi-concave and an interior extreme point will be a global maximum. The Hessian matrix is positive semi-definite at every unconstrained local minimum.

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

translog production function curvature depends on the specific input bundle X_i , as the corresponding bordered Hessian **BH** for the 3 input case shows:

$$BH = \begin{pmatrix} 0 & b_1 & b_2 & b_3 \\ b_1 & h_{11} & h_{12} & h_{13} \\ b_2 & h_{21} & h_{22} & h_{23} \\ b_3 & h_{31} & h_{32} & h_{33} \end{pmatrix} \quad [8]$$

where b_i is given in [6], h_{ii} is given in [7] and h_{ij} is:

$$\frac{d^2 \left(\frac{q}{q'} \right)}{d \left[\left(\frac{x_i}{x_i'} \right) \left(\frac{x_j}{x_j'} \right) \right]} = \left[\alpha_{ij} + \left(\alpha_i + \sum_{j=1}^n \beta_{ij} \ln \left(\frac{x_j}{x_j'} \right) \right) * \left(\alpha_j + \sum_{i=1}^n \alpha_{ij} \ln \left(\frac{x_i}{x_i'} \right) \right) \right] * \left(\frac{\left(\frac{q}{q'} \right)}{\left(\frac{x_i}{x_i'} \right) \left(\frac{x_j}{x_j'} \right)} \right) < 0 \quad [9]$$

Given a point x^0 , necessary and sufficient for curvature correctness is that at this point $\mathbf{v}'H\mathbf{v} \leq 0$ and $\mathbf{v}'\mathbf{s} = 0$ where \mathbf{v} denotes the direction of change.⁵ For some input bundles quasi-concavity may be satisfied but for others not and hence what can be expected is that the condition of negative semi-definiteness of the bordered Hessian is met only locally or with respect to a range of input bundles. The respective bordered Hessian is negative semi-definite if the determinants of all of its principal submatrices are alternate in sign, starting with a negative one (i.e. $(-1)^j D_j \geq 0$ where D is the determinant of the leading principal minors and $j = 1, 2, \dots, n$).⁶ Hence, with respect to our normalized translog production model it has to be checked a posteriori for every input bundle that monotonicity and quasi-concavity hold. If these theoretical criteria are jointly fulfilled the obtained estimates are consistent with microeconomic theory and consequently can serve as empirical evidence for possible policy measures.

With respect to the proposed normalized translog production model quasi-concavity can be imposed at a reference point (usually at the sample mean) following Jorgenson and Fraumeni (1981). By this procedure the bordered Hessian in [8] is replaced by the negative product of a lower triangular matrix Δ times its transpose Δ' (see appendix A1). Imposing curvature at the sample mean is then attained by setting

$$\beta_{ij} = -(\Delta \Delta')_{ij} + \alpha_i \lambda_{ij} + \alpha_i \alpha_j \quad [10]$$

⁵ Which implies that the Hessian is negative semi-definite in the subspace orthogonal to $\mathbf{s} \neq 0$.

⁶ Determinants of the value 0 are allowed to replace one or more of the positive or negative values. Any negative definite matrix also satisfies the definition of a negative semi-definite matrix.

where $i, j = 1, \dots, n$, $\lambda_{ij} = 1$ if $i = j$ and 0 otherwise and $(\Delta\Delta')$ _{ij} as the ij-th element of $\Delta\Delta'$ with Δ a lower triangular matrix.⁷ As our point of approximation is the sample mean all data points are divided by their mean transferring the approximation point to an $(n + 1)$ -dimensional vector of ones. At this point the elements of \mathbf{H} do not depend on the specific input price bundle. The estimation model of the normalized translog production function is then reformulated as follows:

$$\begin{aligned} \ln\left(\frac{q}{q'}\right) = & \alpha_0 + \alpha_1 \ln\left(\frac{x_1}{x_1'}\right) + \alpha_2 \ln\left(\frac{x_2}{x_2'}\right) + \alpha_3 \ln\left(\frac{x_3}{x_3'}\right) + \frac{1}{2}(-\delta_{11}\delta_{11} + \alpha_1 - \alpha_1\alpha_1) \ln\left(\frac{x_1}{x_1'}\right)^2 + \frac{1}{2}(-\delta_{22}\delta_{22} - \delta_{22}\delta_{22} + \alpha_2 - \alpha_2\alpha_2) \ln\left(\frac{x_2}{x_2'}\right)^2 \\ & + \frac{1}{2}(-\delta_{33}\delta_{33} - \delta_{23}\delta_{23} - \delta_{33}\delta_{33} + \alpha_3 - \alpha_3\alpha_3) \ln\left(\frac{x_3}{x_3'}\right)^2 + \frac{1}{2}(-\delta_{12}\delta_{11} - \alpha_1\alpha_2) \ln\left(\frac{x_1}{x_1'}\right)^2 \ln\left(\frac{x_2}{x_2'}\right)^2 + \frac{1}{2}(-\delta_{31}\delta_{11} - \alpha_1\alpha_3) \ln\left(\frac{x_1}{x_1'}\right)^2 \ln\left(\frac{x_3}{x_3'}\right)^2 \\ & + \frac{1}{2}(-\delta_{32}\delta_{12} - \delta_{23}\delta_{22} - \alpha_2\alpha_3) \ln\left(\frac{x_2}{x_2'}\right)^2 \ln\left(\frac{x_3}{x_3'}\right)^2 + \sum_{k=1}^m \gamma_k z_k + \varepsilon_i \end{aligned} \tag{11}$$

However, the elements of Δ are nonlinear functions of the decomposed matrix, and consequently the resulting normalized translog model becomes nonlinear in parameters. Hence, linear estimation algorithms are ruled out even if the original function is linear in parameters. By this “local” procedure a satisfaction of consistency at most or even all data points in the sample can be reached. The transformation in [11] moves the observations towards the approximation point and thus increases the likelihood of getting theoretically consistent results at least for a range of observations (see Ryan and Wales 2000). However, by imposing global consistency on the translog functional form Diewert and Wales (1987) note that the parameter matrix is restricted leading to seriously biased elasticity estimates. Hence, the translog function would lose its flexibility. By a second analytical step we finally (a posteriori) check the theoretical consistency of our estimated model by verifying that the first derivatives of [6] are positive (monotonicity) the own second derivatives are negative and finally the Hessian is negative semi-definite (concavity).

Using equation [5], the optimal level of x_i is obtained by setting the marginal productivity (i.e. the first order condition) equal to the input/output price ratio. Using the predicted yield response at the optimum level of x_i , predicted profit levels are compared between the two soil fertility management practices. The predicted profit equation is given as:

$$\pi = p \cdot q - \sum_{i=1}^j c x_{ij} \tag{12}$$

⁷ Alternatively one can use Lau’s (1978) technique by applying the Cholesky factorization $\Delta = -LBL'$ where L is a unit lower triangular matrix and B as a diagonal matrix.

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

where p and c are output and input prices. Assuming that all farmers are price-takers (in both the factor and product markets), then profit will solely depend on the yield response function given by the marginal productivity of the input. Thus:

$$\frac{\partial \pi}{\partial x_i} = \bar{p} * \frac{\partial q}{\partial x_i} - \bar{c} \quad [13]$$

Therefore, substituting the optimal level of x_i into equation [12], and solving for q , keeping all the other variables at the mean, results in the optimal yield, which is then used in calculating the level of profit. This procedure is performed for all alternative soil fertility management options and the levels of optimal yield and profit are then compared. Similarly, we also compute the average total costs for maize production using the two soil fertility management practices.

5 Data

The data used for analysis in this study is based on a farm household survey administered to a stratified sample of 376 farmers. These farmers were randomly drawn from those that had been participating, more or less consistently, in the soil fertility management efforts involving public research institutions, donor organizations and NGOs for at least 5 previous seasons. The farmers were sampled from Blantyre, Lilongwe and Mzuzu Agricultural Development Divisions (ADD) using the stratified random sampling approach. From these farmers, maize technology information related to variety grown, rate of input application, other soil fertility options applied as well as the general husbandry practices applied to the crop were collected and used in the analysis. The sample used for the analysis comprises of 253 plots (out of a total of 573 plots) on which hybrid maize was grown as the main crop⁸.

