Gender-Sensitive LP Models in Soil Fertility Research for Smallholder Farmers: Reaching de jure Female Headed Households in Zimbabwe

MAXWELL. MUDHARA, PETER. E. HILDEBRAND, AND CHRISTINA. H. GLADWIN

Introduction

Zimbabwe faces a challenge in meeting food requirements of its 12 million people. The population is growing at three percent per annum compared to 1-1.5 percent per annum growth in agricultural production. Therefore, per capita food production is declining. To meet its food requirements, the country needs a four percent per annum growth rate in agricultural production.[1] Residents of smallholder farms comprise seventy percent of Zimbabwe's population. In 1999, they only contributed 14 percent of the value of sales of principal crops, i.e., maize, groundnuts, sorghum, soybeans, coffee, wheat, cotton, tobacco and sunflower. The contribution of smallholder farmers to marketed crops is skewed, with only a small proportion participating. The majority of the smallholder farmers struggle to meet their subsistence food requirements. High levels of poverty on these farms exacerbate the food problem, as they are unable to purchase food from the retail markets. Therefore, their food security is fragile.

Crop yields in the smallholder crop-livestock based production systems are low. Farmers plant hybrid maize seed that has potential yields of up to 12,000 kg ha^{-1}. Yet, average maize yields of 1,300 kg ha^{-1}, ranging from 350 to 2,200 kg ha^{-1}, are realized.[2] The disparity in potential and actual yields suggests that yields realized by farmers can be raised from current levels. Higher yields would enable farmers to meet their food and cash requirements, thus improving their food security status. More resources are required for achieving higher yields, yet smallholder farmers face multiple resource constraints. Financial capital, farming implements and draft power are limiting. The soils on which smallholder farms are located are inherently of low fertility. Due to over population, smallholder farmers have encroached on to the marginal lands, which have even lower yield potential. Infertile soils and lack resources to improve soil fertility threaten the goal of increasing smallholder farmers' food production.

Farmers have hitherto not adopted the higher levels of fertilizer application recommended to them, as they are incompatible with the limited resources of the farmers, especially women farmers. Traditional economic analyses for evaluating new technologies commonly only consider the production gains of a particular enterprise, with and without the technology, and ignore the impacts on the rest of the farm. Rohrbach noted that this approach errs in inferring that if a technology is profitable, it will attract capital and labor investments for its adoption.[3] Instead, the technology needs to be more profitable than alternative investment opportunities

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for the farm as a whole. The assertion in this paper is that there is a need for gender-sensitive methodologies to help research, extension and policy makers determine technologies likely to be adopted by farmers before a technology is propagated. Using such methodologies, the potential impact of various policies on farmers' livelihood systems can be determined.

This paper develops a Linear Programming (LP) model to determine the influence of gender of head of household on how households are likely to respond to technological options and economic policies. The impacts such technologies have on livelihoods of farm households are considered. Female-headed households (FHHs) have fewer resources, particularly male labor required for specific activities on the farm, compared to male-headed households (MHHs). With fewer resources, FHHs are more likely to adopt technologies that require less of their limiting resources.

HOUSEHOLD MODELS

Household modeling, based on the new household economics theory introduced by Becker that considers households as unified units of production and consumption, is appropriate for the unique characteristics of smallholder farmers. Smallholder farmers produce (using family labor) and consume their own product, which distinguishes them from most firms economists have studied.

In the new household economics theory, households maximize utility subject to a resource and time constraint.[4] Cases studies have given further support to this theory.[5] Given that smallholder farmers are rational and maximize cash incomes subject to fulfilling subsistence requirements, they are expected to respond positively to economic stimuli so hypotheses about their responses to economic policies can then be made. Therefore, economic variables in LP models, e.g., prices of inputs, can be adjusted to determine how farmers are likely to respond.

Smallholder farmers' livelihood systems can be represented by LP models. The household LP model is a set of equations, including an objective function that the household seeks to optimize, e.g., income, as well as a set of constraints that the household must satisfy, e.g., subsistence requirements. The model handles multiple cropping activities undertaken on the farm by representing them as different columns of the LP matrix.[6] Different constraints on the small farm household are then represented by the different rows of the LP matrix. Production and consumption decisions can then be accommodated by the model.

