Modeling Agroforestry Adoption and Household Decision Making in Malawi

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Abstract: Low resource farmers make decisions about adopting new technologies as part of the overall strategy for ensuring subsistence and cash income for their food security needs. This paper reports on a study conducted in Kasungu, Malawi, southern Africa, to evaluate the potential for small-scale farmers to adopt improved fallows. Simulations of two representative households, a male and a female headed, were carried out using dynamic ethnographic linear programming (ELP) in a ten-year model. Results show that the adoption pattern for improved fallows is driven by the amount of land and labor available rather than the gender of the household head. Female-headed households with insufficient labor may hire labor for other cropping activities, which enables them to plant improved fallows. Furthermore, simulations show that when households are able to sell seed from the woody species in the fallow, both male and female households stop taking credit for fertilizer for their cash crop. They still grow the cash crop, in this case tobacco, but produce most of their maize without chemical fertilizers. It is concluded that in Kasungu, Malawi, improved fallows will be adopted in households with sufficient land and labor.

Introduction

Soil fertility depletion is considered a major constraint for smallholder farmers in nutrient–poor tropical soils, especially in sub-Saharan Africa. High population pressure has led to land shortages and continuous arable cultivation without fallowing, leading to high nutrient losses in Malawi where agriculture is the mainstay of the economy. About 85% of the population in Malawi is rural and is dependent on agriculture. Long duration natural fallows that were traditionally used to overcome soil fertility depletion [1] are no longer possible due to increasing population pressures on the land. The decline in soil fertility has led to reduced soil productivity and hence more food insecure households. However, among other benefits,

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agroforestry has the potential to improve soil fertility through the maintenance or increase of soil organic matter and biological N_2 fixing from nitrogen fixing tree species. [2] Agroforestry also protects the soil from eroding, thereby improving the soil's productive potential. Some woody species also provide diversified outputs for smallholder farmers in the form of fuelwood and poles. In some cases, agroforestry technologies such as fruit trees can provide a more diverse farm income and reduce food insecurity. Nair [3] and Young [4] have detailed the benefits of agroforestry.

The problem of soil fertility has been exacerbated by institutional constraints such as structural adjustment programs required by the World Bank and other donors. The impact of these "reforms" on food security in Malawi and other African countries has been a reduction in the use of chemical fertilizers that were commonly used by farmers to replenish soil fertility. Fertilizer prices have risen sharply in Malawi since the removal of fertilizer subsidies during the time period from 1986 to 1995. [5] Farmers are able to purchase very little fertilizer, if any at all. Most affected are women farmers, who account for over 70% of the food production group in Malawi [6] and who grow most of the subsistence food crops.

Recently, researchers in southern and eastern Africa have reported on the use of improved fallows as a means to return nutrients to the soil in a short period of time (e.g., nine months in Kenya with two rainy seasons to two years in eastern Zambia and Malawi with one rainy season). [7] Short duration rotations of managed fallows of sesbania [*Sesbania sesban* (L) Merr.], tephrosia [*Tephrosia vogelii*], and gliricidia [*Gliricidia sepium*] have the potential to replenish soil fertility and thereby increase crop yields of subsequent crops. [8] Consequently, these fallows are being promoted at many sites throughout the tropics, [9] due to their ability to improve soil fertility. However, experiences of agroforestry adoption show that in some cases agroforestry adoption has generally been low. [10] Furthermore, only recently has some attention been given to socioeconomic studies relating to agroforestry adoption. [11] Agroforestry research to date has predominantly focused on the biophysical aspects, with attention given mainly to yield benefits from researcher-managed agroforestry plots. In most cases, comparisons are made only on the maize yield benefits from agroforestry technology, which disregard the farmer's overall loss in maize production by planting part of the farm with trees.

To promote and increase the adoption of improved fallows as a sustainable method to increase food production and environmental protection, both researchers and development workers should understand the nature of limited-resource family farms. First of all, these farms are not businesses, but homes where diversity is a necessity. [12] Their major production goal is to secure sufficient food supplies for their families. They pursue diverse food procurement strategies in order to first satisfy home needs, and then sell any surpluses.

The different strategies pursued by farmers have significant implications for the types of technologies they are able to adopt. For example, the introduction of a new technology, such as an agroforestry innovation, may require fundamental changes in the way farm families approach their farming methods. Hildebrand has argued that researchers report on averages, which often misrepresent limited-resource farmers' real situations. [13] The rationale for this argument is that averages have little meaning in limited-resource family-farm households, who are so risk-averse that they base their expectations on a worst-case scenario of a bad-weather year, not on an "average year." Researchers who assume farmers expect average yields may therefore find their models do not predict the reality of the small, limited-resource farm. Due to this misunderstanding of resource–limited farms, researchers and extension workers often wrongly conclude that farmers are ungrateful laggards when they do not adopt agricultural technologies. [14]

In order to increase acceptability and promote wider adoption of improved fallows by resource-poor farmers, it is important to identify and analyze factors that affect the technology's adoptability for farm households with differing characteristics such as household composition and gender of the household head. [15] Gender of the household head plays an important role in the productivity of smallholder farming systems. Differences in the household's access to land and labor resources, financial and commodity markets, significantly influence cultivated land size, kind of crops planted, and farm income. [16] Relatively, African women farmers get lower crop yields than men; [17] but this is due to differences in the intensity of input use such as inorganic fertilizers, labor, credit, and extension education. [18] Given the same resources, Adesina and Djato found no differences in the efficiency of men and women in African agriculture and concluded that women are equally good farm managers as men. [19] When women have control over resources, however, they tend to use them differently than men, often spending more on their children, with different results for the welfare of the household. [20] Their choice of cropping activities is therefore different from that of the males, and tends to focus on food rather than cash crops. A deeper understanding of household decision-making will thus help policy makers and technology developers target individuals in the most effective way.