To validate the performance of various soil fertility management practices, we compared the farmers' yields with those obtained from two on-farm trails. The first is the Area-specific Fertilizer Recommendation Trail conducted by the Maize Productivity Task Force (MPTF) of the Ministry of Agriculture in which 1750 demonstrations were laid out on farmers' fields in all the agricultural extension sections in the country in 1997/98 season. The second data set is also a Nationwide Best-bet Trial that was implemented on 1400 on-farm sites by the Malawian Extension Service in 1998/99, using the same set-up as the Area-specific Fertilizer Recommendation Trail. The objective was to compare the maize yield responses of fertilized and unfertilized legume cropping systems. In total six treatments were included in the experiment: (i) green legume rotation involving either soybean or groundnuts; (ii) *Mucuna pruriens* rotation; (iii) maize pigeon pea intercrop; (iv) fertilized maize; (v) unfertilized maize; and (vi) local maize (fertilized and unfertilized) as the control. The fertilized option involved either 35 or 69 kg/ha of N fertilizers (Urea or 23:21:0+4S) depending on the area-specific fertilizer recommendations. In all treatments except the control, the same maize varieties i.e. MH17 and MH18 were planted depending on the altitude of an area.

In comparing the on-farm trail results with those estimated from the farm household survey, the on-farm trials data were adjusted downwards by a total of 26% comprising a 7.5% adjustment to account for a higher than standard grain moisture and an additional 20% to reflect

⁸ We only analyze the productivity of hybrid maize mainly because government policy only promotes farmer' adoption of hybrid and not low yielding local maize varieties. The yield figures were based on farmers' recall and adjusted for pre and post harvest losses. Labour data was also collected during the survey based on farmers' recall of the number of hours they spend on maize per day, on average, during the maize season. These figures were then converted to mandays based on standard conversion factors. The area measurements were cross-checked with those from the MPTF dataset and also confirmed during the process of soil sampling. While not all data errors could be corrected for, our confidence with the data stems from the fact that if we adjust for different levels of management, our data compares well with that from on-farm trails collected from the same farmers by MPTF.

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

the difference in yields from the trial plots and that which the majority of farmers achieve on larger plots under comparable management (Benson, 1999).

Apart from the key inputs such as fertilizer, seed and labour, the specification of the productivity model includes also a number of important control variables that substantially affect yields, especially in the smallholder farming systems. These include rainfall, crop husbandry practices such as weeding frequency and date of planting as well as the critical policy variables i.e. frequency of extension visits, access to seasonal agricultural credit, access to product and factor markets and agro-ecological dummies. A soil fertility management dummy (either fertilizer only or integrated soil fertility management (ISFM) involving fertilizer and grain legume intercrops for biological nitrogen fixation) was also included. The descriptive statistics for all the variables that were included in the productivity model are presented in Table 1.

Table 1: Descriptive Statistics

VARIABLE	DESCRIPTION	MEAN	STD.
<i>YIELD</i>	Hybrid maize yield (kg/ha)	914.9	886.6
<i>FERTILIZER</i>	Fertilizer intensity (kg/ha)	30.9	38.3
<i>LABOUR</i>	Labour intensity (mandays/ha/month)	67.3	34.8
<i>SEED</i>	Seed intensity (kg/ha)	25.7	15.6
<i>SFM</i>	Soil fertility management (1=ISFM;0=fert)	0.6	0.5
<i>WEEDING</i>	Frequency of weeding	1.4	0.8
<i>PLANTING</i>	Date of planting (1=early; 0=later than first rains)	0.7	0.5
<i>RAIN⁹</i>	Rainfall in mm	899.1	59.0
<i>EXT_FREQ</i>	Frequency of extension visits per month	0.8	1.0
<i>CREDIT</i>	Access to credit (1=yes; 0=no)	0.4	0.5
<i>MACCESS</i>	Market access (1=accessible; 0=remote)	0.4	0.5

Source: Own survey (2003)

⁹ In the treatment of stochastic variables like rainfall, we have maintained the Gauss-Markov theorem that in a classical linear regression model, the least squares estimator has the minimum variance and is linear and unbiased irrespective of whether the regressor is stochastic or not (Greene 2003). We have not tested for the exogeneity of independent variables due to lack of proper instruments. Rainfall entered the estimation as a dummy where 1 represents normal rainfall in an area as perceived by the farmer, and 0 otherwise.

6 Discussion of the results

The estimation results are shown in Table 2. Given the cross-sectional data set and the imposed regularity constraints, the overall model fit is significant at the 1%-level ($P < 0.000$). Nearly 87% of all observations are consistent with the regularity conditions of monotonicity, diminishing marginal returns and quasi-concavity respectively. We also conducted a test of all relevant econometric problems such as multi collinearity and heteroscedasticity and the variables that were highly correlated were excluded from the analysis. Refer to the appendix for the numerical details of the regularity tests performed. The subsequent discussion is based on the theoretically consistent range of observations in the sample.

All input parameters show the expected sign. Among the inputs, fertilizer, its quadratic and seed interaction terms are highly significant. The parameter on soil fertility management is highly significant implying that the use of integrated soil fertility practices significantly influences maize yield.

Table 2: Estimation Results

PARAMETER	COEFF.	SE	T-VALUE	P-VALUE
Constant	-1.349	4.019	-0.336	0.737
ln(labour)	0.108	0.101	1.074	0.284
ln(fertilizer)***	0.428	0.105	4.067	0.000
ln(seed)	0.493	0.390	1.265	0.207
ln(labour_sq)	0.007	0.082	0.088	0.930
ln(fertilizer_sq)***	-0.014	0.004	-3.654	0.000
ln(seed_sq)	0.005	0.535	0.009	0.993
ln(labour)X ln(fertilizer)	0.004	0.011	0.361	0.719
ln(labour) X ln(seed)	-0.034	0.315	-0.107	0.915
ln(fertilizer)Xln(seed)***	0.156	0.027	5.795	0.000
SFM***	0.042	0.013	3.126	0.002
Rainfall	0.245	0.594	0.412	0.681
Weeding frequency	0.005	0.008	0.537	0.592
Planting date	0.034	0.121	0.278	0.781
Market access	0.007	0.008	0.909	0.364
Extension frequency**	0.013	0.007	2.001	0.046
Credit access	0.007	0.006	1.205	0.229
ADJ. R ²	0.708	MONOTONICITY (%)	86.9	
F-VALUE	335.577	DIM. MARGINAL RETURNS (%)	86.9	
PROB>F	0.000	QUASI-CONCAVITY (%)	86.9	
# OBS.	253	REGULAR (%)	86.9	

Note: *** P<0.000; **P<0.05; *P<0.10

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

Although the parameters for rainfall, weeding frequency and planting dates show the expected signs, they are all insignificant. Among the policy variables, extension frequency is positively and significantly ($P < 0.05$) related to maize productivity, while market and seasonal agricultural credit access are positively related to maize productivity, but are both insignificant. While we would expect significant influences of rainfall and its variation on maize yield, given the rainfed systems, the insignificance may be attributed to two reasons: First, hybrid varieties e.g. MH18 are bred specifically for drought resistance among other aspects and in Malawi most of these are particularly recommended for areas that are prone to intermittent droughts. Secondly, we attribute the insignificance to the way the rainfall data were collected. Rainfall figures are collected at an Extension Planning Area (EPA) level and thus do not reflect the actual variations experienced by different farms within an EPA. To correct for this, we used a dummy variable that indicates the perception of the farmers regarding the intensity and distribution of the rainfall within the area, compared to what they view as normal. The husbandry practices are all positively related to yield for both varieties but are not significant.

