INTERNATIONAL FOOD
POLICY RESEARCH INSTITUTE
sustainable solutions for ending hunger and poverty

Supported by the CGIAR

IFPRI Discussion Paper 01089

May 2011

Heterogeneous Treatment Effects of Integrated Soil Fertility Management on Crop Productivity

Evidence from Nigeria

Edward Kato

Ephraim Nkonya

Frank M. Place

Environment and Production Technology Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

PARTNERS AND CONTRIBUTORS

IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, the Netherlands, Norway, the Philippines, South Africa, Sweden, Switzerland, the United Kingdom, the United States, and the World Bank.

AUTHORS

Edward Kato, International Food Policy Research Institute
Research Analyst, Environment and Production Technology Division
e.kato@cgiar.org

Ephraim Nkonya, International Food Policy Research Institute
Senior Research Fellow, Environment and Production Technology Division

Frank M. Place, World Agroforestry Centre
Economist

Notices

Contents

List of Tables

ABSTRACT

This study compares the impacts of integrated soil fertility management (ISFM) on crop production with use of either mineral fertilizer or organic manure alone. We also investigate the conditions under which .ISFM technology has greater beneficial effects on yields and the factors constraining its uptake. To answer these questions, the study uses a cross-sectional, plot-level data set collected in Nigeria by the International Food Policy Research Institute and the World Bank in 2009. Using both quasi experimental matching estimators and multivariate regression approaches, it finds that overall ISFM has robustly significant positive effects on crop production. The study also finds that ISFM positively affects crop production on plots with customary tenure, sandy soils, and clay soils—conditions that are normally perceived to be less favorable for crop production. The results also show ISFM to be more effective on plots with mild erosion or no erosion. On the constraints, we find that households with limited livestock, equipment, labor, and land are less likely to use ISFM technology, and the extension services currently do not seem to be disseminating ISFM. This evidence provides strong support for efforts to promote ISFM in Nigeria and in other regions with comparable conditions, but adequate attention must be paid to the biophysical conditions of the plots and the household's access to labor endowments, livestock, equipment, and tenure conditions if this technology is to be scaled up and more widely used in Sub-Saharan Africa.

Keywords: integrated soil fertility management, crop production, matching estimators, Nigeria

1. INTRODUCTION

Land degradation is still a major problem in Nigeria (FAO 2005; Thiombiano and Tourino-Soto 2007), with some anecdotal evidence suggesting a loss of 8.6 percent of its gross domestic product (GDP) due to poor land management that undermines efforts to reduce household poverty. A similar problem has been shown to exist in other parts of Africa (Barrett, Place, and Aboud 2002; Conway 2001; FAO 2001; Sanchez 2002; World Bank 2003; IFDC 2005, 2006).

Consequently the Nigerian government has recognized it as a priority investment area, as clearly stipulated in its seven-point agenda policy framework, which indicates that agricultural productivity should be increased by improving soil fertility. This national effort has been further enhanced by the establishment of a National Sustainable Land Management Committee, which is in consonance with other regional initiatives such as the Comprehensive Africa Agriculture Development Program's Pillar 1 (which aims to extend the area under sustainable land and water management throughout Sub-Saharan Africa) and the World Bank's TerrAfrica Sustainable Land Management initiative for scaling up sustainable land management in Africa. Under this policy framework, it is therefore important to provide evidence on the performance of different sustainable land management technologies to enable policymakers and other practitioners to make informed choices for sustainable land management investments in different locations of Sub-Saharan Africa.

Integrated Soil Fertility Management (ISFM)—a strategy that combines mineral fertilizers and locally available organic soil amendments— is increasingly seen in Sub-Saharan Africa as a way to improve fertilizer efficiency and bolster soil quality (Palm, Myers, and Nandwa 1997; Buresh, Sanchez, and Calhoun 1997; Bot and Benites 2001; IFDC 2002; Vanlauwe et al. 2002; Place et al. 2003, and recognition is growing that fertilizer use alone may not be able to achieve the required agricultural production growth rates to reduce poverty (Sanders, Shapiro, and Ramaswamy1996; Desai 1988; Murage et al. 2000; Bot and Beintes 2001; Kaboré and Reij 2004). However, the effectiveness and beneficial effects of ISFM practices are likely to differ from place to place in Sub-Saharan Africa, due to the many heterogeneous agroecological zones in the region. Available reviews on the effects (Place et al. 2003) are mixed and inconclusive. Only limited empirical evidence exists on the potential of ISFM for improving yields and profitability that can be used to support the arguments for use of ISFM as an alternative to high doses of fertilizers to maintain favorable nutrient balances and soil quality (World Bank 2006). Using a plot-level, cross- sectional data set from Nigeria, this study helps fill this gap by providing more rigorous microeconometric empirical evidence on the impacts of ISFM on crop productivity and efficiency. It also identifies the socioeconomic and biophysical conditions under which ISFM may provide greater positive significant impacts on yields, which is useful information in guiding targeting of ISFM promotion. Previous studies that have attempted to assess the effects of ISFM have used multivariate regression approaches without correcting for selection biases, when making inferences on ISFM causal effects. However, in this study, in computing the treatment effects, we have employed quasi-experimental matching estimators that eliminate selection bias issues by creating comparable control and treatment groups with similar observable characteristics.