Gender also plays a role in the adoption of agroforestry technologies. Previous studies of adoption of improved fallow technologies in eastern Zambia show that female headed households are more likely to adopt improved fallows than are male headed households, holding constant other factors such as household size, previous experience with natural fallows, age and club membership of the household head. [21] It remains to be seen, however, whether or not this will also be the case in other, more populated regions of sub-Saharan Africa where improved fallow technologies are now being tested and promoted.

BACKGROUND TO IMPROVED FALLOWS IN MALAWI

The improved fallow technology in Malawi was introduced in 1997 after ICRAF initiated farmer-to-farmer contact with early adopters of improved fallows in eastern Zambia. In November of 1997, 18 farmers from Kasungu crossed the border into eastern Zambia, where farmers are at an advanced stage in the testing of improved fallows, and were given hands-on training on the planting and management of improved fallows of sesbania, tephrosia, and gliricidia tree species. Reportedly, they returned to Malawi determined to plant their own improved fallows trial plots. [22]

Unlike the southern part of Malawi, smallholder land holdings in Kasungu are slightly higher than the national average. Table 1 shows that in Kasungu ADD in the 1992/93 season, only 34% of plots (called gardens in Malawi) were less than 1 hectare; while almost 43% of gardens were between 1 and 1.99 hectares and 23% were at least 2 hectares. [23] Therefore, land availability is adequate in Kasungu when compared to southern Malawi. In fact, ICRAF introduced the improved fallow technology in Kasungu because farmers there have relatively more land than average in Malawi. In addition, the improved fallow technology is targeted at those farmers with large landholdings. Because we drew our sample from the ICRAF list of testers of the technology, the sample of farmers chosen for this study also have larger-than-average landholdings for Kasungu.

Table 1. Land holding sizes in Malawi by Agricultural Development Division (ADD)

Agric Dev. Div.	Total Est. Gardens (number)	Holding size by Category (%)		
		<1.00 ha	1.00-1.99 ha	2.00 ha & over
All Malawi	2738607	67.6	24.3	8.1
Karonga	132493	73.5	23.7	2.8
Mzuzu	238820	51.0	32.2	16.8
Kasungu	305598	33.7	43.6	22.7
Salima	153812	69.2	23.0	7.8
Lilongwe	487285	64.8	27.0	8.2
Machinga	610613	72.7	23.3	4.0
Blantyre	646718	86.8	11.6	1.6
Shire Valley	163268	62.5	23.3	13.7

Source: National Sample Survey of agriculture 1992/93 Volume II

This paper evaluates the potential of adopting improved fallows by the Kasungu farmers who are now testing improved fallows. Ethnographic linear programming (ELP) is used to assess whether adoption of improved fallows is feasible and economically viable for these smallholder farmers, given their agro-climatic and socioeconomic conditions. The next section of the paper gives the description of the study area and an outline of the study methodology. It also establishes the modeling framework and details the main resource constraints included in the model, and describes the results and discussion.

METHODOLOGY

The research was conducted in Kasungu (13° 1' 60S, 33° 28' 60E), central Malawi, in the Kasungu Agricultural Development Division (KADD) agroecosystem. Kasungu district covers 14% of the country and contains 11% of the country's total rural population covering four administrative districts of Kasungu, Dowa East, Ntchisi, and Mchinji. Kasungu experiences a warm tropical climate characterized by a unimodal rainfall pattern with a wet season of approximately five months, running from November/ December to March/April with erratic rains ranging from 500 to 1200 mm per year and a prolonged dry season for the rest of the year. The town of Kasungu lies at an altitude of 1342 meters and has a mean annual temperature of 19-22.5°C. The soils are predominant oxisols, ultisols, and alfisols (USDA taxonomy). [24] Specifically, the study was conducted in two extension-planning areas (EPAs), Chulu (13° 40' 60S, 33° 40' 0E) lying at 1211 meters above sea level and Kasungu–Chipala (13° 0' 0S, 33° 28' 60E) at 1151 meters above sea level (Figure 1).