The elasticities presented in Table 3 indicate that, keeping all factors constant, a unit increase in seed, fertilizer and labour will result in a 0.43%, 0.42% and 0.11% increase in maize yield respectively. Hence smallholder farmers are not producing at their optimal point with respect to the usage of variable inputs. The relative input usages could be radially increased to increase the maize output. The use of integrated soil fertility management improves the yield of maize by 4.2% on average, compared to the use of inorganic fertilizer only. The elasticity of maize yield with respect to the amount of rainfall further indicates a relatively importance of climatic factors. The effect of the other control and policy variables on maize yield is fairly low as shown in Table 3:

Table 3: Mean Output Elasticities

VARIABLE	ELASTICITY $\left(\frac{\partial \ln\left(\frac{q}{q'}\right)}{\partial \ln\left(\frac{x_i}{x_i'}\right)} \right)$
Labour***	0.106 (0.0077)
Fertilizer***	0.420 (0.0613)
Seed***	0.428 (0.1621)
Soil fertility management*	0.042
Rainfall	0.245
Weeding Frequency	0.005
Planting date	0.034
Market access	0.007
Extension Frequency	0.013
Credit access	0.007

Note: *** $P < 0.000$; ** $P < 0.05$; * $P < 0.10$

♣: Invariant over observations as linear added control variables for SFM to Credit access

In Table 4, we compare the returns to scale associated with smallholder maize production using alternative soil fertility management options. The results indicate that smallholder farmers exhibit considerable returns to scale, consistent with other previous studies (Kamanga et al. 2000). This is because most smallholder farmers operate in a region of the production function where marginal productivity of inputs is increasing (stage I in figure 2). However, returns to scale for farmers using integrated soil fertility management practices are significantly higher ($P < 0.000$) than for farmers using only inorganic fertilizer. The relatively higher returns to scale for integrated soil fertility management options imply that there is still scope for smallholder farmers to exploit scale economies through the use of ISFM options which improve the soil fertility and thus enhance the efficiency of inputs. This is particularly important among smallholder farmers who are unable to afford higher quantities of inorganic fertilizer.

Table 4: Returns to Scale by Soil Fertility Management Option

SOIL FERTILITY MANAGEMENT OPTION	RTS	RTS RANGE	
		MIN.	MAX.
INORGANIC FERTILIZERS ONLY	1.12 (0.07)	0.98	1.35
INTEGRATED SOIL FERTILITY MANAGEMENT	1.50 (0.12)	1.09	1.71
TOTAL SAMPLE	1.31 (0.22)	0.98	1.71

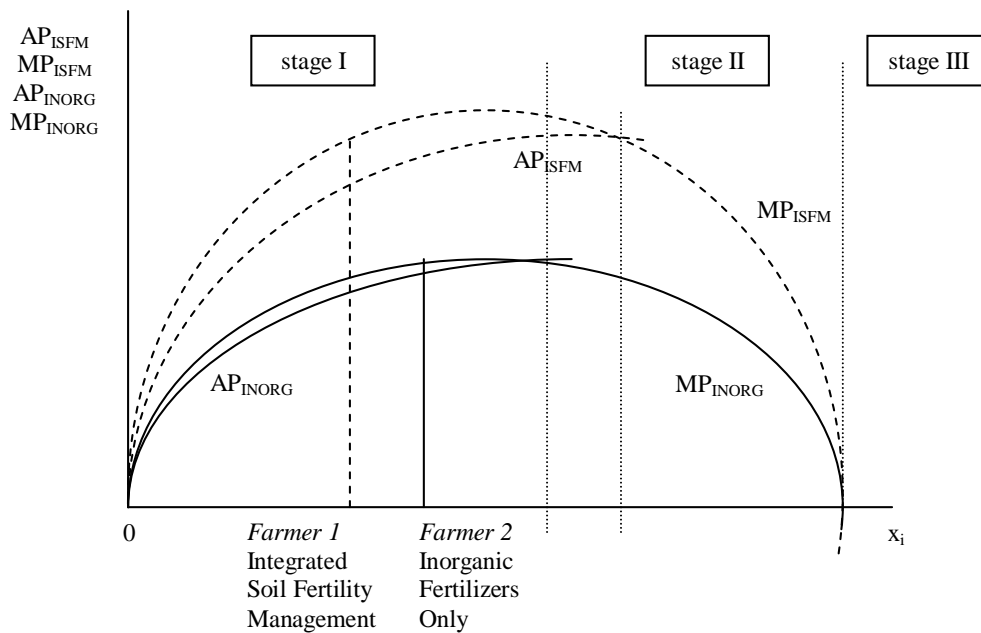
Note: Returns to scale (RTS) difference between soil fertility management options is significant at ($P < 0.000$), Figures in parentheses are standard errors.

These results imply that assuming constant maize/fertilizer price ratios, the optimal yield response for inorganic fertilizer (as well as other inputs) is higher in the case of integrated soil fertility management, due to the significance of the SFM parameter. Thus, with farmers facing more or less the same maize price and input cost, the profitability of smallholder maize production is likely to be higher when farmers integrate inorganic fertilizers with grain legumes. This is illustrated by figure 2 which compares the marginal product (MP) and average product (AP) associated with each soil fertility management option, with chemical fertilizer level on the x-axis.

Farmer 1 as the average farmer using integrated soil fertility management enjoys a higher marginal product (MP_{ISFM}) as well as average product (AP_{ISFM}) than farmer 2 who applies inorganic fertilizers only (MP_{INORG} , AP_{INORG}). As depicted by figure 2 both smallholder farmers experience increasing returns to scale and this could enhance the production of maize. However, the average returns to scale for farmer 1 are relatively higher than those for farmer 2 (space in between the MP and AP curve).

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

Figure 2: Average and Marginal Products



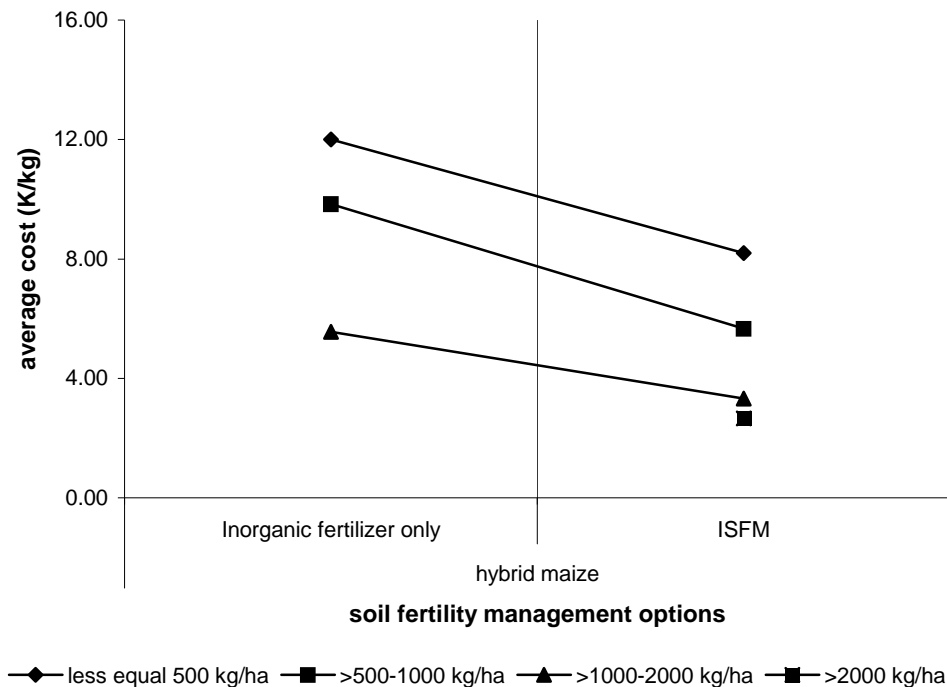
Although the yield effect implied by the elasticity of SFM is somehow low (at 4.2% on average), given the low yields experienced by smallholder farmers, if we account for other bonus crops such as grain legumes (groundnuts, soya and pigeon peas), the overall additional yield effect of ISFM is quite substantial. In fact it is likely to be higher among farmers which are unable to afford optimal quantities of inorganic fertilizer, but still have access to hybrid maize seed.

These results corroborate those of past studies in many ways. Most studies indicate that in general, ISFM options are more remunerative where purchased fertilizer alone remains unattractive or highly risky, as is the case with the maize-based smallholder farming systems in Malawi. For example, marginal rate of return analysis conducted on baby trials in Malawi also identified maize-pigeon pea intercropping, groundnut-maize intercropping and rotation as being economically attractive to smallholder farmers (Tomlow et al. 2001). In Zimbabwe, Whitebread et al. (2004) reported a 64% higher yield when maize is planted following green manure rotation compared to continuous fertilized maize. Mekuria and Waddington (2002) also reported that ISFM options gave a return to labour of \$1.35 per day compared to \$0.25 per day when either mineral fertilizers or organic soil fertility management options are used alone in Zimbabwe. In Kenya, Place et al. (2002) reported that the returns to labour from ISFM options ranged from \$2.14- \$2.68 per day compared to \$1.68 per day when only one of the options is used. Economic analysis in central Zambia also indicates that velvet bean and sunhemp green manure followed by maize gives higher rate of returns compared to fertilized maize crop alone (Mwale et al.