In the LP model, the profitability to the households of using new and old technologies can be compared. The constraints can be gender specific, such that the effects of different genders of the household head on the objective function can also be determined. In addition, the model evaluates compatibility of new technologies with levels of resources available to the households, which may vary over time. Decisions about allocation of cash to different goods (including farm goods for own consumption and leisure) and the allocation of fixed and variable inputs to different production activities in the short run can be incorporated. LP models are flexible: assumptions, technical coefficients, and activities in the farming system can be changed. Single or multiple objectives can be incorporated in the model, e.g., subsistence food requirements and income. This makes such a model particularly appropriate because farmers often consider several options at the same time when making decisions that affect their welfare.

The solution to the LP model gives the optimum livelihood activities undertaken by a specific household, such as crops produced under different technologies or off-farm income-earning activities undertaken by different family members. A solution corresponds to a set of household, market, and institutional conditions. The solution leads to a particular set of livelihood strategies for the household. Changing the set of conditions also changes the solution to the model so that a different type of livelihood becomes feasible. Models have "infeasible solutions" when the constraints are not satisfied, e.g., when subsistence food requirements are not met by the combination of household production and income-earning activities. In this case, the results imply that the household's livelihood system is not *sustainable*.[7] In other words, the household requires external support to survive over the time period specified.

Crops or crop techniques that might be used by farmers but are not currently in use, can be introduced into models to assess their potential for adoption, *ceteris paribus*. [8] The case of a cowpeas green manure crop with residual effects lasting two years after application, is used to illustrate how the introduction of a nitrogen-fixing crop for ameliorating soil fertility would affect the livelihoods of households with heads of different gender. Cowpeas were selected for this study as it performed well during evaluations of green manure alternatives conducted on farm. The crop is already grown by farmers but in tiny quantities. Its seed and leaves are consumed. Sample farmers indicated that among the crops they already grow, they would be willing to plow cowpea biomass into the ground to enhance soil fertility. A cowpea green manure crop is ideal for resource poor smallholder farmers as it does not require huge direct cash costs as they only require seed, labor and draft power. Farmers also indicated that they would plant maize in a plot in which cowpea biomass had been incorporated. In another survey in an area with similar circumstances, farmers expressed unwillingness to plant traditional green manure crops such as sun hemp and velvet beans. The traditional legume crops were resented since they are not edible and besides, farmers would need to purchase the seed for such crops. [9]

DESCRIPTION OF THE STUDY SITE AND ITS FARMING SYSTEM

Primary data were collected in 2001 from Mangwende Communal Area (CA). The CA is located in the north east of Zimbabwe, 90 kilometers from the capital city of Harare. Administratively, Mangwende CA is divided into five areas. An area is split into 28 wards. On average, each ward has 1000 households.

Based on head of household, three types of households exist in the area. There are MHHs, where the male head is resident on the farm, FHHs where the male head is not residing on the farm (*de facto* female-headed) and FHHs, where there is no husband (*de jure* female headed).

Maize is the staple food and major cash crop in Mangwende CA. Any surplus to subsistence requirements is sold. About 80 percent of revenue from crop sales is from maize. It occupies approximately two thirds of the cultivated area and absorbs close to 60 percent of the total household labor used for farming. [10] The planting of maize is staggered to reduce the burden on labor and to avoid the need to have all purchased inputs in place at the same time.

Staggering of plantings also minimizes the risk of failure of the maize crop due to mid-season drought. It also prolongs the period over which farmers can harvest green maize for consumption. Chemical fertilizer and cattle manure are applied on maize crops. Other crops grown in the area are finger millet, pumpkins, groundnuts, beans, sweet potatoes, cotton, cowpeas, Bambara nuts and sunflower.

Cattle are the dominant livestock. They provide draft power, manure and milk. Ownership of cattle influences the cropping pattern. Farmers with cattle usually have larger arable holdings, achieve better land preparation, weed on time, apply manure and achieve higher levels of agricultural production compared to non-cattle owners. [11]

SAMPLE SIZE AND SAMPLE SELECTION

Three wards were randomly selected out of the 28 in the CA. Thirty-five households were selected randomly from each ward, to give a sample size of 105 households. A household was defined as a group of people sharing food from the same kitchen permanently.

A structured questionnaire was administered to the sample. Informal discussions were also held with the households. In addition, three focus group meetings, where discussion guidelines were used, were convened in different locations within the study area. Groups provided data on the labor requirements of various farming operations, e.g., land preparation, planting, weeding, harvesting etc., which were based on general practices in the area. Gender-differentiated labor requirements were specified for operations undertaken using ox-drawn implements versus hand-held implements. The next section presents the constituent elements of the model and assumptions of the model regarding their use.