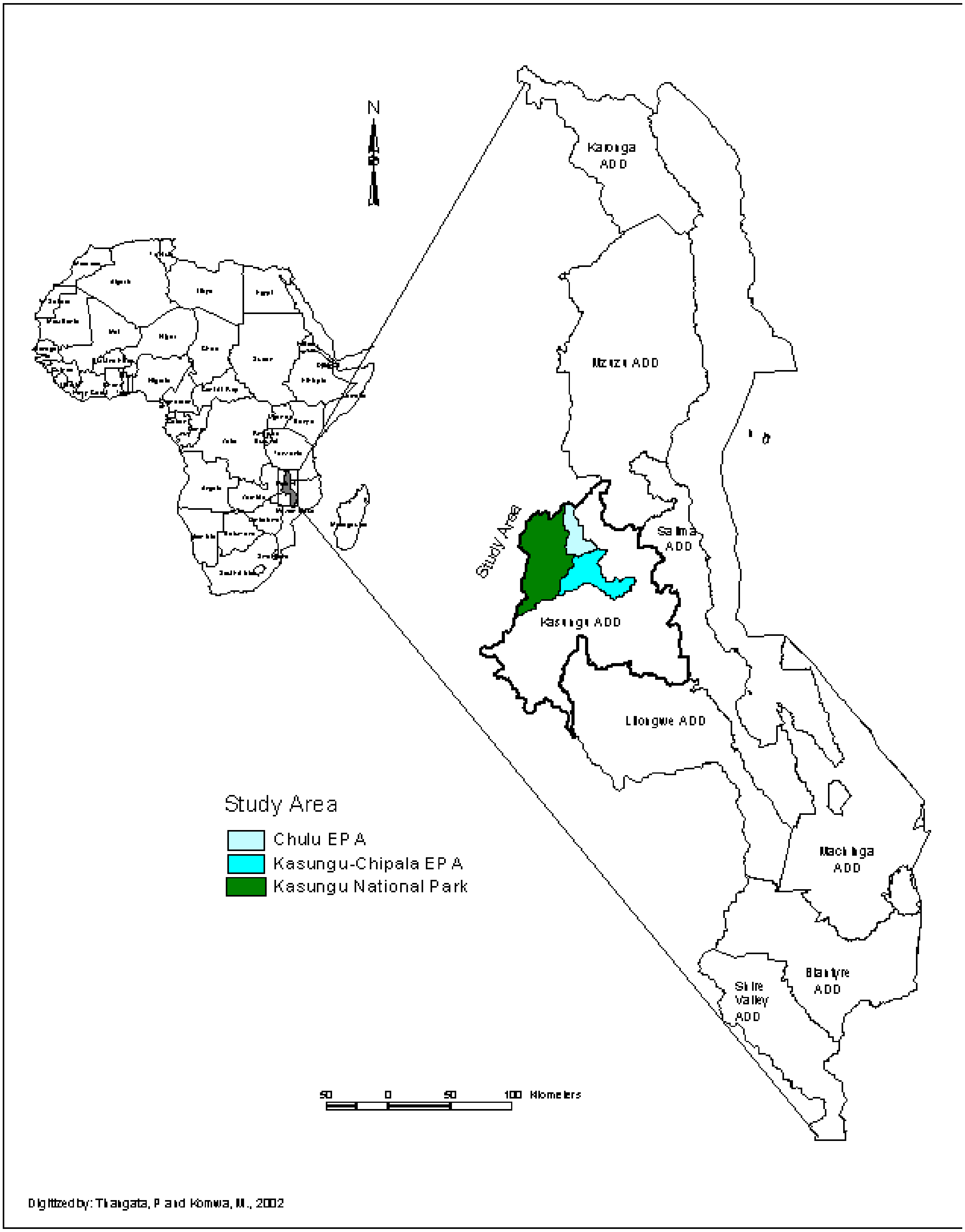

Figure 1. Study area.

DEMOGRAPHICS AND ECONOMIC ACTVITIES

Kasungu has a population of 476,000 people (about 51.5% are male). Of the total district population, 52% of the people are under 18 years old. [25] Most of the people in the rural areas of Kasungu are farmers. About 52% of the women in the area are involved in farming activities (Table 2).

Table 2. People aged 10 years and over and the economic activities by gender in Kasungu.

Economic Activity	Male	Female
Total	169,451	154,452
Economically active	118,502	95,566
Total Working	117,601	95,156
Farmer	79,384	84,505
Employee	29,835	7,621
Family business worker	2,350	1,294
Self-employed	5,624	1,694
Employer	408	42
Total Unemployed	901	410
Worked before, seek work	243	127
Worked before, not seeking	150	50
Never worked, seeking	508	233
Not economically active	50,949	58,886
Never worked, not seeking	1,349	1,389
Homeworker	1,344	17,420
Student	47,049	38,758
Other	1,207	1,319

Source: National Statistical Office (1998) Malawi Population and Housing Census.

Crop Production

The major crops grown by all farmers in the area are maize (*Zea mays* L), tobacco (*Nicotiana tabacum* L.), the main cash crop, and groundnuts (*Arachis hypogaea* L.). In Kasungu, maize production occupies 70% of the cultivated area, followed by groundnuts (12%), and tobacco (3-10%). Crop rotation is a requirement for tobacco producers in order to reduce disease/ pest infestation. Groundnuts are important in the farming system. [26] Due to low producer prices, however, groundnut production has decreased in recent years. Minor crops include cassava and sweet potatoes. Some beans and/or bambara nuts are planted as intercrops with maize. Vegetables are grown in the wetland areas (dambos), mostly during the dry season. However, most of the wetland areas are used for tobacco nurseries.

Tobacco is given the first priority together with maize, followed by groundnuts. Tobacco is sown in nurseries and transplanted from October to December or early January. Minae and Msuku [27] report that planting of the tobacco nursery starts early, around July-August. Field preparation starts soon after harvesting in April, but not on all farms. Tobacco and maize fields are prepared first and made ready for planting when rains come. Peak labor periods are September to December. Planting depends on the start of the rains, amount of rainfall and distribution (mostly October/ November). Tobacco can be dry planted in December as long as farmers are sure of rainfall within two to four weeks. Weeding requires large amounts of labor and is done from December to February or when weeds appear for all crops. Towards the end of February, farmers who plant early can start harvesting tobacco. In most cases, cassava and sweet potatoes are planted during land preparation.

The family is the main source of labor, although some households that can manage do hire labor. Communal labor is common at maize harvest but not at tobacco harvest. Men sometimes help each other in grading and baling tobacco. There is a very limited use of ox-plows, but the majority of farmers use hand tools. The farmers in this study consider hiring equipment too expensive.