2003). Such superior economic performance indicators are also reported by Mekuria and Siziba (2003) in the case of Zimbabwe.

Applying the assumption that all farmers face the same input and maize price ratios, these results imply that on average, use of ISFM in maize production improves profitability compared to use of inorganic fertilizer only. The average profitability indicators computed from the study data also support these results as shown in Table 5. The gross margin per unit of fertilizer and labour is higher when farmers use ISFM. As a result, using average as well as marginal rate of return, the results indicate that it is more profitable for farmers to produce maize under ISFM than using inorganic fertilizer only as shown in Figure 3:

Figure 3: Average Cost of Maize Production



Use of ISFM reduces the average cost of maize production by as much as 30% (especially among low-productive farmers). This implies that smallholder stand to gain in cost efficiency by adopting ISFM. These results agree with those obtained using on-farm trials data which indicate higher yields in green legume rotation systems compared to maize applied with inorganic fertilizer only. *Mucuna* rotation gives the highest optimal yield compared to maize applied with inorganic fertilizer only. Similarly the optimal yield for groundnut / soybean rotation and maize pigeon pea intercrop is higher than that of maize with inorganic fertilizer only (Kumwenda 1997; Gilbert 1998a, b; Sakala et al. 2003). Also in addition to short-term gains, there is extensive evidence in literature that ISFM provides a lot of scope for improving the sustainability of smallholder production systems through their effect on enhancing soil organic matter accumulation (Vanlauwe et al. 2004).

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

Table 5: The economics of maize production (2003 smallholder output and prices)

	Hybrid maize	
	Inorganic fertilizer only (N= 110)	Integrated SFM (N=143)
Average yield (kg/ha)	702.9	964.7
Gross revenue (Kwacha per ha)	9488.80	13124.09
Labour cost (Kwacha per ha)	1816.02	1478.91
Fertilizer cost (Kwacha per ha)	1520.34	1994.42
Gross margin (Kwacha per ha)	6107.44	9650.76
Gross margin per Kg of fertilizer	368.41	530.26
Gross margin per manday	99.91	191.03
Average variable cost per kg of maize	4.81	3.60
Value/Cost ratio (VCR)	2.81	3.78
Marginal Rate of Return (%)	181	278

Note: Hybrid maize includes MH17 and MH18, Kwacha is the local currency, Fertilizers include a combination of 23:21:0+4s and CAN, Integrated soil fertility management (SFM) involves the application of inorganic fertilizers and incorporation of grain legumes i.e. groundnuts (*Arachis hypogea*) or pigeon peas (*Cajanas cajan*) in an intercrop system.

7 Conclusions and policy implications

The study clearly shows that maize productivity under ISFM is higher than when farmers use inorganic fertilizer only. Gross margin per unit of inputs is also higher, assuming farmers face the same maize prices and input costs. Furthermore, there are long-term benefits associated with ISFM. These results are also likely to be more meaningful among smallholder farmers that can hardly afford optimal levels of inorganic fertilizer, and those in very risky environments. These results in some way also assist to dispel skepticism associated with the benefits of integrated soil fertility management options, especially among farmers that have been crowded out of the agricultural inputs market for reasons of affordability.

In terms of policy implications, ISFM provides scope for improving maize productivity especially where use of inorganic fertilizer is highly unaffordable and risky. Thus from a policy perspective, the results indicate that it is worthwhile to scale-up smallholder farmer adoption of integrated soil fertility management options made available by the Department of Agricultural Research. Since an effective ISFM package needs to include hybrid maize, inorganic fertilizer and improved grain legume seeds, it is highly unlikely that smallholder farmers can afford such a package. From the findings of our study and others, farmers are unable to effectively engage in sustainable soil fertility management due to financial setbacks. Consistent use of hybrid maize, grain legume seed and chemical fertilizer require financial outlays that farmers are either unable to afford or can hardly risk to part with, without assurance of expected benefits. Moreover, there are substantial risks associated with adoption of improved varieties, chemical fertilizer and grain legumes as a result of abiotic stresses such as drought. The building up of soil organic matter also requires some considerable time lag before significant yield effects are achieved. This explains why farmers' adoption of ISFM is still low despite massive research evidence of its productivity. Thus there is need for policy interventions to promote smallholder uptake of ISFM options. It is also important to note that the scope for ISFM to resuscitate the productivity of the maize-based smallholder farmers depends on consistent integration of grain legumes with inorganic fertilizers and access to improved maize varieties. The performance of grain legumes in fixing nitrogen is greatly compromised under low soil fertility conditions. Thus ISFM establishment in smallholder farming systems can be facilitated through cross-compliance interventions through among others, seasonal credit provision (within the context of starter-pack type initiatives as well as public subsidies as proposed by the Government starting from the 2005/06 season). This will enable farmers to afford inorganic fertilizers and improved maize and legume seeds. Similarly, an improvement in rural output and input markets, including the grain legume market would act as an additional incentive that will motivate farmers to grow grain legumes together with maize. Public extension still remains the main caveat for reaching smallholder farmers with technologies developed by researchers. Where the capacity for public

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

extension is overstretched e.g. due to the HIV/AIDS pandemic, there is need for policy to create favourable conditions for the involvement of non-governmental organizations that have proved instrumental in reaching smallholder farmers.

References

- Ackello-Ogutu, C., Q. Paris and W.A. Williams (1985): "Testing von Liebig Crop Response Function Against Polynomial Specifications," *American Journal of Agricultural Economics* 67, pp. 873-880.
- Angus, J.F., J.W. Bowden and B.A. Keating (1993): Modeling nutrient response in the field. *Plant Soil* 155 & 156, pp. 57-66.
- Belanger, G., J.R. Walsh, J.E. Richards, P.H. Milburn and N. Zaidi (2000): Comparison of three statistical models describing potato yield response to nitrogen fertilizer. *Agronomy Journal* 92, pp. 902-908.
- Benson, T. (1997): *The 1995/96 fertilizer verification trial in Malawi: Economic analysis of results for policy discussion*. Action Group I, Maize Productivity Task Force, Chitedze Research Station, Lilongwe, Malawi.
- Benson, T. (1999): *Validating and strengthening the area specific fertilizer recommendations for hybrid maize grown by Malawian smallholders*, Maize Commodity Team, Chitedze Research Station, Lilongwe, Malawi.
- Bock, B.R., and F.J. Sikora (1990): Modified quadratic plateau model for describing plant responses for fertilizer. *Soil Sci. Soc. Am. J* 54, pp. 1784-1789.
- Bullock, D.S. and D.G. Bullock (1994): Calculation of optimal nitrogen fertilizer rates. *Agronomy Journal* 86, pp. 921-923.
- Byerlee, D., with P. Anandajayasekeram, A. Diallo, B. Gelaw, P.W. Heisey, M. Lopez-Pereira, W. Mwangi, M. Smale, R. Tripp and S. Waddington (1994): *Maize Research in Sub-Saharan Africa: An overview of past impacts and future prospects*. CIMMYT Economics Working Paper 94-03. Mexico, D.F.: CIMMYT.
- Chambers, R.G. (1988): *Applied Production Analysis: A Dual Approach*. Cambridge University Press. New York.
- Chiang, A. (1994): *Fundamentals of Mathematical Economics*. McGraw Hill Inc.