DATA USED IN THE LP MODEL

Crop yields

A production function, quadratic with respect to top dressing fertilizer applications rates, was developed for maize. Variables included in the production function and the signs expected on their coefficients are presented in Table 1. Coefficients of the production function are presented in Table 2. In the LP model, maize yields were obtained from the production function.

Table 1: Variables included in the Maize production function

VARIABLE NAME	VARIABLE DESCRIPTION	EXPECTED SIGN OF COEFFICIENT
Maize yield in 2001	1000 kg/ha	Dependent Variable
Compound D (7 percent N)	kg/ha	+
Ammonium Nitrate	kg/ha	+

(Ammonium Nitrate)^2	(kg/ha)^2	-
Organic Addition	Yes/No variable: 1 = Manure or other organic matter; 0 = No organic matter	+
Frequency of meeting with extension	Yes/No variable: 1= More than three times per year = 1; 0 = Less than three times per year	+
Draft Power Ownership	**1= Owners; 0 = Non-owners**	**+**
Total farm size	Area in Hectares	**+**
Time of Planting	0= Planted after 15 December; 1= Planted before 15 December	**-**

Table 2. Regression Coefficients of the maize production function

	VARIABLE SIGNIFICANCE LEVEL	COEFFICIENT	STANDARD ERROR FOR COEFFICIENT
Compound D* (kg/ha)	0.000170	0.000960	0.8593
Ammonium Nitrate (kg/ha)	0.010142	0.002682	0.0002
Ammonium Nitrate (kg/ha)^2	-0.000012	0.000001	0.0757
Organic Addition	0.117557	0.227740	0.6064
Frequency of meeting with extension	0.568046	0.207931	0.0069
Draft Power Ownership	0.439930	0.202655	0.0313
Total farm size	0.177394	0.994460	0.0762
Time of Planting	-0.515524	0.253945	0.0439
Constant	0.254294	0.319724	0.4275
Significance F = 0.0000	Adjusted R square = .026		

The coefficients in the regression model have the expected signs. Coefficients for Compound D and whether manure was applied were not significant. In the case of Compound D, the lack of significance of the coefficient could arise from the time when it is applied. Farmers apply it after the crop has emerged so that they only use the meager resources on plants that are already growing. This might limit the response of the crop to the basal fertilizer. Regarding manure, previous studies have alluded to the problems associated with manure in the smallholder farming sectors. Manure is of poor and variable quality, limiting its effectiveness in improving plant growth. [12]

The model was structured to accommodate the multiple plantings that farmers established. Survey results showed that 63 percent of the sample farmers had two plantings, 19 percent had one, 16 percent had three and one percent had four plantings of maize in separate plots. Plantings were spaced at two-week intervals. Maize was planted over the period from the end of October to early January. Seven percent of the maize plots were planted during late October. Thirty percent of these occurred over the first two weeks of November, 26 percent were planted during late November, 22 percent in early December, 13 percent in late December and two percent in early January.

LABOR REQUIREMENTS FOR MODEL ACTIVITIES

Smallholder farmers typically use family labor, with each member of the household old enough to participate in farming operations contributing. Because members often have different skills, labor might have to be allocated to different tasks, to maximize the contribution of each member. Males do most operations that use ox-drawn implements. However, when male labor is not available, females participate in the operations or male labor is hired.

Labor input coefficients into different operations were obtained from focus groups. Labor requirements for land preparation depend on whether or not a household uses draft power. Households without draft power need to hire it at a cost. Further, households without draft power use hand hoes for weeding while those with draft power use ox-drawn cultivators in combination with hand hoes. This has implications for labor use, particularly female labor. Hand hoe weeding requires more labor than do combinations of hand hoes and ox-drawn cultivators. Since female labor is usually used for hand weeding in households where labor use is differentiated, more female labor is required when there is no draft power.

The differentiation of labor by gender when undertaking operations is included in the model, although all family members take part in maize production activities. In 52 percent of the sample, male and female labor is differentiated during farming operations. When labor is differentiated, men use the ox-drawn implements. Females undertake planting and weeding using hand hoes in groundnuts, Bambara groundnuts and finger millet. When households do not differentiate their labor, males undertake operations that require ox-drawn implements and still take part in weeding with hand hoes.