Data Collection

Data collection in this study occurred between September and December 1999 and again between June and August 2001. Primary data collected in 1999 involved household surveys, participatory rural appraisals (PRA), and informal interviews to produce data for the ethnographic linear programming (ELP) models. First, meetings were held with extension workers. Group meetings followed with farmers from the two areas, Chulu and Kasungu–Chipala. Later, using structured and semi-structured questionnaires, detailed formal interviews were conducted with ten households, randomly sampled from the extension agent's list of testers of the technology. Different households were selected so that they could eventually serve as representations of different recommendation domains. [28] Secondary data, such as yield data, were gathered from ICRAF, the Malawi Agroforestry Extension Project (MAFE), and the Kasungu Agricultural Development Division. The first author conducted all the interviews, but the third author also later visited some of the households. Ethnographic linear programming (ELP) models were developed for each of the ten households interviewed. Two representative households are reported in this paper.

In 2001, the ten households interviewed in 1999 were re-visited to test the models' prediction ability, and to validate and check areas where the models needed improvements. Discussions were held with farmers to see whether the models' preliminary output results adequately depicted what they produce and how. Another 31 farmers were interviewed to ascertain the labor data and to check how well the models selected from the households interviewed in 1999 represent the community by comparing the household compositions, labor availability, and food requirements.

MODEL FRAMEWORK

The model is a ten-year, dynamic linear programming model. The matrix of technical coefficients is identical for all households, but the resource endowments change with each new household solved in the model. The model maximizes an objective function, e.g., household income or food production, subject to constraints on the household, such as cash, labor and land, after meeting home consumption requirements. The ELP models used in this study are ethnographic in nature, meaning that specification of the objective function and constraints in this model were determined based on interview data from the Kasungu farmers.

Ethnographic linear programming (ELP) simulates the farmers' strategies by choosing between different alternative livelihood activities available to farmers in the region and representing different degrees of crop intensity, labor, and land saving techniques available. It takes into account their respective costs, constraints, and advantages, as they report them. It is an adaptation of linear programming that Hildebrand and others at the University of Florida have developed. [29] ELPs are a means of quantifying ethnographic data, mostly qualitative, and are thus both descriptive and analytic. By modeling all the activities of and constraints on the farming household, they help researchers understand the complexity and diversity of smallholder farming systems.

The objective function in the ELP is represented by the general format:

$$\text{Maximixe } Z = cx$$

subject to

$$Ax \leq b$$
$$x \geq 0$$

where *Z* in this model is the discretionary cash income farmers have at the end of the year after using their constrained resources (represented by the rows of the matrix) to engage in different livelihood activities (represented by the columns of the matrix). *C* is the row vector of enterprise year-end cash, *x* is a column vector of enterprise levels (and all *x*'s are equal to or greater than zero), *A* is a matrix of technical coefficients, and b is a column vector of farm resource endowments or consumption requirements on the right hand side of the inequality sign. The rows of the matrix also represent the constraints farming households operate under; for example, they must meet necessary cash expenses and provide food security in the household given their resources such as land, labor and cash (*b*). The consumption constraints in the model reflect the need for the households to first satisfy household food requirements before marketing any surplus. To specify consumption constraints, minimum food requirements for the household are specified for each crop. The particular model size reflects the detailed specification of the relationships of different activities being represented. The model was implemented in MS Excel® [30] spreadsheet. MS Microsoft Visual Basic® 2000 [31] was used to make calling and solving different households easy and flexible. The premium add-in solver [32] for Excel was used to handle the large number of variables.

Assumptions of the Model with Respect to Production Activities

The model makes certain assumptions about smallholder production, based on farmer reports. For example, crops in Kasungu are assumed to be monocrops. They include maize, the staple food; tobacco, the cash crop; and sweet potatoes, cassava, and groundnuts. Improved fallows of sesbania and tephrosia are considered as alternative cropping activities that can be planted every year and thus are also represented by columns in the matrix. Maize is produced either fertilized or non-fertilized, or following a two-year improved fallow of sesbania or tephrosia. Because the improved fallow trees can be planted every year, maize can be planted after the fallow plots every year after the second year. Tobacco, the main cash crop, is never planted after the fallow trees, because both sesbania and tephrosia are hosts to root knot nematode, and tobacco is susceptible to nematode attack. Due to storage and marketing problems, the model also limits the production of sweet potatoes and cassava to 0.25 and 0.33 hectares respectively. Minimum food requirements used in the model are presented in Table 3. The data used in the model (e.g., total input costs for each cropping activity, yield and price data for each activity), are presented in the bottom rows of Table 4.

Table 3. Minimum food requirements for a household for each crop in kilograms per year.

Crops	---------Food Requirements (kg/year)-------		
	Adult	Child	Infant (<5 years)
Maize	250	150	50
Cassava	70	35	35
Sweet potato	70	35	35
Groundnut	100	50	50

RESOURCE CONSTRAINTS IN THE MODEL

The model also makes certain assumptions about the limits to farmers' use of cash and agricultural input credit. Most households have limited cash available to them; the total amount of cash inputs available is enough for one hectare of purchased fertilizer, seed, nursery chemicals, and transportation to the auction floors in the case of tobacco. Farmers who plant tobacco also have access to credit. Women farmers, especially FHHs, split the fertilizer received on credit for tobacco and apply a portion of it on their maize crop. In 1999/2000, the interest rate for loans was 55%. The model also allows for cash to be transferred from one year to the next to be used for purchasing agricultural inputs.

Labor Assumptions

Similarly, the model makes assumptions about farmers' use of labor, again based on farmer reports. The labor data used in the model (in labor-person days) for each activity are presented in the top rows of Table 4. It is assumed that each adult male or female in the household provides 25 labor days in a month. Because the harvesting of tobacco is quite labor demanding, households may hire additional labor from outside the region and pay them a lump sum payment at the end of the season after tobacco sales. This is in contrast to maize, for which additional labor demands can be met by communal labor.