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

- Conroy, A. (1997): *Examination of policy options facing Government in the event of a short-fall in maize production*. Discussion paper, Ministry of Finance, Lilongwe, Malawi.
- Chirwa, E.W. (1996): An Econometric Analysis of the Determinants of Agricultural Credit Repayment in Malawi. *Agronomy Journal*, 1-2, pp. 107-122.
- Chirwa, E.W. (2003): *Fertilizer and Hybrid Seeds Adopting Among Smallholder Maize Farmers in Southern Malawi*. Department of Economics. University of Malawi (manuscript).
- Diagne, A., and M. Zeller (2001): Access to credit and its impacts on welfare in Malawi. *IFPRI Research Report* 116. International Food Policy Research Institute, Washington D.C.
- Donovan, G., and F. Casey (1998): Soil fertility management in Sub-Saharan Africa. *World Bank Technical Paper* 408, World Bank, Washington, D.C.
- Dorward, A. (1999): Farm Size and Productivity in Malawian Smallholder Agriculture. *Journal of Development Studies* 35, 5, pp. 141-161.
- Edriss, A., H. Tchale and P. Wobst (2004): *The Impact of Labour Market Liberalization on Maize Productivity and Rural Poverty in Malawi* (draft manuscript).
- Franke, M.D., B.R. Beattie, and M.F. Embelton (1990): A comparison of alternative crop response models. *American Journal of Agricultural Economics* 72, pp. 597-602.
- Frohberg, K. (2001): Comments on the paper 'Review of Agricultural Trade Models: An Assessment of Models with EU Policy Relevance'. In: Frandsen, S.E. and M.J.H. Staehr (Eds.): *Assessment of GTAP Modeling Framework for Policy Analysis from a European Perspective*, pp. 32-39.
- Gilbert, R.A. (1998a): Comparison of best-bet soil fertility interventions: Preliminary results. In: *Annual report of the cereals commodity group for 1997-98*, Ministry of Agriculture and Irrigation, Lilongwe, Malawi.
- Gilbert, R.A. (1998b): Undersowing green manures for soil fertility management in the maize-based cropping systems of Malawi. In: Waddington, S., H.K. Murirwa, J.D.T. Kumwenda, D. Hikwa and F. Tagwira (Eds.): *Soil Fertility Research for Maize Based Farming Systems in Malawi and Zimbabwe*.

- Green, D.A.G and Ng'ong'ola D.H. (1993): Factors affecting fertilizer adoption in less developed countries: An application of multivariate logistic analysis in Malawi. *Journal of Agricultural Economics* 44, pp. 99-109.
- Heisey, P.W. and M. Smale (1995): Maize technology in Malawi, A green revolution in the making? *CIMMYT Research Report* 4, Mexico City, Mexico.
- Jorgenson, D.W. and B.M. Fraumeni (1981): Relative Prices and Technical Change. In: Berndt, E. R.: *Modeling and Measuring Natural Resource Substitution*, pp. 17–47.
- Kamanga, B.C.G., Kanyama-Phiri and S. Minae (2000): Maize production under tree-based cropping systems in southern Malawi: A Cobb-Douglas approach. *African Crop Sciences Journal*, Vol. 8, No. 4, pp. 429-440.
- Keyser, M.A. (1998): *Formulation and Spatial Aggregation of Agricultural Production Relationships within the Land Use Change (LUC) Model*, Interim Report IR-98-092, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.
- Kumwenda, J.D.T. and Gilbert, R.A. (1998): Biomass production by legume green manures on exhausted soils in Malawi, A Soil Fertility Network Trial. In: Waddington, S., H.K. Murirwa, J.D.T. Kumwenda, D. Hikwa and F. Tagwira (Eds.): *Soil Fertility Research for Maize Based Farming Systems in Malawi and Zimbabwe*.
- Kydd, J. (1989): Maize research in Malawi, Lessons from failure. *Journal of International Development* 11, pp. 112-144.
- Lau, L.J. (1978): Testing and imposing monotonicity, convexity and quasi-convexity constraints. In: Fuss, M. and D. McFadden (Eds.): *Production Economics: A Dual Approach to Theory and Applications*, Volume I: *The Theory of Production*, Amsterdam.
- Lau, L.J. (1986): Functional Forms in Econometric Model Building. In: Griliches, Z., and M.D. Intriligator (Eds.): *Handbook of Econometrics*, Volume III, pp. 1515-1565.
- McFadden, D. (1978): Cost, Revenue and Profit Functions. In: Fuss, M., and D. McFadden: *Production Economics: A Dual Approach to Theory and Applications*, Vol. 1: *The Theory of Production*, Vol. 2: *Applications of the Theory of Production*; North-Holland, New York.
- Minot, N., M. Kherallah and P. Berry (2000): *Fertilizer market report and determinants of fertilizer use in Benin and Malawi*. MSSD Discussion Paper No. 40, International Food Policy Research Institute, Washington D.C.

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

- Mekuria, M and S. Siziba (2003): Financial and risk analysis to assess the potential adoption of green manure technology in Zimbabwe and Malawi. In: S.R. Waddington (Ed.): *Grain legumes and green manures for soil fertility in Southern Africa: Taking Stock of Progress*, Soil FertNet, CIMMYT, Harare, Zimbabwe.
- Mekuria, M., and S. Waddington (2002): Initiatives to encourage farmer adoption of soil fertility technologies for maize-based cropping systems in Southern Africa. In: Barrett, C.B., F. Place, and A. Abdillahi (Eds.): *Natural Resources Management in African Agriculture: Understanding and Improving Current Practices*. CABI, Wallington, UK, pp. 219-234.
- Mwale, M., C. Masi, J. Kabongo and L.K. Phiri (2003): Soil fertility improvement through the use of green manure in central Zambia. In: S.R. Waddington (Ed.): *Grain legumes and green manures for soil fertility in Southern Africa: Taking Stock of Progress*. Soil FertNet, CIMMYT, Harare, Zimbabwe.
- Mwangi, W.M. (1997): Low use of fertilizers and low productivity in sub-Saharan Africa, *Nutrient Cycling Agro-forestry Systems* 47, pp. 135-147.
- Nkonya, E. (2001): *Modeling Soil Erosion and Fertility Mining: The case of wheat production in Northern Tanzania*. PhD Dissertation.
- Place, F., S. Franzel, J. Dewolf, R. Rommelse, F. Kwesiga, A. Niang and B. Jama (2002): Agroforestry for soil fertility replenishment: evidence on adoption processes in Kenya and Zambia. In: Barrett, C.B., F. Place, and A. Abdillahi (Eds.): *Natural Resources Management in African Agriculture: Understanding and Improving Current Practices*. CABI, Wallington, UK, pp. 275-286.
- Ryan, D.L. and T.J. Wales (2000): Imposing Local Concavity in the Translog and Generalized Leontief Cost Functions, *Economic Letters* 67, pp. 253 – 260.
- Sadoulet E., and A. de Janvry (1995): *Quantitative Development Policy Analysis*. The John Hopkins University Press, Baltimore and London.
- Sakala W.D., I. Ligowe, and D. Kayira (2003): Mucuna–maize rotations and short fallows to rehabilitate smallholder farms in Malawi. In: Waddington, S.R.: *Grain Legumes and Green Manures for Soil Fertility in Southern Africa: Taking Stock of Progress*, pp. 161-163.

Sauer, J., K. Froberg and H. Hockmann (2004): *Black-box frontiers and implications for development policy: theoretical considerations*. Development Policy Discussion Paper No. 92, Center for Development Research, Bonn, Germany.

Smale, M., and T. Jayne (2003): *Maize in Eastern and Southern Africa: Seeds of success in retrospect*. Environment and Production Technology Division, Discussion paper No. 97, International Food Policy Research Institute, Washington D.C.

Twomlow, S.J., J. Rusike and S.S. Snapp (2001): Biophysical or economic performance-which reflects farmer choice of legume 'best-bets' in Malawi. 7th Eastern and Southern Africa Regional Maize Conference, pp. 480-486.

Whitbread, A.M., O. Jiri and B. Maasdorp (2004): The effect of managing improved fallows of *Mucuna pruriens* on maize production and soil carbon and nitrogen dynamics in sub-humid Zimbabwe. *Nutrient Cycling in Agroecosystems* 69, pp. 59-71.

Vanlauwe, B. (2004): Integrated Soil Fertility Management Research at Tropical Soil Biology and Fertility (TSBF): The Framework, Principles and their Application. In: Bationo, A. (Ed.): *Managing Nutrient Cycles to Sustain Soil Fertility in Africa*, CIAT.

Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System

Appendix

Bordered Hessian decomposition

$$\begin{aligned}
 -(\Delta\Delta)' &= - \left[\begin{pmatrix} \delta_{11} & 0 & 0 & 0 \\ \delta_{21} & \delta_{22} & 0 & 0 \\ \delta_{31} & \delta_{32} & \delta_{33} & 0 \\ \delta_{41} & \delta_{42} & \delta_{43} & \delta_{44} \end{pmatrix} \begin{pmatrix} \delta_{11} & \delta_{12} & \delta_{13} & \delta_{14} \\ 0 & \delta_{22} & \delta_{23} & \delta_{24} \\ 0 & 0 & \delta_{33} & \delta_{34} \\ 0 & 0 & 0 & \delta_{44} \end{pmatrix} \right] = \\
 &= \begin{pmatrix} -\delta_{11}\delta_{11} & -\delta_{11}\delta_{12} & -\delta_{11}\delta_{13} & -\delta_{11}\delta_{14} \\ -\delta_{11}\delta_{21} & -\delta_{12}\delta_{12} - \delta_{22}\delta_{22} & -\delta_{12}\delta_{13} - \delta_{22}\delta_{23} & -\delta_{21}\delta_{14} - \delta_{22}\delta_{24} \\ -\delta_{11}\delta_{31} & -\delta_{31}\delta_{12} - \delta_{23}\delta_{22} & -\delta_{31}\delta_{13} - \delta_{23}\delta_{23} - \delta_{33}\delta_{33} & -\delta_{31}\delta_{14} - \delta_{23}\delta_{34} - \delta_{33}\delta_{34} \\ -\delta_{11}\delta_{41} & -\delta_{21}\delta_{14} - \delta_{22}\delta_{24} & -\delta_{31}\delta_{14} - \delta_{23}\delta_{34} - \delta_{33}\delta_{34} & -\delta_{14}\delta_{14} - \delta_{24}\delta_{24} - \delta_{34}\delta_{34} - \delta_{44}\delta_{44} \end{pmatrix} \quad [A1]
 \end{aligned}$$

Regularity details for the sample mean

	<i>LABOUR</i>	<i>FERTILIZER</i>	<i>SEED</i>
Monotonicity $[\partial(q/q')/\partial(x_i/x_i')] > 0$	0.0316	0.2218	0.2282
Diminishing Marginal Returns $[\partial^2(q/q')/\partial(x_i/x_i')^2] < 0$	-0.0096	-0.0304	-0.0313
	<i>BH₁</i>	<i>BH₂</i>	<i>BH₃</i>
Quasi-Concavity $(-1)^j D_j \geq 0$	-0.0010	0.0006	-1.3E-05

The following papers have been published so far:

- | | | |
|--------|--|--|
| No. 1 | Ulrike Grote,
Arnab Basu,
Diana Weinhold | Child Labor and the International Policy Debate
Zentrum für Entwicklungsforschung (ZEF), Bonn,
September 1998, pp. 47. |
| No. 2 | Patrick Webb,
Maria Iskandarani | Water Insecurity and the Poor: Issues and Research Needs
Zentrum für Entwicklungsforschung (ZEF), Bonn,
Oktober 1998, pp. 66. |
| No. 3 | Matin Qaim,
Joachim von Braun | Crop Biotechnology in Developing Countries: A
Conceptual Framework for Ex Ante Economic Analyses
Zentrum für Entwicklungsforschung (ZEF), Bonn,
November 1998, pp. 24. |
| No. 4 | Sabine Seibel,
Romeo Bertolini,
Dietrich Müller-Falcke | Informations- und Kommunikationstechnologien in
Entwicklungsländern
Zentrum für Entwicklungsforschung (ZEF), Bonn,
January 1999, pp. 50. |
| No. 5 | Jean-Jacques Dethier | Governance and Economic Performance: A Survey
Zentrum für Entwicklungsforschung (ZEF), Bonn,
April 1999, pp. 62. |
| No. 6 | Mingzhi Sheng | Lebensmittelhandel und Kosumtrends in China
Zentrum für Entwicklungsforschung (ZEF), Bonn,
May 1999, pp. 57. |
| No. 7 | Arjun Bedi | The Role of Information and Communication Technologies
in Economic Development – A Partial Survey
Zentrum für Entwicklungsforschung (ZEF), Bonn,
May 1999, pp. 42. |
| No. 8 | Abdul Bayes,
Joachim von Braun,
Rasheda Akhter | Village Pay Phones and Poverty Reduction: Insights from
a Grameen Bank Initiative in Bangladesh
Zentrum für Entwicklungsforschung (ZEF), Bonn,
June 1999, pp. 47. |
| No. 9 | Johannes Jütting | Strengthening Social Security Systems in Rural Areas of
Developing Countries
Zentrum für Entwicklungsforschung (ZEF), Bonn,
June 1999, pp. 44. |
| No. 10 | Mamdouh Nasr | Assessing Desertification and Water Harvesting in the
Middle East and North Africa: Policy Implications
Zentrum für Entwicklungsforschung (ZEF), Bonn,
July 1999, pp. 59. |
| No. 11 | Oded Stark,
Yong Wang | Externalities, Human Capital Formation and Corrective
Migration Policy
Zentrum für Entwicklungsforschung (ZEF), Bonn,
August 1999, pp. 17. |

- No. 12 John Msuya Nutrition Improvement Projects in Tanzania: Appropriate Choice of Institutions Matters
Zentrum für Entwicklungsforschung (ZEF), Bonn,
August 1999, pp. 36.
- No. 13 Liu Junhai Legal Reforms in China
Zentrum für Entwicklungsforschung (ZEF), Bonn,
August 1999, pp. 90.
- No. 14 Lukas Menkhoff Bad Banking in Thailand? An Empirical Analysis of Macro Indicators
Zentrum für Entwicklungsforschung (ZEF), Bonn,
August 1999, pp. 38.
- No. 15 Kaushalesh Lal Information Technology and Exports: A Case Study of Indian Garments Manufacturing Enterprises
Zentrum für Entwicklungsforschung (ZEF), Bonn,
August 1999, pp. 24.
- No. 16 Detlef Virchow Spending on Conservation of Plant Genetic Resources for Food and Agriculture: How much and how efficient?
Zentrum für Entwicklungsforschung (ZEF), Bonn,
September 1999, pp. 37.
- No. 17 Arnulf Heuermann Die Bedeutung von Telekommunikationsdiensten für wirtschaftliches Wachstum
Zentrum für Entwicklungsforschung (ZEF), Bonn,
September 1999, pp. 33.
- No. 18 Ulrike Grote,
Arnab Basu,
Nancy Chau The International Debate and Economic Consequences of Eco-Labeling
Zentrum für Entwicklungsforschung (ZEF), Bonn,
September 1999, pp. 37.
- No. 19 Manfred Zeller Towards Enhancing the Role of Microfinance for Safety Nets of the Poor
Zentrum für Entwicklungsforschung (ZEF), Bonn,
October 1999, pp. 30.
- No. 20 Ajay Mahal,
Vivek Srivastava,
Deepak Sanan Decentralization and Public Sector Delivery of Health and Education Services: The Indian Experience
Zentrum für Entwicklungsforschung (ZEF), Bonn,
January 2000, pp. 77.
- No. 21 M. Andreini,
N. van de Giesen,
A. van Edig,
M. Fosu,
W. Andah Volta Basin Water Balance
Zentrum für Entwicklungsforschung (ZEF), Bonn,
March 2000, pp. 29.
- No. 22 Susanna Wolf,
Dominik Spoden Allocation of EU Aid towards ACP-Countries
Zentrum für Entwicklungsforschung (ZEF), Bonn,
March 2000, pp. 59.

- No. 23 Uta Schultze Insights from Physics into Development Processes: Are Fat Tails Interesting for Development Research?
Zentrum für Entwicklungsforschung (ZEF), Bonn,
March 2000, pp. 21.
- No. 24 Joachim von Braun,
Ulrike Grote,
Johannes Jütting Zukunft der Entwicklungszusammenarbeit
Zentrum für Entwicklungsforschung (ZEF), Bonn,
March 2000, pp. 25.
- No. 25 Oded Stark,
You Qiang Wang A Theory of Migration as a Response to Relative
Deprivation
Zentrum für Entwicklungsforschung (ZEF), Bonn,
March 2000, pp. 16.
- No. 26 Doris Wiesmann,
Joachim von Braun,
Torsten Feldbrügge An International Nutrition Index – Successes and Failures
in Addressing Hunger and Malnutrition
Zentrum für Entwicklungsforschung (ZEF), Bonn,
April 2000, pp. 56.
- No. 27 Maximo Torero The Access and Welfare Impacts of Telecommunications
Technology in Peru
Zentrum für Entwicklungsforschung (ZEF), Bonn,
June 2000, pp. 30.
- No. 28 Thomas Hartmann-
Wendels
Lukas Menkhoff Could Tighter Prudential Regulation Have Saved Thailand's
Banks?
Zentrum für Entwicklungsforschung (ZEF), Bonn,
July 2000, pp. 40.
- No. 29 Mahendra Dev Economic Liberalisation and Employment in South Asia
Zentrum für Entwicklungsforschung (ZEF), Bonn,
August 2000, pp. 82.
- No. 30 Noha El-Mikawy,
Amr Hashem,
Maye Kassem,
Ali El-Sawi,
Abdel Hafez El-Sawy,
Mohamed Showman Institutional Reform of Economic Legislation in Egypt
Zentrum für Entwicklungsforschung (ZEF), Bonn,
August 2000, pp. 72.
- No. 31 Kakoli Roy,
Susanne Ziemek On the Economics of Volunteering
Zentrum für Entwicklungsforschung (ZEF), Bonn,
August 2000, pp. 47.
- No. 32 Assefa Admassie The Incidence of Child Labour in Africa with Empirical
Evidence from Rural Ethiopia
Zentrum für Entwicklungsforschung (ZEF), Bonn,
October 2000, pp. 61.
- No. 33 Jagdish C. Katyal,
Paul L.G. Vlek Desertification – Concept, Causes and Amelioration
Zentrum für Entwicklungsforschung (ZEF), Bonn,
October 2000, pp. 65.