Manure is dug out of the cattle pen, transported and spread by males. Therefore, households that do not have male labor would not be able to use cattle manure, unless they can hire it. This is common with *de jure* FHHs. Table 3 shows the differentiation of labor by gender.

Table 3. Differentiation of operations by gender

Crop and Operation	Male	Female
Plowing	X	X
Maize	X	X
Planting: Hand hoes	X	X
In plow furrow	X	
Weeding: Hands		
Ox-drawn cultivator		
Ox-drawn plow		
Groundnuts/Bambara Groundnuts	X	X
Hand hoes planting	X	X
Hand hoe weeding		
Finger millet		X
Planting by dribbling behind plow		X
Hand hoe weeding		
Cotton	X	X
Planting in plow furrow	X	X
Weeding: Using cultivator	X	X
Hand hoes		
Harvesting/Picking		
Sweet Potatoes	X	X
Hand hoe made planting beds	X	X
Hand hoe weeding		
Sunflower	X	X
		X

Planting by dribbling in plow furrow Weeding: Using cultivator Hand hoes		
Cattle manure Digging Transporting Spreading	X X X	

RESOURCE CONSTRAINTS

Resource constraints in the model included cash at the beginning of each year, labor (differentiated by gender) available at different times of the year, and land area available to the households.

The composition of the household determines available family labor. Additional labor can be hired in when cash is available. Hired-in labor and family labor are regarded as perfect substitutes. Labor can also be hired out for a daily wage. Labor days are divided into two-week periods to take account of the congestion of the activities between late October and the end of March. Households report facing labor constraints during this period.

Cash at the beginning of the year

This variable is the cash used for farming from the beginning to the end of the season obtained from sources such as sales of the previous crop, remittances, and non-farming activities. Use of credit has been declining over the years. Credit was used by 26 percent versus 6 percent of the sample farmers in 1990 and 2000, respectively. In 2000, credit was only available for groundnut inputs.

Household subsistence consumption requirements

Typically, semi-commercial smallholder farm households grow and store some food for consumption. The quantity of the staple food crops that each household stores every season was obtained during from the survey. These requirements are consumption constraints in the model.

A three-year LP model was constructed and run for all sample households. In each run, dimensions of specific households obtained from the questionnaire survey and average coefficients from group interviews were used. The objective function in the model was to maximize disposable cash income at the end of the third year.

Cowpeas technology

The LP model assumes a cowpea crop is planted in the first year, maize in the following two years of the three-year model. The model assumes the cowpea biomass is incorporated soon *after* the pods are harvested but *before* the leaves are dry, as opposed to the more conventional assumption that the biomass of the "green manure" crop is incorporated green, i.e., before it sets seed. In agreement with Uttaro's results here, the conventional approach is rejected here because smallholders plant grain legume crops in their farming systems for food rather than for soil fertility. Food security is their primary concern.

In on-farm trials of cowpea improved fallows in Mangwende CA, it was observed that maize yield improvements from residual effects of cowpea were observed in the first two seasons after the cowpea fallow. Thereafter the fallows species or duration had no effect on the maize yields. [13] Maize planted after a cowpea crop produced yields between 4000 and 6000 kg per hectare in the on-farm trials. [14] Maize yields realized in the first season following the improved fallow declined by 10 percent in the second season. The residual effect of high quality biomass after the second year was found to be very low. [15] In the LP model in this paper, it was therefore assumed that the residual soil fertility benefits of cowpeas last for two seasons after incorporating their biomass, with a 10 percent of yield reduction in the second season.

The analysis of the effect of introducing cowpeas proceeded as case studies of three households differentiated by the gender and marital status of the household head, to see the effect of gender on potential adoption of cowpea technology. One household was headed by a male resident on the farm (MHH), the second was headed by a male who resided away from the farm (*de facto* FHH), and the last household was female-headed (*de jure* FHH). The composition of the households is given in Table 4. In the sample, 50 percent were MHHs, 29 percent were *de jure* FHHs and 21 percent were *de facto* FHHs. This distribution of the households shows that females (*de jure* or *de facto*) constituted a significant part of the decision makers in smallholder farms.