The model separates out labor inputs by gender and by month; and labor supply in any calendar month is the total amount of labor available from the contribution of all household members and hired labor. Because women are responsible for childcare, the number of infants (under 5 years old) reduces the female labor contribution to production in a household. Therefore, labor from a female with an infant is reduced from the 25 labor days available in a month to 22 labor days, due to childcare activities. Most cropping activities are done either by men or women. Males, however, are responsible for most of the tobacco activities; while groundnut production and maize transportation are mostly a woman's job. For school-going adolescents, labor contributions vary, depending on whether they live at home during the school year. As the children in the household grow, they also contribute more labor (and require more food), and the data in the model reflect these changes.

Table 4. Summary of crop activities, income and resource use for production activities on a per hectare basis as used in the matrix.

Crop activity	TBCCO		FERT MZE		NF MZE		SS I	SS II	TV I	TV II	SS MZEI	TV MZE I	GNUT		CSVA	SWPOT
Labor-P/dys	M	F	M	F	M	F							M	F		
September	50	12	7	7	7	7	5	-	5	-	19	5	14	14	5	5
October	25	25	10	10	10	10	24	-	25	-	15	25	11	11	6	6
November	25	25	20	20	20	20	19	-	10	-	12	10	5	11	9	9
December	30	30	11	11	11	11	32	-	23	-	22	23	8	8	6	6
January	18	18	11	11	11	11	39	10	5	-	19	5	15	20	9	9
February	29	29	12	12	12	12	10	10	-	7	9	-	11	11	9	9
March	49	30	5	5	5	5	-	-	7	7	5	7	20	40	6	6
April	63	30	-	-	-	-	-	-	7	-	12	7	20	40	5	5
May	57	30	7	7	7	7	-	-	-	-	11	-	20	40	5	5
June	20	20	5	5	5	5	-	-	-	-	9	-	12	22	5	5
July	27	10	2	2	2	2	-	-	-	-	5	-	-	-	5	5
August	27	10	2	2	2	2	-	-	-	-	3	-	-	-	2	2
Inputs (US$)	170.30		98.22		18.47						18.47	18.47	51.82			
Yield (kg/ha)	700		**4250**		800		180	530	145	335	**3930**	**2913**	800		**2500**	**2500**
Year II	-		-		-		-	-	-	-	**3000**	**2850**	-			-
Year III	-		-		-		-	-	-	-	**2850**	**2375**	-		-	-
Selling Price ($/Kg)	1.10		0.09		0.09		1.04	0.79	1.04	0.79	**0.09**	**0.09**	0.49		0.15	0.15

Crop key: M, F = Male, Female; TBCO=Tobacco; FERTMZE=Fertilized maize; NFMZE=Unfertilized maize; SS= Sesbania fallow; TV= tephrosia fallow; SSMZE= Maize following a sesbania fallow; TVMZE=Maize following a tephrosia fallow; GNUT=groundnut; CSVA=Cassava; SWPOT=Sweet potato; Inputs=amount of cash required to purchase fertilizers, chemicals, seed etc

MODELING GENDER DIFFERENCES

To model gender differences, two representative households, a male-headed household (MHH) and a female-headed household (FHH) were simulated. The MHH is composed of one adult male, one adult female and two boys in the 6-10 age group. The FHH has one adult female and four adolescent children, three girls of school age (11-14) and one younger girl, under 10 years old. The MHH is assumed to have 2.12 ha of land (the median land size of the 32 MHHs in this sample); while the FHH has 2.55 ha of land (the median land size of the eight FHHs in this sample). [33] The households have the option to take credit in the form of farm inputs, and both households have the option to hire labor.

At the initial stage of diffusion of improved fallow technologies, ICRAF and other NGOs were buying seeds from sesbania and tephrosia to give to other farmers. Sales of tree seeds amount to a windfall profit for early adopters and a monetary incentive to adopt improved fallow technologies for late adopters. This was a temporary benefit, which has almost stopped. To evaluate whether this additional income from improved-fallow seeds enhances adoption, and to test under what conditions farmers adopt improved fallow technologies, we test two scenarios. In scenario 1, farmers do not sell sesbania or tephrosia seeds; in scenario 2, there is a market for the seeds. In both scenarios, we run simulations with all crops and both fallow species, and solve for the optimal resource allocation, and see if farmers adopt improved fallow technologies. The only difference between scenarios 1 and 2 is that scenario 2 allows the households to engage in selling sesbania and tephrosia seed both to their neighbors and ICRAF personnel.

RESULTS AND DISCUSSION

In dynamic modeling, we start the first season with an arbitrary amount of cash available in the model. therefore the first year is not representative. Starting from year 1, cash can be transferred to the following season. From experience the arbitrary amount can also affect the second year. By the third year, this effect disappears. therefore, the first two years are not reported in this study.

End-of-planning-horizon effects have to be taken into account. These are situations whereby the model chopsoff the analysis at some finite time in the future. Because there is no future in the model in the last years of the dynamic program, it can see no benefits from certain activities in those years (such as livestock production or multi-year agroforestry trials), and so it eliminates those activities from the "optimal solution" in the last years of the program.

Because improved fallows planted in the 9th and 10th year do not yield any benefits until after the 10th year, when the model has ended, the model chooses only those activities that are of benefit to the farm in the 9th and 10th year and thus drops agroforestry activities from the simulated results in those last two years. To reflect the above dynamic , only results from years three to eight are reported.