2. STUDY AREA AND DATA

Study Area

For this climate change and sustainable land management project, the study uses crosssectional data collected from Niger State by the International Food Policy Research Institute (IFPRI) and the World Bank, in collaboration with a local institution, Minna Federal University of Technology. Data were collected during the month of August 2009 from four subcounties: Fuka and Emigida, representing high market access areas, and Badeggi and Gini, representing low market access areas. Niger is a state in the western part of the country, and it is the largest state in Nigeria. Minna is the state capital. Niger State is located within the North Central Geopolitical Zone of Nigeria between latitudes 8°10′N to 11°30′N and longitudes 4°00′E to 7°15′E, covering a landmass of approximately 72,278 square kilometers (km^2). It is the largest state in Nigeria, accounting for 8 percent of the land area, with a population of 3,950,249 (according to 2006 census figures). Generally, it straddles two agroecological zones: guinea savannah in the southern part and sudan savannah in the northern fringes. The rainfall varies from a bimodal rainfall peak in the southern part (June and September) to a unimodal peak in September. The annual rainfall for Minna is about 1,181 millimeters per year (**Nigeria** Metrological Agency, raw data). It is ethnically diverse and the people mainly engage in crop farming, fishing, and cattle rearing.

Data

The study collected both household- and plot-level data, covering a total of 118 households with 322 plots, by administering a structured questionnaire to each household by a team of trained enumerators. At the plot level, detailed questions were asked on land management practices, including use of organic and inorganic inputs, labor inputs, crop production, perceived soil erosion status, soil texture, and land tenure. At the household level, information on household head characteristics and household composition, livelihood strategies, climate change awareness and adaptation measures, livestock, and assets were collected. These data types formed the basis of construction of the outcome variable and confounding variables used in the subsequent analysis.

Variables

The main outcome sought in this study is the effect of ISFM on crop production. We express this outcome in terms of the value of crop production per hectare, which is a better representation of yield because most of the plots were intercropped with more than one crop, an estimation approach that has been used in many previous studies in Sub-Saharan Africa (Pender et al. 2001, 2004; Jansen et al. 2006; Pender and Gebremedhin 2008; Nkonya et al. 2008; Kato et al. 2009; Kato et al. 2010). The confounders we used included plot size, land tenure, plot distance from homestead, and perception of the farmer on the erosion status of the plot to represent plot level heterogeneity. For household-level controls, we included physical capital (value of equipment and value of livestock), financial capital (access to formal and informal credit), human capital (education of household head, livelihood strategy, and household size, and female and male labor force), natural capital (farm size), and access to services (extension and market access). These covariates have been used in previous studies as predictors of the decision to use land management practices and also as drivers and conditioning factors predicting crop productivity in microeconometric studies (Jansen et al. 2006; Pender and Gebremedhin 2008; Nkonya et al. 2008; Kato et al. 2009; Kato et al. 2010).

3. EMPIRICAL APPROACHES

In this study we investigate the impacts of ISFM on crop productivity and production efficiency. Because the data being used in this analysis was not generated from a random experiment, this then creates an identification problem of the treatment effects of ISFM; therefore the econometric strategy to be used needs to correct for this source of bias. The source of bias is mainly from the possible endogeneity and selection bias in the users of ISFM technology. It's possible that using ISFM technology is an endogenous choice made by farmers, where users and nonusers of the technology have significantly different characteristics and endowments, and the selection decision on which plot to apply ISFM is purely nonrandom in that farmers prefer to apply ISFM on plots with certain observable characteristics, which results in a placement selection bias. We have used quasi-experimental matching estimators and multivariate regression as our econometric identification approaches to try to account for these problems, which might bias our impact statistical inference.