Table 4. Household composition of case study households

Gender	Labor contribution	De jure FFH 29 percent	De facto FHH 21 percent	MHH 50 percent
Males	Full time working adults	0	0	2
	Part time working adults	0	1	0
	Working school children	0	1	0
	Non-working children	2	0	0
Females	Full time working adults	2	1	1
	Working school children	2	2	1

	Non-working children	0	1	0

To allow for comparison across households, selected households had Z$6,000 cash at the beginning of the year, the average that MHHs and *de jure* FHHs reported during the survey. The average for *de facto* FHH was Z$9,400. The higher beginning cash is expected because the male heads in these households were away and probably working. They would remit funds for farming activities. All households also had draft power. That the households possess draft power means that the group represents the better off farmers. The size of the arable land was 2.5 hectares, which was the average for the sample.

RESULTS AND DISCUSSION

Verification of the model

To see how well it simulated the livelihood systems of the sample households, results from the model were verified by comparing them to those from the survey. The two variables used for verification were the area under maize, the major crop in the system, and the arable area left fallow. The difference in the area obtained from the model solutions and from the survey was not statistically significant ($p \leq 0.1$). A correlation coefficient of 0.67 existed between the areas planted to maize obtained from the two data sources. A similar test on the arable area left fallow showed that the model closely reflected the survey data. The area reported to be under fallow in the survey data was not significantly different ($p \leq 0.05$) from that obtained from the model. The two fallow areas had a correlation coefficient of 0.72. This verification suggests that the model simulates the sample households well and is adequately robust to be used for establishing how households with different characteristics are likely to respond to interventions in their livelihood systems. Such interventions can be in the form of new technologies or new policies. The effect of such technologies on the households is then predicted from the results of the model. The model can then be used to assess the potential adoption of new green manure technologies, specifically cowpea technologies, on households headed by *male* heads versus *de jure* female heads versus *de facto* female heads.

Fertility Management

The assessment of the potential impact of the cowpea green manure technology was conducted by evaluating the performance of case study households, before and after the introduction of the technology. Before the introduction of the cowpea green manure into the model, households only relied on chemical fertilizers or combinations of chemical fertilizers and cattle manure for improving the fertility of their soils. The *de jure* FHHs did not use any manure because it required male labor, which they did not have. *De facto* FHHs with male heads of households only working part-time on the farm applied manure on 0.16 hectares. The MHHs applied cattle manure to 0.4 hectares of the arable land in the first season.

After the cowpea green manure technology was introduced into the model, the *de jure* FHH planted 0.4 hectares to cowpeas in the first season. The *de facto* FHH and MHH planted 0.31 and

0.74 hectares to cowpeas in the first season, respectively. The area planted to cowpeas by the latter two households was additional to that planted to maize with manure.

The net effect of adopting the cowpea technology can be seen in the cash incomes maximized by the different kinds of households in Table 5. The *de jure* FHH had the least income at the end of three years, with and without the cowpea green manure technology. Without the cowpea green manure technology, the income of the *de jure* FHH at the end of three years was Z$2,940 and Z$1,810 less than that for the *de facto* FHH and the MHH, respectively. With the cowpea green manure technology, which was adopted by the *de jure* FHH, the disparity in income levels decreased to Z$2,690 and Z$1,700.00 compared to that of *de facto* FHH and MHH, respectively.

Table 5. Incremental effects of cowpea green manure on end of year income

Type of Household	**Season**		
	1	**2**	3
De jure FHH	**550**	**900**	**360**
De facto FHH	40	290	110
MHH	-80	610	240

Table 5 shows the incremental change in the end of year income that farmers realized over the three-year period. The *de jure* FHH received the highest increase in disposable income from the use of cowpea green manure in all years. Therefore, even though the cowpea green manure technology can potentially be adopted by all types of households, the marginal effects of the technology depend on the technologies that households were using before introduction of the new technology and the resources available to the household. In this study, the *de jure* FHH, which had the least income level before adopting the cowpea technology, realized the largest positive impact on their income from the introduction of the cowpeas. These findings suggest that when identifying disadvantaged households, researchers should identify the factors contributing to the disadvantage so that appropriate interventions can be designed.

These results also counter the consensus opinion in the WID literature that de jure and de facto female-headed households are equally disadvantaged in resources and ability to utilize technologies. [16] The *de facto* FHH had the highest income before and after the introduction of the cowpea technology. This household used cattle manure because it had access to male labor, albeit limited. This indicates that only some of the female headed households are disadvantaged in their ability to adopt technologies. Indeed, farmers in the study site testified to the effect that some *de facto* female-headed households performed at par or better than male headed households.

