

## **Agroforestry Innovations in Africa: Can They Improve Soil Fertility on Women Farmers' Fields?**

CHRISTINA H. GLADWIN, JENNIFER S. PETERSON, AND ROBERT  
UTTARO

**Abstract:** Most observers agree that the verdict is still out for agroforestry innovations known as improved fallows, which may take a decade for farmers to test properly. First farmers plant several small plots of different tree species, cut them after two years and plant a cash or food crop, and then wait to see the results of that harvest. Because the improved fallow cycle takes four or five years, farmers' adoption or adaptation of this technology takes a lot longer than adoption of an improved seed or a new fertilizer. Until the experiment fails, African farmers – like most researchers – are willing to experiment, probably due to the lack of other options available as soil fertility amendments in Africa today. This is especially true for women farmers, even more so for female headed households whose lack of adult family labor presents them with severe cash and credit constraints. This paper describes their adoption decision processes when presented with new agroforestry technologies such as improved fallows in western Kenya, southern Malawi, and eastern Zambia.

### **Introduction**

Agricultural experts claim that the food security situation in Africa now is analogous to the situation of Asia 40 years ago and Latin America 30 years ago, before the Green Revolution transformed both continents and enabled them to structurally transform their economies from being overly dependent and dominated by a stagnant agricultural sector to becoming more diversified with fledgling but growing manufacturing, services, and agricultural sectors.<sup>1</sup> Until Asian and Latin American policy makers adopted development strategies that encouraged small farmers to increase their agricultural productivity on small landholdings by adopting yield-increasing inputs of production, this structural transformation was not possible.<sup>2</sup>

The bio-physical root cause of low per capita food production is soil fertility depletion; the nutrient capital of African countries is now being mined, just like mineral deposits of metals or fossil fuels.<sup>3</sup> Smaling et al. estimate that soils in sub-Saharan Africa are being depleted at annual rates of 22 kilograms per hectare (kg/ha) for nitrogen (N), 2.5 kg/ha for phosphorus (P), and 15 kg/ha of potassium (K).<sup>4</sup> Soil fertility depletion is all the more alarming, given that

**Christina H. Gladwin** is professor, Food and Resource Economics, Box 110240 IFAS, University of Florida, Gainesville, FL 32611. **Jennifer Sheffee Peterson** holds a Masters in Agronomy and Agricultural Education from the University of Florida and is presently a consultant for Africare in Niamey, Niger. **Robert Uttaro** is a Ph. D. candidate in Political Science at the University of Florida and is finishing his dissertation on the politics of fertilizer in Malawi. They are very grateful for the help and hospitality of farmers interviewed in southern Malawi and eastern Zambia as well as advisors in ICRAF and World Vision. They alone are responsible for errors and omissions in this text.

<http://www.africa.ufl.edu/asq/v6/v6i1-2a10.pdf>

recurring devaluations and removal of fertilizer subsidies, mandated by structural adjustment reforms, have made inorganic fertilizers unaffordable for most African smallholders.<sup>5</sup> In contrast to the situation when Asian and Latin American farmers were encouraged to intensify their crop production by adopting nitrogen-responsive crop varieties and increasing plant populations, African entrepreneurs face constraints that make it difficult for them to freely compete in an open fertilizer market. Among these factors are the small volume of fertilizer most African countries import, high transportation costs within most African countries, and high storage costs.<sup>6</sup> As a result, fertilizers are six to eight times more expensive at the farm gate in Africa than in Asia or Latin America.

Sanchez and colleagues of the International Center for Research on Agroforestry (ICRAF) recommend a two-pronged strategy to stop this mining, the first to replenish phosphorus nutrients and the second to replenish nitrogen. The first strategy involves the high phosphorous fixing soils of Africa, an estimated 530 million hectares where phosphorus-fixation is now considered an asset, and not a liability as previously thought. Here, inorganic phosphorus fertilizers are necessary to overcome phosphorus depletion on these soils.<sup>7</sup> Large applications of phosphorus fertilizer can become “phosphorus capital” as sorbed or fixed phosphorus, almost like a savings account, because most phosphorus sorbed is slowly *desorbed* back into the soil solution during 5-10 years. The larger the initial application rate, the longer the residual effect. If phosphorus is applied as a one time application of phosphate rock, it can be helped to desorb by the decomposition of organic inputs that produce organic acids to help acidify the phosphate rock, e.g., the organic acids in tithonia (*Tithonia diversifolia*), a common shrub in western Kenya.