Matching Estimators

Although often used to evaluate impacts of programs (see, for example, Heckman et al. 1997; Ravallion 2005) such methods are increasingly being used to assess the impacts of other discrete factors, such as the effects of land management practices (Kassie et al. 2008). Here we used matching estimators to assess the impacts of plot level ISFM technology on crop production. We used a propensity score matching estimator (Rosenbaum and Rubin 1983) and the bias-corrected nearest neighbor covariate matching estimator developed by Abadie et al. (2004). In both these methods, a distance metric is used based on observed covariates to select comparable "treatment" versus "control" observations for comparison, with propensity score matching using the predicted probability of an observation being in the treated versus control category as the distance metric; when covariate nearest-neighbor matching is used, each treated individual is matched with the nearest two, three, or any chosen number of control neighbors, while accounting for the difference in the mean values of the covariates between the matched treated and control groups (Abadie and Imbens 2006).

With propensity score matching, we estimate the treatment effects of ISFM on crop production by using propensity scores to match plots with similar observable characteristics, varying only the treatment, which in this case is ISFM use or nonuse. The propensity score is simply the probability that a plot in a given household had ISFM: $P\,(T = 1|Xh, Xp)$. Propensity scores are estimated using a maximum likelihood Probit model in which a vector of household characteristics Xh and a vector of plot-level characteristics Xp are regressed on P, a plot's use of ISFM to obtain predictions of propensity scores. The probit model is specified as

$$P^* = \beta\, Xh + \gamma\, Xp + \varepsilon, \tag{1}$$

where $\varepsilon \sim N\,(0, 1)$ while β and γ are parameters. Then P can be viewed as an indicator for whether this latent variable is positive.

Either of these matching methods has advantages and disadvantages that need to be noted. Propensity score matching has an advantage in that its distance metric gives greater weight to factors that influence the selection process, which are the factors that are most important to match to reduce potential selection bias in comparing the treated versus the control groups, whereas the distance metric of the nearest neighbor covariate matching estimator is more arbitrary. However, there are two disadvantages of propensity score matching relative to the nearest neighbor covariate matching estimator: (1) the estimated impacts are biased to the extent that perfect matching is not achieved (that is, there are still differences in the covariates among the matched samples), and (2) the estimated standard errors are not correct because the propensity scores are estimated (Abadie and Imbens 2006). Bootstrapping was used to estimate standard errors with propensity score matching, but this was found to be invalid in the case of propensity score matching with nearest neighbors. By contrast, the nearest neighbor covariate matching estimator with bias correction corrects for bias using auxiliary regressions, and the estimated standard errors are correct (Abadie et al. 2004). Since each method has advantages as well as disadvantages, we report results from both matching estimators.

Multivariate Regression Estimators

We also used several parametric multivariate regression estimators, including ordinary least squares (OLS) regression, instrumental variable (IV) regression to correct for endogeneity of ISFM use, and a robust regression estimator that is robust to outliers. Matching methods have advantages and disadvantages relative to other methods of estimating impacts, such as multivariate regression methods. On the one hand, compared with parametric methods such as linear OLS, matching methods have the advantage of being less dependent upon parametric assumptions to identify impacts, and they can reduce the bias that may result from estimating impacts by comparing noncomparable observations in regression analysis (Heckman et al. 1998). On the other hand, matching estimators rely upon the untestable conditional independence assumption–the assumption that the outcome for the control group is independent of its treatment status and conditional upon the observed covariates. This assumption is similar to the assumption in OLS models that the error term is uncorrelated with the explanatory variables, and violation of either assumption can result in a bias due to "selection of unobservables" (Heckman et al. 1998). This problem can be tested for and addressed using IV estimation if suitable IVs can be identified.

The multivariate regression is specified as

$$Y = \tau\, Xh + \psi\, Xp + \varphi\, ISFM + \varepsilon, \quad (2)$$

where Y is the outcome (in this case, the value of crop per hectare), Xh and Xp are vectors of observable household and plot level factors, $ISFM$ is the treatment dummy, and ε captures unobserved factors that are correlated with Y but not correlated with included explanatory variables. The parameter φ is the main estimate of interest in this study showing the treatment effect of using ISFM on crop productivity, while τ and ψ, the other parameters to be estimated, are not of interest because they are only included to minimize omitted variable bias, which would otherwise confound our treatment parameter of focus, ψ .

To improve on the performance of our estimations, we converted all continuous variables to their logarithmic transformations, which improves normality of the residuals, thus reducing problems of nonlinearity, heteroskedasticity, and sensitivity to outliers (Mukherjee, White, and Wuyts 1998). We also use generalized method of moments (GMM) with IV estimation, which is efficient under heteroskedasticity (Davidson and MacKinnon 2004). The validity of the overidentifying restrictions in the GMM model is tested using the Hansen J-test. The relevance of the excluded instrumental variables as predictors of the potentially endogenous explanatory variables is also tested, indicating that the chosen instruments are good predicators of the potentially endogenous ISFM treatment.