Conclusion

In this paper, an LP model that is sensitive to smallholder farmer circumstances was described and used to show the differential impacts of cowpea technology on cropping patterns of *de jure* female-headed households, *de facto* female-headed households, and male-headed households in Zimbabwe. The robustness of the model to handle the diverse characteristics of smallholder farmers was illustrated by the ability of the model to simulate sample farmers.

Results suggest that women farmers in general and female-headed households in particular are not a homogenous group; and for the purposes of design of appropriate soil-fertility technologies, they need to be disaggregated to identify the constraints that hinder (or promote in this case) the adoption of specific technologies. The case study presented here of the potential adoption of cowpea technologies shows that *de jure* female-headed households would have more to gain by adoption of cowpea technologies, although MHHs and *de facto* FHHs would realize higher disposable cash incomes compared to the *de jure* FHH households. The availability of male labor is key to this result. Part time male labor available to the *de facto* FHH household enables it – as well as MHHs -- to apply cattle manure and thus decreases their demand for a substitute soil-fertility amendment in the form of cowpeas. Without male labor and thus cattle manure, *de jure* FHHs should realize the highest percentage increase in their incomes from adoption of cowpeas. Therefore, the technology should be more attractive to these *de jure* female-headed households than those with higher incomes, and we therefore predict a higher adoption rate of cowpeas by *de jure* female-headed households in Mangwende, Zimbabwe.

This paper showed how household LP models can be used for understanding why households undertake different activities or adopt different technologies. For the purposes of this volume, it also shows what soil-fertility interventions are capable of reaching which subgroups of women farmers, given the assumption they are not all alike. Development efforts can be made sensitive to characteristics of different households such as gender and marital status. Realization of the specific traits that make technology adoption possible and the effects that the technologies would have on the potential adopters will assist policy planners in redirecting technology development to households most in need of technologies. Technologies can also be designed to achieve the desired effect on households, such as meeting subsistence food requirements, reducing the female labor requirements during specific activities, and increasing total household income. Technologies developed with a clear objective, a specific problem to be solved, and a specific target clientele in mind are likely to be adopted.

Notes

* Compound D is 8 percent Nitrogen, 14 percent Phosphate and 7 percent Potassium.

Ammonium Nitrate is 34.5 percent Nitrogen

1. Pingali and Binswanger, 1998

2. Farm Management Research Section, 1990
3. Rorhbach 1997
4. Nakajima, 1965 and Becker, 1965
5. Singh et al., 1986, Netting,1993; Ellis,1992 and Tibaijuka, 1994
6. Singh and Janakiram, 1986
7. Chambers and Conway, 1992
8. Timmer *et al*, 1983
9. Gatsi, at al, 2000
10. Masters, 1994
11. Cousins, Weiner and Amin, 1990
12. Mugwira and Murwira 1998
13. Mafongoya and Dzowela 1999
14. Chibudu 1997
15. Mafongoya et al 1997
16. Due 1991, Due and and Gladwin 1992

References

Becker, G.S. "A theory of allocation of time." *Economic Journal* 75. 1965 493-517.

C.S.O. Statistical Yearbook, Central Statistical Office 1997, Harare, 1998, 228 pp.

Chambers, R., and G. Conway. Sustainable rural livelihoods: practical concepts for the 21st century. Discussion Paper 296, Institute for Development Studies, University of Sussex. 1992.

Chibudu, C. Green manuring crops in a maize-based communal area, Mangwende: Experiences using participatory approaches. In Waddington, S.R.m Murwira, H.K., Kumwenda, J.D.T., Hikwa, D. and Tagwira, F. (eds). Soil fertility research for maize-based farming systems in Malawi and Zimbabwe. Proceedings of a Soil Fert Net Results and Planning Workshop held from 7-11 July 1997 at Africa University, Mutare, Zimbabwe. Soil Fert Net and CIMMYT-Zimbabwe, Harare, Zimbabwe 1998, 312 pp.

Cousins, B., Weiner, B. and Amin, N. The dynamics of social differentiation in communal lands of Zimbabwe. Review of African Political Economy 53: 5-24. 1992

Due, J.M. "Policies to Overcome the Negative Effects of Structural Adjustment Programs on African Female-Headed Households," in: Gladwin, C.H., ed. Structural Adjustment and African Women Farmers, p. 103-127. Gainesville, FL: University of Florida Press, 1991.

Due, J.M., and C.H. Gladwin. "Impacts of Structural Adjustment Programs on African Women Farmers and Female-Headed Households." American Journal of Agricultural Economics 73 (1991): 1431-1439.