While phosphorus replenishment still requires an externally sourced chemical input that may be beyond the reach of the small farmer, this is not necessarily the case for nitrogen.

To reverse nutrient depletion of nitrogen in African soils, a second strategy exists, namely an increased use of organic sources of nitrogen nutrients. The organic sources of nitrogen include: animal manures and compost, biomass transfers of organic matter into the field, and also more efficient use of trees and shrubs whose deep roots capture nutrients from subsoil depths beyond the reach of crop roots and transfer them to the topsoil via decomposition of tree litter. By strategic planting of trees, nitrogen lost over the last 20 years can be replenished with nitrogen from agroforestry innovations such as hedgerow intercropping with leucaena (*Leucaena leucocephala* (Lam.) De Wit), biomass transfer with tithonia, manures improved with calliandra (*Calliandra calothyrsus* Meissner), and improved fallow systems using nitrogen-fixing shrubs like sesbania (*Sesbania sesban*), tephrosia (*Tephrosia vogelii*), pigeon pea (*Cajanus cajan*), and gliricidia (*Gliricidia sepium*).

Questions persist about this innovative approach to Africa’s soil degradation crisis, however, and center on the issue of whether the nitrogen demands of food crops can be met in full with only organic sources of nutrients. ICRAF scientists claim that biophysically, organic sources can produce mid-range level yields of 4 tons/ha, but not the 6 tons/ha that could result from combinations of organic and inorganic fertilizers. Such combinations are needed because recovery of nitrogen by the crop from leaves of leguminous plants is lower (10-30%) than recovery from nitrogen inorganic fertilizers (20-40%). To reach these higher crop yields, more

research is needed on the synergistic effects of combining the different kinds of organic and inorganic fertilizers.<sup>8</sup>

## AGROFORESTRY INNOVATIONS: A SOLUTION FOR AFRICAN WOMEN FARMERS?

Whether or not this innovative approach to replenishing Africa's soil fertility is a success is likely to depend on its adoption by African rural women, who by custom produce the food crops in many African societies, while men produce the export crops.<sup>9</sup> As food producers, women farmers are the key to *reversing the crisis* and increasing domestic food production in Africa. Yet their lack of power inside their own households is a unique problem facing them in their roles as African food producers; food producers in Asia and Latin America, although small farmers, were not similarly constrained during the time of their Green Revolution. This is what we call the *invisibility factor* in the African food security literature, most of which is de-linked from the women in development (WID) literature. Food security analysts correctly argue that development strategies need to reach African smallholders to be effective, but they ignore the fact that the constraints facing women smallholders may be an important part of the problem. Eicher, for example, consistently does not mention that 45% of the smallholders responsible for Zimbabwe's second Green Revolution (1980-1986) are women; nor does he indicate the percentage of hybrid maize adopted by women nor the percentage of fertilizer subsidies benefiting women.<sup>10</sup> Similarly, Smale's report on Malawi's *delayed* Green Revolution does not indicate women's adoption of hybrid maize;<sup>11</sup> yet women's maize varieties, as shown here by Uttaro, are mostly local maize varieties, while hybrid varieties are mostly cash crops sold by men.

Because women farmers are such important players in African agriculture, the success of any strategy to replenish African soils needs to answer questions such as: will women farmers adopt agroforestry innovations to provide their soils with needed nitrogen, or will they face constraints to adoption more severe than those facing men farmers? Will women have more limiting factors to adoption? Do women have different motivations and reasons to adopt than men? Finally, do women in female headed households (FHHs) differ from women in male headed households (MHHs), and are the former more constrained than the latter?