- No. 34 Oded Stark On a Variation in the Economic Performance of Migrants by their Home Country's Wage
Zentrum für Entwicklungsforschung (ZEF), Bonn,
October 2000, pp. 10.
- No. 35 Ramón Lopéz Growth, Poverty and Asset Allocation: The Role of the State
Zentrum für Entwicklungsforschung (ZEF), Bonn,
March 2001, pp. 35.
- No. 36 Kazuki Taketoshi Environmental Pollution and Policies in China's Township and Village Industrial Enterprises
Zentrum für Entwicklungsforschung (ZEF), Bonn,
March 2001, pp. 37.
- No. 37 Noel Gaston,
Douglas Nelson Multinational Location Decisions and the Impact on Labour Markets
Zentrum für Entwicklungsforschung (ZEF), Bonn,
May 2001, pp. 26.
- No. 38 Claudia Ringler Optimal Water Allocation in the Mekong River Basin
Zentrum für Entwicklungsforschung (ZEF), Bonn,
May 2001, pp. 50.
- No. 39 Ulrike Grote,
Stefanie Kirchhoff Environmental and Food Safety Standards in the Context of Trade Liberalization: Issues and Options
Zentrum für Entwicklungsforschung (ZEF), Bonn,
June 2001, pp. 43.
- No. 40 Renate Schubert,
Simon Dietz Environmental Kuznets Curve, Biodiversity and Sustainability
Zentrum für Entwicklungsforschung (ZEF), Bonn,
October 2001, pp. 30.
- No. 41 Stefanie Kirchhoff,
Ana Maria Ibañez Displacement due to Violence in Colombia: Determinants and Consequences at the Household Level
Zentrum für Entwicklungsforschung (ZEF), Bonn,
October 2001, pp. 45.
- No. 42 Francis Matambalya,
Susanna Wolf The Role of ICT for the Performance of SMEs in East Africa – Empirical Evidence from Kenya and Tanzania
Zentrum für Entwicklungsforschung (ZEF), Bonn,
December 2001, pp. 30.
- No. 43 Oded Stark,
Ita Falk Dynasties and Destiny: On the Roles of Altruism and Impatience in the Evolution of Consumption and Bequests
Zentrum für Entwicklungsforschung (ZEF), Bonn,
December 2001, pp. 20.
- No. 44 Assefa Admassie Allocation of Children's Time Endowment between Schooling and Work in Rural Ethiopia
Zentrum für Entwicklungsforschung (ZEF), Bonn,
February 2002, pp. 75.

ZEF Discussion Papers on Development Policy

- No. 45 Andreas Wimmer,
Conrad Schetter Staatsbildung zuerst. Empfehlungen zum Wiederaufbau und zur Befriedung Afghanistans. (German Version)
State-Formation First. Recommendations for Reconstruction and Peace-Making in Afghanistan. (English Version)
Zentrum für Entwicklungsforschung (ZEF), Bonn,
April 2002, pp. 27.
- No. 46 Torsten Feldbrügge,
Joachim von Braun Is the World Becoming A More Risky Place?
- Trends in Disasters and Vulnerability to Them -
Zentrum für Entwicklungsforschung (ZEF), Bonn,
May 2002, pp. 42
- No. 47 Joachim von Braun,
Peter Wobst,
Ulrike Grote "Development Box" and Special and Differential Treatment for
Food Security of Developing Countries:
Potentials, Limitations and Implementation Issues
Zentrum für Entwicklungsforschung (ZEF), Bonn,
May 2002, pp. 28
- No. 48 Shyamal Chowdhury Attaining Universal Access: Public-Private Partnership and
Business-NGO Partnership
Zentrum für Entwicklungsforschung (ZEF), Bonn,
June 2002, pp. 37
- No. 49 L. Adele Jinadu Ethnic Conflict & Federalism in Nigeria
Zentrum für Entwicklungsforschung (ZEF), Bonn,
September 2002, pp. 45
- No. 50 Oded Stark,
Yong Wang Overlapping
Zentrum für Entwicklungsforschung (ZEF), Bonn,
August 2002, pp. 17
- No. 51 Roukayatou Zimmermann,
Matin Qaim Projecting the Benefits of Golden Rice in the Philippines
Zentrum für Entwicklungsforschung (ZEF), Bonn,
September 2002, pp. 33
- No. 52 Gautam Hazarika,
Arjun S. Bedi Schooling Costs and Child Labour in Rural Pakistan
Zentrum für Entwicklungsforschung (ZEF), Bonn
October 2002, pp. 34
- No. 53 Margit Bussmann,
Indra de Soysa,
John R. O Neal The Effect of Foreign Investment on Economic Development
and Income Inequality
Zentrum für Entwicklungsforschung (ZEF), Bonn,
October 2002, pp. 35
- No. 54 Maximo Torero,
Shyamal K. Chowdhury,
Virgilio Galdo Willingness to Pay for the Rural Telephone Service in
Bangladesh and Peru
Zentrum für Entwicklungsforschung (ZEF), Bonn,
October 2002, pp. 39
- No. 55 Hans-Dieter Evers,
Thomas Menkhoff Selling Expert Knowledge: The Role of Consultants in
Singapore's New Economy
Zentrum für Entwicklungsforschung (ZEF), Bonn,
October 2002, pp. 29

- No. 56 Qiuxia Zhu
Stefanie Elbern Economic Institutional Evolution and Further Needs for Adjustments: Township Village Enterprises in China
Zentrum für Entwicklungsforschung (ZEF), Bonn,
November 2002, pp. 41
- No. 57 Ana Devic Prospects of Multicultural Regionalism As a Democratic Barrier Against Ethnonationalism: The Case of Vojvodina, Serbia's "Multiethnic Haven"
Zentrum für Entwicklungsforschung (ZEF), Bonn,
December 2002, pp. 29
- No. 58 Heidi Wittmer
Thomas Berger Clean Development Mechanism: Neue Potenziale für regenerative Energien? Möglichkeiten und Grenzen einer verstärkten Nutzung von Bioenergieträgern in Entwicklungsländern
Zentrum für Entwicklungsforschung (ZEF), Bonn,
December 2002, pp. 81
- No. 59 Oded Stark Cooperation and Wealth
Zentrum für Entwicklungsforschung (ZEF), Bonn,
January 2003, pp. 13
- No. 60 Rick Auty Towards a Resource-Driven Model of Governance: Application to Lower-Income Transition Economies
Zentrum für Entwicklungsforschung (ZEF), Bonn,
February 2003, pp. 24
- No. 61 Andreas Wimmer
Indra de Soysa
Christian Wagner Political Science Tools for Assessing Feasibility and Sustainability of Reforms
Zentrum für Entwicklungsforschung (ZEF), Bonn,
February 2003, pp. 34
- No. 62 Peter Wehrheim
Doris Wiesmann Food Security in Transition Countries: Conceptual Issues and Cross-Country Analyses
Zentrum für Entwicklungsforschung (ZEF), Bonn,
February 2003, pp. 45
- No. 63 Rajeev Ahuja
Johannes Jütting Design of Incentives in Community Based Health Insurance Schemes
Zentrum für Entwicklungsforschung (ZEF), Bonn,
March 2003, pp. 27
- No. 64 Sudip Mitra
Reiner Wassmann
Paul L.G. Vlek Global Inventory of Wetlands and their Role in the Carbon Cycle
Zentrum für Entwicklungsforschung (ZEF), Bonn,
March 2003, pp. 44
- No. 65 Simon Reich Power, Institutions and Moral Entrepreneurs
Zentrum für Entwicklungsforschung (ZEF), Bonn,
March 2003, pp. 46
- No. 66 Lukas Menkhoff
Chodechai Suwanaporn The Rationale of Bank Lending in Pre-Crisis Thailand
Zentrum für Entwicklungsforschung (ZEF), Bonn,
April 2003, pp. 37