4. EMPIRICAL RESULTS

Determinants of Use of ISFM

The results in Table 1 show the driving and conditioning factors that influence a farmer's decision to use ISFM or not on a certain plot. We investigate this by using a maximum likelihood Probit regression which is also the model selected to generate the propensity scores that are used in matching control and treated plots in propensity score matching. Table 4.1 presents Probit regression estimates and also examines the robustness of the results by estimating it with and without village fixed effects and also with a linear probability model.

Table 4.1—Probit regression determining use or nonuse of ISFM (selection model for propensity score matching) (Marginal Effects)

Variable	Probit without village fixed effects	Probit with village fixed effects	Linear probability model
Plot-level factors			
Erosion mild (no erosion)	0.057	0.011	0.064
Erosion severe	-0.124***	-0.124***	-0.241***
Tenure lease (c.f customary)	-0.075***	-0.103***	-0.049
Tenure freehold	-0.127***	-0.124***	-0.164***
Log (plot area ha)	0.029	0.03	0.032
Log (plot distance from homestead-km)	-0.033	0.006	-0.076***
Household-level factors			
Log (value of equipment)	0.046**	0.015	0.034***
Log (value of Livestock)	0.021***	0.042***	0.013***
Log (farm area-ha)	0.165***	0.099**	0.156***
Log (household size)	-0.675***	-0.964***	-0.402***
Female household head	-0.073	-0.04	-0.094*
Log (number of adult males)	0.391***	0.580***	0.220***
Log (number of adult females)	0.320***	0.691***	0.114*
Education, primary (c.f no education)	-0.134***	-0.144***	-0.114***
Education, secondary	-0.023	0.099	0.079
Education, post secondary	-0.121***	-0.121***	-0.074
Primary activity, livestock (c.f crop production)	0.000	0.000	0.000
Primary activity, nonfarm	-0.122***	0.211**	-0.04
Log (distance from output markets-km)	0.084***	0.182***	0.039*
Market access (1=high, 0=low)	0.110*	0.06	0.018
Extension (1=yes, 0=no)	-0.082*	-0.275***	-0.03
Credit, formal (1=yes, 0=no)	-0.005	0.031	-0.01
Credit, nonformal (1=yes, 0=no)	-0.107*	-0.147***	-0.058
N	312	312	312

Source: Authors calculation from survey data.
Note: *, **, *** asterisks represent 10, 5, and 1 percent levels of significance, respectively.

Focusing on robust results across the different regression specifications, we find that among the plot-level variables, use of ISFM is less likely on severely eroded plots and more likely on plots with no erosion, indicating that farmers prefer to use ISFM on plots with better management where they expect to get higher returns, possibly because fertilizer is a purchased input and hence they need to recover the cost. Use of ISFM is also less likely on plots with leasehold and freehold tenures but more likely on plots with customary tenure, suggesting that tenure poses a constraint on use of ISFM in Nigeria. As expected households with more equipment and more livestock have a higher likelihood of using ISFM, since livestock is a source of in-situ manure and equipment is required for transportation and mix of the bulky manure. This is further supported by the finding in the results that farmers are less likely to use ISFM on plots that are farther away from their homes, possibly because of the bulkiness of IFSM materials, as shown by the strongly significant negative coefficient in the linear probability model, which is consistent with findings in Ethiopia (Gebremedhin and Swinton 2003). The results also show that households with more adult males and females are associated with use of ISFM technology, which further indicates that labor constraints are a key impediment to farmers using ISFM.

Interestingly, households with more farm land have a higher likelihood of using ISFM. This suggests that it is the wealthier households that are using ISFM technology, which is consistent with the earlier finding that associates ISFM use with ownership of more equipment and livestock (normally owned by richer families). This is also further supported by and consistent with the finding in our results that larger households are less likely to use ISFM, since larger families are associated with poverty in rural areas, resulting in liquidity constraints. Extension services and nonformal credit are both associated with a lower likelihood of using ISFM, possibly because current extension efforts in Nigeria may not be focusing on ISFM technology dissemination and credit is being used for other household priorities.

Homogeneous Impacts of ISFM on Crop Production

The overall impacts of ISFM on crop production are shown in Table 4.2.

Table 4.2—Impacts of ISFM on crop production (log of value of crop production per ha)

	Nonpropensity score matching estimators			Propensity score matching estimators			Parametric estimators		
	Covariate matching			Kernel matching			Least squares		
	1 neighbor	5 neighbors	15 neighbors	Epanichenov	Normal	Bi-weight	OLS	IV-2SLS	Robust regression
Use of ISFM (ATT)	1.01	2.18**	1.93**	3.58**	3.58**	3.58*	2.45***	0.32	2.02**
Standard errors	1.41	1.10	0.92	1.84	1.47	2.00	0.74	1.02	10.2

Source: Authors calculations from survey data.
Notes: The standard errors in kernel matching are bootstrapped (100 replications). *, **, *** represent 10, 5, and 1 percent levels of significance, respectively.
ATT is average treatment of the treated area.