Eicher, C.K. Facing up to Africa's food crisis. *Foreign Affairs* 61: 151-174, 1982.

Eicher, C.K. Zimbabwe's maize-based green revolution: Preconditions for replication. *World Dev*. 23:805-8181, 1995.

Ellis, F., *Agricultural policies in developing countries*. Cambridge University Press, 1992.

Farm Management Research Section, *The second Annual Report of Farm Management Data for the Communal Area Farm Units, 1989/90 Farming Season.* Harare: Economic and Markets Branch. 1990.

Gatsi, T., Bellow, M.R. and Gambara, P. The adoption of soil fertility technologies in Chiota, Zimbabwe: Potential and constraints. CIMMYT Maize and Economics Programmes, Network Research Results Working Paper No. 6. 2000.

Gladwin, C.H. Gendered impacts if fertilizer subsidy removal programs in Malawi and Cameron. *Agric. Econ*. 7: 141-153. 1992.

Mafongoya, P.L., and Dzowela, B.H. Biomass production of tree fallows and their residual effect on maize in Zimbabwe. *Agroforestry Systems* 47: 139-151. 1999.

Mafongoya, P.L., Nair, N.P.K. and Dzowela, B.H. Multipurpose tree prunings as a source of nitrogen to maize under semiarid conditions in Zimbabwe. 3. Interactions of pruning quality and time and method of application on nitrogen recovery by maize in two soil types. *Agroforestry Systems* 35: 57-70. 1997.

Masters, W.A. *Government and Agriculture in Zimbabwe*. Westport: Praeger Publishers. 1994.

Mugwira L.M. and Murwira, H.K. A review of research on cattle manure as a soil fertility amandment in Zimbabwe: Some perspectives. In Waddington, S.R., Murwira, H.K., Kumwenda, J.D.T., Hikwa, D. and Tagwira, F. (eds). Soil fertility research for maize-based farming systems in Malawi and Zimbabwe. Proceedings of a Soil Fert Net Results and Planning Workshop held from 7-11 July 1997 at Africa University, Mutare, Zimbabwe. Soil Fert Net and CIMMYT-Zimbabwe, Harare, Zimbabwe 1998, 312 pp.

Nakajima, C. "Subsistence and Commercial Family Farms: Some Theoretical Models of Subjective Equilibrium." In C.R. Wharton (ed.) *Subsistence Agriculture and Economic Development*, Aldine Publishing, Chicago. 1969.

Netting, R. M., *Smallholders, Householders*. Stanford University Press, California. 1993.

Pingali, P. and Binswanger, H.P., "Population Density and Farming Systems: The Changing Locus of Innovations and Technical Change." In Lee, R.D., Arthur WB Kelly AF Rogers, G. and Srinvasan T.N. *Population, Food and Rural Development*. Oxford: Oxford University Press. 1998.

Rorhbach, D.D. Developing more practical fertility management recommendations. In Waddington, S.R. , Murwira, H.K., Kumwenda, J.D.T., Hikwa, D. and Tagwira, F. (eds*). Soil fertility research for maize-based farming systems in Malawi and Zimbabwe*. Proceedings of a Soil Fert Net Results and Planning Workshop held from 7-11 July 1997 at Africa University, Mutare, Zimbabwe. Soil Fert Net and CIMMYT-Zimbabwe, Harare, Zimbabwe 1998, 312 pp.

Singh, I. and Janakiram, S. "Agricultural Household Modeling in a Multi crop Environment: Cases Studies in Korea and Nigeria." In Singh, I., Squire, L. and Strauss, J., (*eds*.) *Agricultural Household Models: Extensions Applications and Policy.* Washington: World Bank. 1986.

Singh, I., Squire, L. and Strauss, J., (*eds*.) *Agricultural Household Models: Extensions Applications and Policy.* Washington: World Bank. 1986.

Smale, M. Maize is life: Malawi's delayed Green Revolution. *World Dev*. 23:819-831. 1995.

Tibaijuka, A., "The Costs of Differential Gender Roles in African Agriculture: A Case Study of Smallholder Banana-coffee Farms in the Kagera Region, Tanzania." *Journal of Agricultural Economics* 45(1) (1994): 69-81.

Timmer C.P., Falcon W.P. and Pearson S.R. *Food Policy Analysis*. Baltimore: The John Hopkins University Press. (1983).

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