Scenario 1. Simulations without seed selling activity in the male-headed household (MHH)

Table 5 summarizes the results of the MHH without the seed selling activity. Without the option of selling improved fallow seeds, the results show the MHH plants over half a hectare of improved fallows in all years, with more sesbania planted than tephrosia. This is despite the fact that sesbania establishment requires nursery management like tobacco and hence requires more labor. This can be due to the fact that although tephrosia is directly seeded like maize and therefore needs less labor, the maize yield following the sesbania fallows is greater than after tephrosia. As a result, there is a slow but steady expansion of land under sesbania fallow.

The household plants similar amounts of tobacco and groundnuts and sufficient cassava or sweet potatoes to satisfy consumption requirements. No labor is employed and family members do all the work. The household uses less total land than available in all years and a tobacco loan is taken in each year, but it is unable to keep any cash for future use and there is no discretionary cash income. [34]

Table 5. Simulated crop production (ha) activities for MHH without seed selling

Activities	-----------------------------------Year----------------------------------					
	3	4	5	6	7	8
Production (ha)						
New Sesbania	0.23	0.36	0.20	0.40	0.38	0.36
New Tephrosia	0.10	0.10	0.10	0.10	0.10	0.10
Old Sesbania	0.15	0.23	0.36	0.20	0.34	0.38
Old Tephrosia	0.10	0.10	0.10	0.10	0.10	0.10
Fert. Maize	0.00	0.00	0.00	0.00	0.00	0.00
IF Maize	0.25	0.25	0.33	0.44	0.30	0.44
New IF	0.33	0.46	0.30	0.50	0.48	0.46
Year Old IF	0.25	0.33	0.46	0.30	0.44	0.48
Total IF	0.58	0.79	0.76	0.80	0.92	0.94
Tobacco	0.09	0.09	0.09	0.09	0.09	0.09
Groundnut	0.07	0.07	0.09	0.10	0.10	0.10
Cassava	0.02	0.02	0.03	0.04	0.04	0.04
Sweet potato	0.02	0.02	0.03	0.04	0.04	0.04
Total land	1.03	1.24	1.33	1.51	1.49	1.65
Selling (kg)						
Tobacco	61	61	63	65	66	65
Cash (US$)						
Loan	21	21	24	27	28	27
End Year Cash	0	0	0	0	0	0

In all years, all the maize for home consumption comes from land previously in improved fallows and, starting from the 6th year, there is an increase (in fact, a doubling) in the amount of land planted to maize from improved fallow land. This increase could be due to the increased food requirements and labor contribution from the children in the household as they age. In our judgment, however, the expansion of maize production is caused by the large decrease in the costs of growing maize with improved fallow technologies. As the input-costs row of Table 4 shows, it is cheaper to grow maize with the improved fallow technologies (US$ 18.5) rather than with purchased inorganic fertilizers (US$ 98). As a result, the model predicts farmers expand their improved fallow plots and maize plantings in those plots, and grow *no* maize planted with expensive inorganic fertilizers.

Scenario 1. Simulations without seed selling activity in the female-headed household (FHH)

Results show the FHH adopts improved fallows as the MHH; she plants at least half a hectare of sesbania fallow in five of the six years of the time period, along with 0.2 ha of tephrosia fallow. This result is in line with those reported by Gladwin et al. [35] from eastern Zambia that FHHs adopt improved fallow technologies; and is not surprising, given the larger farm size of the small sample of FHHs in this study. Indeed, it is only surprising because to date FHHs in eastern Zambia have planted only very small plots of improved fallows and are struggling to plant plots of one-fourth a hectare.

Table 6. Simulated crop production (ha) activities for FHH without a seed selling activity.

Activities	----------Year----------					
	3	4	5	6	7	8
Production (ha)						
New Sesbania	0.24	0.26	0.26	0.29	0.33	0.28
New Tephrosia	0.10	0.10	0.10	0.10	0.10	0.11
Old Sesbania	0.31	0.24	0.26	0.26	0.29	0.33
Old Tephrosia	0.10	0.10	0.10	0.10	0.10	0.10
Fert. Maize	0.00	0.00	0.00	0.00	0.00	0.00
IF Maize	0.39	0.41	0.34	0.36	0.36	0.39
New IF	0.34	0.34	0.36	0.39	0.43	0.39
Year Old IF	0.41	0.34	0.36	0.36	0.39	0.43
Total IF	0.75	0.68	0.72	0.75	0.82	0.82
Tobacco	0.06	0.19	0.07	0.08	0.08	0.09
Groundnut	0.09	0.09	0.09	0.09	0.09	0.09
Cassava	0.03	0.03	0.03	0.03	0.03	0.03
Sweet potato	0.03	0.03	0.03	0.03	0.03	0.03

Total land	1.35	1.45	1.33	1.34	1.41	1.42
Selling (kg)						
Tobacco	44.3	133.7	51.2	55.4	59.3	64.8
Cash (US$)						
Loan	20.4	42.5	21.2	22.5	23.5	26.5
End Year Cash	0	0	0	0	0	0

Like the MHH, the FHH plants simular amounts of tobacco and groundnuts. However, since tobacco requires more labor, the FHH hires male labor. The hired labor has to be fed daily, as well as paid at the end of the season. Therefore, hired labor results in the need to plant more maize. The need for cash for home use dictates that they grow tobacco, which requires a loan, and the hired labor increases the maize consumption requirements.

A comparison of Tables 5 and 6 show both households plant tobacco, probably since it is their only source of income. Without any other source of cash, the households need to grow tobacco and take tobacco loans with an interest rate of 55%. Although the MHH may employ labor, the model opts not to, because there is enough family labor.