Compared with plots using either mineral fertilizer or organic fertilizer only, ISFM technology has a significant positive impact on crop production, as shown by the average treatment effects of the treatment on the treated (ATT) in Table 4.2. This finding is robust in both the matching estimators (covariate and kernel matching) and nonmatching estimators (OLS and robust estimators). This result provides strong empirical evidence in support of promoting and disseminating ISFM technologies in Nigeria, which will reduce the use of high dosages of costly fertilizers and promote sustainable land management.

Heterogeneous Impacts of ISFM on Crop Production

In Table 4.3, we investigate further the heterogeneous effects of ISFM technology, in order to provide additional insights and knowledge to the task of isolating the conditions under which ISFM has more beneficial effects in Nigeria. We find robust evidence on tenure and soil differences in both matching and nonmatching estimators that affect the impacts of ISFM on crop production. ISFM had significant and positive effects on crop yields on plots under customary tenure and also on plots with sandy soils and clay soils. This indicates that areas with sandy and clay soils can improve their soil quality through the use of ISFM technologies. The results also indicate that ISFM has positive impacts on crop production on plots with mild or no erosion. Therefore, ISFM has more beneficial impacts on plots that are well managed.

Table 4.3—Heterogeneous impacts of ISFM on crop production (log of value of crop production per ha)

	Non-Propensity score matching Estimators			Propensity Score Matching Estimators			Parametric Estimators
	Covariate matching			Kernel Matching			
	1 neighbor	5 neighbors	15 neighbors	Epanichenov	Normal	Biweight	Robust regression
Customary tenure	0.51 (1.39)	2.90*** (1.80)	2.35*** (0.94)	-0.02 (1.80)	-0.02 (1.75)	-0.02 (1.80)	2.45*** (0.95)
Leasehold tenure	-2.20 (2.92)	-2.25 (2.09)	-0.67 (1.12)	NE	NE	NE	4.32 (1.32)
Black soils	-2.71 (2.06)	-0.88 (1.44)	-1.13 (1.35)	-1.50 (2.56)	-1.50 (3.03)	-1.50 (2.19)	-1.72 (1.33)
Sandy soils	0.95 (4.06)	1.17 (3.12)	2.47 (2.79)	0.35* (0.19)	0.35* (0.19)	0.35* (0.18)	0.348*** (3.46x10^{-12})
Clay soils	4.35 (3.23)	5.54*** (2.24)	8.21*** (1.91)	3.86 (6.36)	3.86 (6.19)	3.86 (6.64)	5.32*** (4.16e-14)
Erosion, mild	10.5*** (1.85)	2.07 (1.61)	2.83*** (1.21)	4.62 (5.01)	4.62 (6.18)	4.62 (6.62)	1.41 (1.56)
No erosion	0.48 (1.56)	0.008 (1.22)	0.79 (1.08)	1.23 (1.80)	1.23 (2.01)	1.23 (1.87)	2.99*** (0.81)

Source: Authors calculations from survey data.

Notes: The standard errors in kernel matching are bootstrapped (100 replications). *, **, *** represent 10, 5 and 1 percent levels of significance, respectively.

NE: Not estimable.

5. CONCLUSIONS AND IMPLICATIONS

This study investigates the impacts of ISFM on crop production and the conditions under which farmers may realize more beneficial effects of this technology in Nigeria. Using both matching estimators and multivariate regression approaches, it finds that adoption of ISFM has robustly significant positive effects on crop production, compared with the results for plots where either inorganic fertilizer or organic manure is used alone. We also find that ISFM had significant positive effects on yields on plots with customary tenure, sandy soils, and clay soils, which are normally presumed to be poorer in quality. This finding provides support for farmers to use these technologies under conditions where fertilizers are not normally used. We therefore recommend promotion of ISFM use by development practitioners in Nigeria and in other regions with conditions similar to Nigeria's. Paying close attention to biophysical conditions on farmers' plots and to households' labor, land, livestock, equipment, and tenure endowments will help to ensure scaled up adoption of this technology.

REFERENCES

Abadie, A., D. Drukker, J. Leber Herr, and G.W. Imbens. 2004. "Implementing Matching Estimators for Average Treatment Effects in Stata." *Stata Journal*, vol. 4(3), 290-311.