Previous ethnographic and policy research suggest women have more limiting factors to adoption than men. Rocheleau finds an interaction between gendered property relations and gendered resource uses, user groups, landscapes, and ecosystems in Western Kenya, a region where agroforestry had been practiced since the 1600s.<sup>12</sup> As population increased and fallow lands became smaller and trees more scarce, people began planting trees, since they were no longer able to gather as many products from the forest and communal lands. Women did not own land but played an important role, as decisions about where sons would cultivate was the mother's; while wives and daughters also had usufruct rights to the land and its products. With the advent of land reformation laws in 1956, men aged 18 and over were automatically entitled to land titleship by the colonial government.<sup>13</sup> This policy lowered women's status in the lineage system since sons no longer had to go through their mothers to acquire land. Women's rights to land, trees, animals and water became subject to male permission. Today, however, with the implementation of more and more agroforestry projects in the area and continued

decreases in fallow lands, women have begun to plant trees despite the traditional taboo that holds that bad luck will ensue should they do so.

Scherr finds that gender differences in agroforestry practices are still quite significant.<sup>14</sup> In one study, men had 50% more trees on their farms and almost 30% higher tree density. Men tended to plant trees in cropland while women's farms had more trees used primarily for fuelwood. These differences reflect men and women's differential ability to independently decide how trees will be used and allocated. Women are not permitted to make decisions without consulting their husbands, and are also less likely to question men or their policies at the institutional and state levels. This power differential between men and women lays the foundation for gender bias from household level decisions to policy level decisions.

## AGROFORESTRY ADOPTION DECISION TREE MODELS

In order to definitively answer questions about whether or not factors like power differentials influence agroforestry adoption decisions, in this paper we propose a testable model of the adoption decision process, and test it on a gender-disaggregated sample of both adopters and non-adopters. Here, as in the paper by Uttaro, we use "ethnographic decision trees" or *hierarchical* decision models<sup>15</sup> whose usefulness comes from their relatively high prediction rate: at least 80% of the historical choices made by farmers interviewed in an area are predicted by a decision tree model. Previously, decision tree models have been used to predict farmers' choices between chemical fertilizer and manure in Guatemala and Malawi, to increase fertilizer use in Mexico, to use credit for fertilizer in Mexico, Malawi, and Cameroon, to adopt other agroforestry technologies such as hedgerow intercropping in Kenya and Malawi, and to use grain legumes as soil-fertility-amendments in Malawi and E. Zambia.<sup>16</sup>

Decision trees predict because they are *cognitive-science* models, which aim to process information in the same way humans do,<sup>17</sup> as opposed to *artificial-intelligence methods* which are not so concerned with modeling the exact process that humans use but seek some alternative processing technique that approximates the human solution, e.g., linear programming models or multiple regression models of choice (probit, logit, and tobit analysis). Because cognitive science models aim to represent psychological reality and to mimic the mental processes people use, they should be better descriptions of human information processing and better predictors of human choice than are artificial-intelligence models.

When a decision tree is correctly specified, it allows the research team to identify the main factors limiting adoption at a specified time, and if possible, to recommend policy intervention to alleviate these constraints and speed up adoption.<sup>18</sup> These limiting factors may change or disappear over time, however; and the model is assumed valid only for the time period during which it is tested and should be retested at later times. Given low adoption rates, the research team may gradually conclude that the chances of much future adoption of the technology are not good, if there are a number of structural factors persistently blocking adoption (e.g., lack of land) that are *not* amenable to policy intervention (as opposed to limiting factors that are easily changed, e.g., lack of knowledge or seeds or credit). In this case, the usefulness of the adoption decision tree model is in sending the designers of the technology, the biophysical scientists, back to the drawing board to redesign.