Scenario 2. Simulations with a seed selling activity-MHH

Table 7. Simulated crop production (ha) and selling activities for MHH with a seed selling activity.

Activities	--------------------------------Year------------------------------------					
	3	4	5	6	7	8
Production (ha)						
New Sesbania	0.12	0.12	0.12	0.19	0.23	0.21
New Tephrosia	0.10	0.10	0.10	0.10	0.11	0.12
Old Sesbania	0.13	0.12	0.12	0.12	0.19	0.23
Old Tephrosia	0.16	0.10	0.10	0.10	0.10	0.11
Fert. Maize	0.00	0.23	0.10	0.36	0.21	0.13
IF Maize	0.39	0.23	0.22	0.22	0.22	0.29
New IF	0.22	0.22	0.22	0.29	0.34	0.32
Year Old IF	0.30	0.22	0.22	0.22	0.29	0.34
Total IF	0.52	0.44	0.44	0.51	0.63	0.66

Tobacco	0.19	0.22	0.20	0.30	0.33	0.31
Groundnut	0.11	0.12	0.09	0.15	0.10	0.10
Cassava	0.33	0.33	0.33	0.33	0.33	0.33
Sweet potato	0.25	0.25	0.25	0.25	0.25	0.25
Total land	1.80	1.83	1.62	2.12	2.07	2.09
Selling (kg)						
Tobacco	136	156	137	210	230	219
Maize	566	923	0	672	0	0
Groundnut	51	52	0	52	0	0
Cassava	765	765	750	735	735	735
Sweet potato	565	565	550	535	535	535
Sesbania seed	253	159	151	162	207	264
Tephrosia seed	114	92	92	92	94	97
Cash (US$)						
Loan	0	0	0	0	0	0
Cash Transfer	68	50	94	83	75	92
End Year Cash	510	412	244	303	256	219

When an improved fallow seed-selling activity is introduced as an incentive to adopt the improved fallow technology, the MHH grows more tobacco than in scenario 1, but does not take a loan. Ccash from selling sesbania and tephrosia seeds results in the households having enough cash without the need to take loans for their tobacco.

When compared to scenario 1, there is an increase in the total land used, but a decrease in the total land planted to improved fallows. Because the household does not take any loans, it produces more tobacco using the cash from the seed selling activity, grows some fertilized maize, and sells surplus maize. The MHH has discretionary cash at the end of the season, and the household is able to transfer some cash for subsequent years. The MHH does not need to pay for hired labor costs, and therefore produces maize, groundnuts, cassava, and sweet potato for sale to cover cash needs.

Scenario 2: Simulations with a seed-selling activity in a FHH

With the additional option of selling improved-fallow seeds (to ICRAF or to neighbors), the FHH plants even more land to improved fallows (e.g., 0.7 ha of sesbania in year 3). The FHH also plants more improved fallows than the MHH, as was the case in scenario 1 (Tables 4 and 6). However, she gradually reduces the land planted in sesbania fallows from 0.7 ha in year 3 to 0.5 ha in years 4 and 5 to 0.3 ha in years 7 and 8.

This household also plants more maize following improved fallows in year 3, but gradually reduces land in maize following an improved fallow in latter years. As improved fallow land decreases, the household also plants less and less "improved-fallow maize" and even fertilizes maize (0.1 ha) in years 5, 7 and 8. The household has surplus maize for sale in years 3, 4 and 6. It also increases land for tobacco production, probably due to the windfall profits from the seed selling activity, but also maintains groundnut production as in scenario 1. Due to the sales of sesbania and tephrosia seeds as well as sales of tobacco, the FHH has more end year cash than the MHH. This is probably due, however, to the larger land size of FHHs in this sample.

Table 8. Simulated crop production (ha) and selling activities for FHH with a seed selling activity.

Activities	---------------------------------Year-------------------------------------					
	3	4	5	6	7	8
Production (ha)						
New Sesbania	0.10	0.39	0.10	0.10	0.17	0.14
New Tephrosia	0.10	0.10	0.21	0.10	0.10	0.10
Old Sesbania	0.55	0.10	0.39	0.10	0.10	0.17
Old Tephrosia	0.10	0.10	0.10	0.21	0.10	0.10
Fert. Maize	0.00	0.00	0.13	0.00	0.15	0.18
IF Maize	0.62	0.65	0.20	0.45	0.20	0.20
New IF	0.20	0.49	0.31	0.20	0.27	0.25
Year Old IF	0.65	0.20	0.49	0.31	0.20	0.27
Total IF	0.85	0.69	0.80	0.51	0.47	0.52
	0.93	0.56	0.24	0.17	0.23	0.25
Tobacco	0.09	0.09	0.09	0.14	0.11	0.09
Groundnut	0.03	0.31	0.29	0.33	0.33	0.33
Cassava	0.03	0.25	0.25	0.25	0.25	0.25
Sweet potato	0.93	0.56	0.24	0.17	0.23	0.25
Total land	2.55	2.55	2.00	1.85	1.74	1.81
Selling (kg)						
Tobacco	650	394	167	116	164	173
Maize	566	923	0	672	0	0
Groundnut	0	0	0	62	25	0
Cassava	0	701	648	750	750	750

Sweet potato	0	550	550	550	550	550
Sesbania seed	597	425	278	263	138	168
Tephrosia seed	92	92	108	129	93	93
Cash (US$)						
Loan	0	0	0	0	0	0
Cash Transfer	110	60	40	61	66	77
End Year Cash	1304	751	370	289	198	171

With a seed selling incentive, the FHH generates enough cash from selling sesbania and tephrosia seeds, and therefore no longer takes a tobacco loan. As a result, Table 8 shows that land allocated to tobacco is increased substantially in the third and fourth year. Unlike the MHH, the FHH grows less fertilized maize, but also grows other crops like groundnut, cassava and sweet potatoes following the MHH trend. The FHH maintains a production of 0.1 ha of groundnut. The household transfers cash to be used in the next season.