Abadie, A., and G.W. Imbens. 2006. On the Failure of Bootstrapping for Matching Estimators. Unpublished manuscript. John F. Kennedy School of Government, Harvard University, http://www.ksg.harvard.edu/fs/aabadie/.

Barrett, C. B., F. Place, and A. A. Aboud, ed. 2002. *Natural Resources Management in African Agriculture: Understanding and Improving Current Practices*. Wallingford, UK: CABI.

Battese, G., 1992. "Frontier Production Functions and Technical Efficiency: A Survey of Empirical Applications in Agricultural Economics." *Agricultural Economics* 7: 185–208.

Battese, G., and T. Coelli. 1995. "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics* 20: 325–332.

Bot, A., and J. Benites. 2001. *Conservation Agriculture. Case Studies in Latin America and Africa*. Rome: Food and Agriculture Organization of the United Nations.

Buresh, R. J., P. Sanchez, and F. Calhoun, eds. 1997. *Replenishing Soil Fertility in Africa*. Special Publication 51. Madison, WI: Soil Science Society of America and American Society of Agronomy.

Conway, G. 2001. ''The Doubly Green Revolution: Balancing Food, Poverty and Environmental Needs in the 21st century.'' In *Tradeoffs or Synergies? Agricultural Intensification, Economic Development, and the Environment*, ed. D. R. Lee and C. B. Barrett. 17-34 Oxford: CABI Publishing.

Davidson, R. and J.G. MacKinnon. 2004. *Econometric Theory and Methods*. Oxford: Oxford University Press.

Desai, G. 1988. "Policy for Rapid Growth in the Use of Modern Agricultural Inputs." In *Agricultural Price Policy for Developing Countries*, ed. J. Mellor and R. Ahmed. Baltimore, MD: Johns Hopkins University Press for the International Food Policy Research Institute.

FAO (Food and Agriculture Organization of the United Nations). 2001. *The Economics of Soil Productivity in Sub-Saharan Africa*. Rome.

FAO (Food and Agriculture Organization of the United Nations .2005. "Global Assessment of the Status of Human Induced Soil Degradation (GLASOD)."

Gebremedhin, B., and S. Swinton. 2003. "Investment in Soil Conservation in Northern Ethiopia: The Role of Land Tenure Security and Public Programs." *Agricultural Economics* 29 (203): 69–84.

Heckman, J.J., H. Ichimura, J. Smith, and P.E. Todd. 1998. "Characterizing Selection Bias Using Experimental Data." *Econometrica*. 66: 1017-99.

Heckman, J.J., Ichimura, H. and Todd, P.E. 1997. "Matching as an Econometric Evaluation Estimator: Evidence from Evaluating a Job Training Programme." *Review of Economic Studies* 64: 605-654.

IFDC (International Fertilizer Development Center). 2002. *Collaborative Research Programme for Soil Fertility Restoration and Management in Resource-poor Areas of Sub-Sahara Africa*. Muscle Shoals, AL, US: IFDC.

________. 2005. IFDC Report 30, 1.

________. 2006. IFDC Report 31, 1.

Jansen, H. G. P., J. Pender, A. Damon, and R. Schipper. 2006. *Rural Development Policies and Sustainable Land Use in the Hillside Areas of Honduras: A Quantitative Livelihoods Approach*. Research Report 147. Washington, DC: International Food Policy Research Institute.

Kaboré, D., and Chris Reij. 2004. *The Emergence and Spreading of Improved Traditional Soil and Water Conservation Practices in Burkina Faso*. Environment and Production Technology Division Discussion Paper 14. Washington, DC: International Food Policy Research Institute.

Kato, E., E. Nkonya, F. Place, and M. Majaliwa. 2010. *An Econometric Investigation of Impacts of Sustainable Land Management Practices on Soil Carbon and Yield Risk. A Potential for Climate Change Mitigation*. IFPRI Discussion Paper 1038. Washington, DC: International Food Policy Research Institute.

Kato, E., C. Ringler, M.Yesuf, and E. Bryan. 2009. *Are Soil and Water Conservation Technologies a Buffer against Production Risk in the Face of Climate Change? Insights from the Ethiopian Nile Basin.* IFPRI Discussion Paper 871. Washington, DC: International Food Policy Research Institute.

Kassie, M., J. Pender, M. Yesuf, G. Kohlin, R. Bulffstone, and E. Mulugeta. 2008. "Estimating Returns to Soil Conservation Adoption in the Northern Ethiopian Highlands." *Agricultural Economics* 38: 213-232.

Mukherjee, C., H. White, and M. Wuyts. 1998. Econometric and Data Analysis for Developing Countries. London: Routledge.