ZEF Discussion Papers on Development Policy

- | | | |
|--------|---|---|
| No. 67 | Ross E. Burkhart
Indra de Soysa | Open Borders, Open Regimes? Testing Causal Direction between Globalization and Democracy, 1970–2000
Zentrum für Entwicklungsforschung (ZEF), Bonn,
April 2003, pp. 24 |
| No. 68 | Arnab K. Basu
Nancy H. Chau
Ulrike Grote | On Export Rivalry and the Greening of Agriculture – The Role of Eco-labels
Zentrum für Entwicklungsforschung (ZEF), Bonn,
April 2003, pp. 38 |
| No. 69 | Gerd R. Rucker
Soojin Park
Henry Ssali
John Pender | Strategic Targeting of Development Policies to a Complex Region: A GIS-Based Stratification Applied to Uganda
Zentrum für Entwicklungsforschung (ZEF), Bonn,
May 2003, pp. 41 |
| No. 70 | Susanna Wolf | Private Sector Development and Competitiveness in Ghana
Zentrum für Entwicklungsforschung (ZEF), Bonn,
May 2003, pp. 29 |
| No. 71 | Oded Stark | Rethinking the Brain Drain
Zentrum für Entwicklungsforschung (ZEF), Bonn,
June 2003, pp. 17 |
| No. 72 | Andreas Wimmer | Democracy and Ethno-Religious Conflict in Iraq
Zentrum für Entwicklungsforschung (ZEF), Bonn,
June 2003, pp. 17 |
| No. 73 | Oded Stark | Tales of Migration without Wage Differentials: Individual, Family, and Community Contexts
Zentrum für Entwicklungsforschung (ZEF), Bonn,
September 2003, pp. 15 |
| No. 74 | Holger Seebens
Peter Wobst | The Impact of Increased School Enrollment on Economic Growth in Tanzania
Zentrum für Entwicklungsforschung (ZEF), Bonn,
October 2003, pp. 25 |
| No. 75 | Benedikt Korf | Ethnicized Entitlements? Property Rights and Civil War in Sri Lanka
Zentrum für Entwicklungsforschung (ZEF), Bonn,
November 2003, pp. 26 |
| No. 76 | Wolfgang Werner | Toasted Forests – Evergreen Rain Forests of Tropical Asia under Drought Stress
Zentrum für Entwicklungsforschung (ZEF), Bonn,
December 2003, pp. 46 |
| No. 77 | Appukkuttannair
Damodaran
Stefanie Engel | Joint Forest Management in India: Assessment of Performance and Evaluation of Impacts
Zentrum für Entwicklungsforschung (ZEF), Bonn,
October 2003, pp. 44 |

- No. 78 Eric T. Craswell
Ulrike Grote
Julio Henao
Paul L.G. Vlek Nutrient Flows in Agricultural Production and International Trade: Ecology and Policy Issues
Zentrum für Entwicklungsforschung (ZEF), Bonn,
January 2004, pp. 62
- No. 79 Richard Pomfret Resource Abundance, Governance and Economic Performance in Turkmenistan and Uzbekistan
Zentrum für Entwicklungsforschung (ZEF), Bonn,
January 2004, pp. 20
- No. 80 Anil Markandya Gains of Regional Cooperation: Environmental Problems and Solutions
Zentrum für Entwicklungsforschung (ZEF), Bonn,
January 2004, pp. 24
- No. 81 Akram Esanov,
Martin Raiser,
Willem Buiter Gains of Nature's Blessing or Nature's Curse: The Political Economy of Transition in Resource-Based Economies
Zentrum für Entwicklungsforschung (ZEF), Bonn,
January 2004, pp. 22
- No. 82 John M. Msuya
Johannes P. Jütting
Abay Asfaw Impacts of Community Health Insurance Schemes on Health Care Provision in Rural Tanzania
Zentrum für Entwicklungsforschung (ZEF), Bonn,
January 2004, pp. 26
- No. 83 Bernardina Algieri The Effects of the Dutch Disease in Russia
Zentrum für Entwicklungsforschung (ZEF), Bonn,
January 2004, pp. 41
- No. 84 Oded Stark On the Economics of Refugee Flows
Zentrum für Entwicklungsforschung (ZEF), Bonn,
February 2004, pp. 8
- No. 85 Shyamal K. Chowdhury Do Democracy and Press Freedom Reduce Corruption? Evidence from a Cross Country Study
Zentrum für Entwicklungsforschung (ZEF), Bonn,
March 2004, pp. 33
- No. 86 Qiuxia Zhu The Impact of Rural Enterprises on Household Savings in China
Zentrum für Entwicklungsforschung (ZEF), Bonn,
May 2004, pp. 51
- No. 87 Abay Asfaw
Klaus Frohberg
K.S.James
Johannes Jütting Modeling the Impact of Fiscal Decentralization on Health Outcomes: Empirical Evidence from India
Zentrum für Entwicklungsforschung (ZEF), Bonn,
June 2004, pp. 29
- No. 88 Maja B. Micevska
Arnab K. Hazra The Problem of Court Congestion: Evidence from Indian Lower Courts
Zentrum für Entwicklungsforschung (ZEF), Bonn,
July 2004, pp. 31

- No. 89 Donald Cox
Oded Stark On the Demand for Grandchildren: Tied Transfers and the Demonstration Effect
Zentrum für Entwicklungsforschung (ZEF), Bonn,
September 2004, pp. 44
- No. 90 Stefanie Engel
Ramón López Exploiting Common Resources with Capital-Intensive Technologies: The Role of External Forces
Zentrum für Entwicklungsforschung (ZEF), Bonn,
November 2004, pp. 32
- No. 91 Hartmut Ihne Heuristic Considerations on the Typology of Groups and Minorities
Zentrum für Entwicklungsforschung (ZEF), Bonn,
December 2004, pp. 24
- No. 92 Johannes Sauer
Klaus Froberg
Heinrich Hockmann Black-Box Frontiers and Implications for Development Policy – Theoretical Considerations
Zentrum für Entwicklungsforschung (ZEF), Bonn,
December 2004, pp. 38
- No. 93 Hoa Ngyuen
Ulrike Grote Agricultural Policies in Vietnam: Producer Support Estimates, 1986–2002
Zentrum für Entwicklungsforschung (ZEF), Bonn,
December 2004, pp. 79
- No. 94 Oded Stark
You Qiang Wang Towards a Theory of Self-Segregation as a Response to Relative Deprivation: Steady-State Outcomes and Social Welfare
Zentrum für Entwicklungsforschung (ZEF), Bonn,
December 2004, pp. 25
- No. 95 Oded Stark Status Aspirations, Wealth Inequality, and Economic Growth
Zentrum für Entwicklungsforschung (ZEF), Bonn,
February 2005, pp. 9
- No. 96 John K. Mduma
Peter Wobst Village Level Labor Market Development in Tanzania: Evidence from Spatial Econometrics
Zentrum für Entwicklungsforschung (ZEF), Bonn,
January 2005, pp. 42
- No. 97 Ramon Lopez
Edward B. Barbier Debt and Growth
Zentrum für Entwicklungsforschung (ZEF), Bonn
March 2005, pp. 30
- No. 98 Hardwick Tchale
Johannes Sauer
Peter Wobst Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System
Zentrum für Entwicklungsforschung (ZEF), Bonn
August 2005, pp. 29

ISSN: 1436-9931

The papers can be ordered free of charge from:

Zentrum für Entwicklungsforschung (ZEF)
Center for Development Research
Walter-Flex-Str. 3
D – 53113 Bonn, Germany

Phone: +49-228-73-1861
Fax: +49-228-73-1869
E-Mail: zef@uni-bonn.de
<http://www.zef.de>