Such was the case of the first application of decision tree modeling to agroforestry innovations, e.g., hedgerow intercropping (HI), implemented in on-farm trials in Western Kenya since the late 1980s. Much adoption work has been done by ICRAF social scientists using ethnographic decision tree modeling on the adoption and expansion of hedgerow intercropping (HI) or alley cropping.<sup>19</sup> Their work showed that women farmers' constraints of lack of knowledge, labor, and land did not allow many of them to plant hedges of leucaena or calliandra in between rows of maize, the subsistence crop. Their conclusions were matched by those of Deirdre Williams of the University of Florida Soils Management CRSP (collaborative research support program supported by USAID) project, "Gender and Soil Fertility in Africa."<sup>20</sup>

Williams also interviewed 40 women farmers in Maseno, western Kenya, and found less than 20 percent adoption (Gladwin et al. 1997: 225-227), due to a number of structural factors blocking adoption (e.g., lack of land (5 cases) and labor (4 cases)) as well as limiting factors more amenable to policy change (e.g., lack of knowledge (15 cases) and seeds (2 cases) and termite problems (2 cases)).<sup>21</sup> She concluded the future chances of women's adoption of HI in western Kenya were not good.

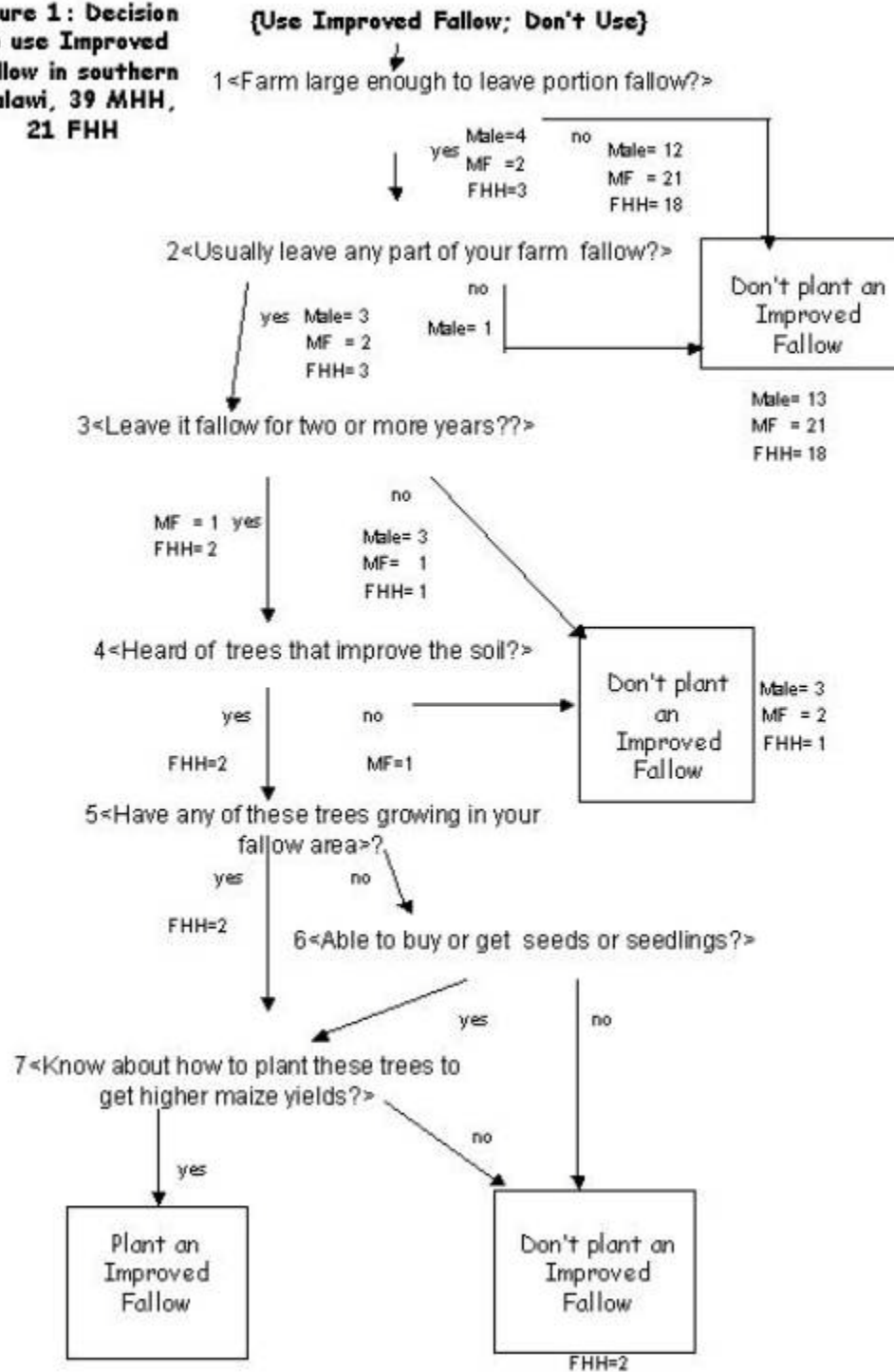
Williams also modeled women farmers' decisions to adopt or not adopt biomass transfer innovations with a subsample of 23 women farmers in western Kenya.<sup>22</sup> Biomass transfer involves the use of leaves and stems from shrubs (*Tithonia diversifolia* and *Lantana camara*) for mulch. These shrubs are homestead border markers found everywhere in rural western Kenya, are under the control of women, but are traditionally used for goat fodder and medicine for stomach ailments and not for mulch. Williams model of women farmers' decisions *not* to use tithonia leaves and cuttings as mulch on their food crops shows why. In this decision tree, for brevity not presented here, more than half the women in the test sample did not pass the first two constraints, "Have access to tithonia or lantana shrubs growing nearby?" and "Know about this technology?" Other constraints included women's lack of labor: many female heads of households and women with small children felt they did not have the time themselves or access to the labor required to cut and carry enough biomass from these shrubs to adequately mulch their crops. The amount of biomass required to produce significant soil fertility benefits is *very* large; by some estimates, 7 tons per hectare of leafy dry matter (and triple that for fresh biomass) is being used in ICRAF's biomass transfer experiments.<sup>23</sup> Other women had problems with termites coupled with no farming practice (like putting on ash) to help with this problem; still others felt they needed the tree or shrub more for fodder or medicine than for soil improvement. The cumulative result of all these constraints was that the decision model predicted only four of the 23 women in the test sample should use tithonia for soil improvement.