Murage, E. W., N. K. Karanja, P. C. Smithson, and P. L. Woomer. 2000. "Diagnostic Indicators of Soil Quality in Productive and Non-productive Smallholders Fields of Kenya's Central Highlands." *Agriculture, Ecosystems and Environment* 79: 1–8.

Nkonya, E., J. Pender, C. K. Kaizzi, E. Kato, S. Mugarura, and H. Ssali. 2008. *Linkages between Land Management, Land Degradation, and Poverty in Sub-Saharan Africa.* Research Report 159. Washington, DC: International Food Policy Research Institute.

Palm, C., R. J. K. Myers, and S. M. Nandwa.1997. "Combined Use of Organic and Inorganic Nutrient Sources for Soil Fertility Maintenance and Replenishment." In *Replenishing Soil Fertility in Africa*, ed. R. J. Buresh, P.Sanchez, and F. Calhoun. Madison, WI: Soil Science Society of American and American Society of Agronomy.

Pender, J. and B. Gebremedhin. 2008. "Determinants of Agricultural and Land Management Practices and Impacts on Crop Production and Household Income in the Highlands of Tigray, Ethiopia." *Journal of African Economies* 17 (3): 395–450.

Pender, J., B. Gebremedhin, S. Benin, and S. Ehui. 2001. "Strategies for Sustainable Agricultural Development in the Ethiopian Highlands." *American Journal of Agricultural Economics* 83 (5): 1231–1240.

Pender, J., S. Ssewanyana, E. Kato, and E. Nkonya. 2004. *Linkages between Poverty and Land Management in Rural Uganda: Evidence from the Uganda National Household Survey*. Washington, DC: International Food Policy Research Institute.

Place, F., C. Barrett, H. A. Freeman, J. Ramisch, and B. Vanlauwe. 2003. "Prospects for Integrated Soil Fertility Management Using Organic and Inorganic Inputs: Evidence from Smallholder African Agricultural Systems." *Food Policy* 28: 365–378.

Ravallion, M. 2005. *Evaluating Anti-Poverty Programs*. World Bank Policy Research Working Paper 3625. The World Bank, Washington, D.C.

Rosenbaum, P. R. and D. B. Rubin. 1983. "The Central Role of the Propensity Score in Observational Studies for Causal Effects." *Biometrika* 70(1): 41–55.

Russell, N. and T. Young. 1983. "Frontier Production Functions and the Measurement of Technical Efficiency." *Journal of Agricultural Economics* 34: 139–149.

Sanchez, P. A. 2002. ''Soil Fertility and Hunger in Africa.'' *Science* 295: 2019–2020.

Sanders, J., B. Shapiro, and S. Ramaswamy. 1996. *The Economics of Agricultural Technology in Semiarid Sub-Saharan Africa.* Baltimore: Johns Hopkins University Press.

Sharif, N. R., and A. Dar. 1996. "An Empirical Study of the Patterns and Sources of Technical Inefficiency in Traditional and HYV Rice Cultivation in Bangladesh." *Journal of Development Studies* 32: 612–629.

Thiombiano, L**.** and I.Tourino-Soto. 2007**.** "Trends and Status of Land Degradation in Africa," 39-53. *In Climate and Land Degradation*, ed. V.K.S. Mannava and N.D. Ndegwa. New York: Springer Publishing Company.

Tzouvelekas, V., C. J. Pantzios, and C. Fotopoulos. 2001. "Technical Efficiency of Alternative Farming Systems: The Case of Greek Organic and Conventional Olive-Growing Farms." *Food Policy* 26: 549–569.

Vanlauwe, B., J. Diels, N. Sanginga, and R. Merck, 2002. *Integrated Plant Nutrient Management Sub-Saharan Africa: From Concept to Practice.* Wallingford, UK, and New York: CABI Publishers in association with the International Institute of Tropical Agriculture.

Wadud, A. and B. White. 2000. "Farm Household Efficiency in Bangladesh: A Comparison of Stochastic Frontier and DEA Methods." *Applied Economics* 32: 1665–1673.

World Bank. 2003. *Sustainable Development in a Dynamic World: Transforming Institutions, Growth, and Quality of Life.* World Development Report 2000. Oxford: World Bank and Oxford University Press.

________. 2006. *Factors Affecting Demand for Fertilizer in Sub-Saharan Africa*. Agriculture and Rural Development Discussion Paper 23. Washington, DC.

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to http://www.ifpri.org/publications/results/taxonomy%3A468.
All discussion papers can be downloaded free of charge.

1088. *Adoption of weather index insurance: Learning from willingness to pay among a panel of households in rural Ethiopia*. Ruth Vargas Hill, John Hoddinott, and Neha Kumar, 2011.