Conclusions

This study predicts that where sufficient land is available as in Kasungu, Malawi, adoption of improved fallow technologies will occur. Farmers with access to land and a productive labor force are going to adopt improved fallows, with or without the extra incentive of also being able to sell the tree seeds back to those promoting the technology (e.g., ICRAF or other NGOs). With the seed-selling activity available, however, adopters of improved fallows expand the size of their improved fallow plots, as well as the amount of maize they produce. They may then produce a surplus of maize and increase the size of land planted to the cash crop, tobacco. Success may come at a price, however, as they can then afford to buy some fertilizer, and will in that case plant some fertilized maize and eventually decrease the amount of land planted to improved fallows.

With hired labor labor FHHs are able to plant more land to improved fallows, in year three, than MHHs. This same result, however, may not hold in other regions of Africa where FHHs have less land than MHHs, and less access to labor. Land holdings in Kasungu are relatively larger than in southern and some of the other districts in central Malawi and therefore, these findings might not be generalizable to areas where land holdings are small. Another point to consider is the source of cash in a farming system. In Kasungu, tobacco is the only cash crop and assuming there were other cash crops requiring less labor, these results would likely be different. With this is in mind we concur with Sullivan (in this volume) [36] and Gladwin et al. [37] who suggest that researchers should disaggregate households by household composition as well as by gender, and target new technologies at subgroups of rural women. This is because small scale farmers are not all alike, and will not respond equally to a technological intervention. This also applies to agroforestry innovations. The results of this study therefore specifically deal with Kasungu and not the whole of Malawi. Apart from land constraints, in order to evaluate the adoptability of agroforestry technologies, it is necessary to determine the availability of labor in the household, which is an important factor in the degree of adoptability of improved fallows.

It can also be concluded that farmers plant tobacco as a way of getting inorganic fertilizers for their maize. They raise enough tobacco to be able to repay the loan and to pay for hired labor. A high price from sales of tree seeds might encourage farmers to plant less tobacco and more improved fallows. Those households with enough labor and land are likely adopters. As observed in this study, when seed selling was introduced, the FHH stopped taking a tobacco loan.

Our analysis shows that in Kasungu, FHHs without adolescent male children employ male labor for the tobacco growing activities, most of which are done by males. In FHHs where there are male adolescents, the male children take the role of a male head in these households, and provide labor for work demanded by crops like tobacco. This allows FHHs to spend their time planting improved fallows rather than tobacco during the rainy season, in addition to other women's tasks such as fetching water, firewood collection, cooking and childrearing. It appears that in Malawi, adoption of improved fallows can happen in both MHHs and FHHs, as long as land and labor available.

Notes

1. Nye and Greenland, 1960
2. Nair,1993
3. Nair,1993
4. Young, 1997
5. Gladwin 1991; Zeller et al., 1998
6. Quisumbing et al., 1995
7. Kwesiga and Beniest, 1999; Jama et al., 1998.
8. Kwesiga, et.al., 1999; Sanchez, 1999
9. Franzel, 1999; Sanchez 1999
10. ICRAF, 1997
11. Kwesiga, et. al., 1999; Franzel, 1999; Franzel, et al., 2001; Gladwin et al., 2001; Gladwin, et al., 2002
12. Hildebrand, 2000a
13. Hildebrand, 2000b
14. Hildebrand, 2000c
15. Franzel, 1999
16. Due et al., 1983; Due and Gladwin, 1991; Quisumbing, 1996
17. Quisumbing, 1995
18. Quisumbing, 1996
19. Adesina and Djato, 1997
20. Frankenberger and Coyle, 1992
21. Gladwin, et al., 2002
22. ICRAF, 2002

23. NSSA, 1994; The NSSA has defined a garden as a small or large piece of land that might be continuous and one garden may have several different crops.
24. Young and Brown, 1962
25. NSO, 1998
26. Minae and Msuku, 1988
27. Minae and Msuku, 1988
28. Hildebrand and Russell, 1996
29. Cabrero,1999; Bastides,2000; Kaya et. al., 2000; Litow, 2000; Hildebrand, 2002c; Sullivan 2000; Mudhara, 2002; Thangata, 2002
30. MS Excel® 2000
31. MS Visual Basic® 2000
32. Frontline Systems, 2000
33. FHHs are slightly underrepresented in this sample of 40 farmers, as they usually comprise 25-35% of households in Malawi. Their surprisingly large land size, larger than that of MHHs, is probably due to the presence in this small sample of two FHHs who own 5 and 6 ha of land. Half of the FHHs in this sample owned and operated only 1.5 ha of land, which is more in line with other reports of mean land size in Kasungu (Gladwin 1987). Due to the small number of FHHs in this sample, however, their data could not be omitted. Hence, FHHs in this sample own and operate more land than the MHHs, in contradiction with the WID literature on FHHs. It is understandable, however, given that ICRAF extension personnel were purposefully looking for larger farmers to test the improved fallow technologies in Kasungu, and this sample came from their list of tester-adopters.
34. Grinold,1983; Schrage,1997
35. Gladwin, et al., 2002
36. Sullivan- this volume;
37. Gladwin et al., 2001

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