1087. *Was the global food crisis really a crisis?: Simulations versus self-reporting*. Derek Headey, 2011.

1086. *The economics of desertification, land degradation, and drought: toward an integrated global assessment*. Ephraim Nkonya, Nicolas Gerber, Philipp Baumgartner, Joachim von Braun, Alex De Pinto, Valerie Graw, Edward Kato, Julia Kloos, and Teresa Walter, 2011.

1085. *Agriculture's role in the Indian enigma: help or hindrance to the undernutrition crisis?*. Derek Headey, Alice Chiu, and Suneetha Kadiyala, 2011.

1084. *Policy options for improving regional fertilizer markets in West Africa*. Balu L. Bumb, Michael E. Johnson, and Porfirio A. Fuentes, 2011.

1083. *Loss prevention for hog farmers: Insurance, on-farm biosecurity practices, and vaccination*. Yue-hua Zhang, Chu-Shiu Li, Chwen-Chi Liu, and Kevin Z. Chen, 2011.

1082. *Institutions, geography, trade, and income per capita: A spatial-simultaneous equation approach*. Guyslain Ngeleza, 2011.

1081. *Assessing the livelihood impacts of a livestock disease outbreak: An alternative approach*. Ekin Birol, Lydia Ndirangu, Devesh Roy, and Yorbol Yakhshilikov, 2011.

1080. *Can conditional cash transfers improve maternal health and birth outcomes?: Evidence from El Salvador's Comunidades Solidarias Rurales*. Alan de Brauw and Amber Peterman, 2011.

1079. *Intercommodity price transmission and food price policies: An analysis of Ethiopian cereal markets*. Shahidur Rashid, 2011.

1078. *Randomizing the "last mile": A methodological note on using a voucher-based approach to assess the impact of infrastructure projects*. Tanguy Bernard and Maximo Torero, 2011.

1077. *Evaluating the long-term impact of antipoverty interventions in Bangladesh: An overview*. Agnes R. Quisumbing, Bob Baulch, and Neha Kumar, 2011.

1076. *Poverty rate and government income transfers: A spatial simultaneous equations approach*. P. Wilner Jeanty and John Mususa Ulimwengu, 2011.

1075. *A model of labeling with horizontal differentiation and cost variability*. Alexander Saak, 2011.

1074. *Cropping practices and labor requirements in field operations for major crops in Ghana: what needs to be mechanized?* Guyslain K. Ngeleza, Rebecca Owusua, Kipo Jimah, and Shashidhara Kolavalli, 2011.

1073. *The consequences of early childhood growth failure over the life course*. John Hoddinott, John Maluccio, Jere R. Behrman, Reynaldo Martorell, Paul Melgar, Agnes R. Quisumbing, Manuel Ramirez-Zea, Aryeh D. Stein, and Kathryn M. Yount, 2011.

1072. *Farm households' preference for cash-based compensation versus livelihood-enhancing programs: A choice experiment to inform avian flu compensation policy in Nigeria.* Adewale Oparinde and Ekin Birol, 2011.

1071. *Petroleum subsidies in Yemen: Leveraging reform for development*. Clemens Breisinger, Wilfried Engelke, and Olivier Ecker, 2011

1070. *Joint estimation of farmers' stated willingness to pay for agricultural services*. John Ulimwengu and Prabuddha Sanyal, 2011.

1069. *Using a spatial growth model to provide evidence of agricultural spillovers between countries in the NEPAD CAADP framework*. John Ulimwengu and Prabuddha Sanyal, 2011.

1068. *Social services, human capital, and technical efficiency of smallholders in Burkina Faso*. Fleur Wouterse, 2011.

1067. *Decentralization of public-sector agricultural extension in India: The case of the District-level Agricultural Technology Management Agency (ATMA).* Claire J. Glendenning and Suresh C. Babu, 2011.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org

IFPRI ADDIS ABABA

P. O. Box 5689
Addis Ababa, Ethiopia
Tel.: + 251 (0) 11-617-2500
Fax: + 251 (0) 11-646-2927
Email: ifpri-addisababa@cgiar.org

IFPRI NEW DELHI

CG Block, NASC Complex, PUSA
New Delhi 110-012 India
Tel.: 91 11 2584-6565
Fax: 91 11 2584-8008 / 2584-6572
Email: ifpri-newdelhi@cgiar.org

IFPRI ACCRA

CSIR Campus
Airport Residential Area, Accra
PMB CT 112 Cantonments,
Accra, Ghana
Tel.: +233 (0) 21 780-716
Fax: +233 (0) 21 784-752