The trees are relatively simple to design and test, as Uttaro's model of the decision to adopt improved fallows (IF) in figure 1 shows, read from top to bottom.<sup>24</sup> They have alternatives in set notation ({ }) at the top of the tree, decision outcomes in boxes ([ ]) at the end of the paths of the tree, and decision criteria in diamonds (< >) at the nodes of the tree. There are only two alternatives or decision outcomes in this set, [Plant an improved fallow now] and [Don't Plant now] and they are mutually exclusive. The only trick to the trees is *eliciting* the decision criteria from the decision makers themselves, who are the experts in making their decisions. They alone know how they make their choices, and so their decision criteria should be elicited from



them in ethnographic interviews and by participant observation and other participatory methods (e.g., role playing).

**Figure 1: Decision to use Improved Fallow in southern Malawi, 39 MHH, 21 FHH**



Given a particular sample of data from decision makers who have decided to both adopt and not adopt improved fallows, e.g., Uttaro's sample of 60 farmers interviewed in Zomba, southern Malawi, in 1998, one can *test* the tree easily by putting the data from each individual choice (as a separate, independent case, like a Bernoulli trial) down the tree and counting the errors in prediction on each path. Results of testing this model shows that lack of land was the most serious constraint to IF adoption in the Zomba region: most of the households in his sample engaged in continuous cropping. Nine informants (15%) had farms large enough to leave part of it fallow; and eight (13%) *usually* left part of the farm fallow (criteria 1 and 2). Only three of the eight farmers left their land fallow for two or more years (criterion 3). Of the three informants left, only two FHHs had any trees or shrubs that improve soil fertility in fallow areas (criterion 5); and they both lacked the knowledge of how to plant an improved fallow so that they would get higher yields after returning the land to maize production (criterion 7). In short, no farmer of the 60 used improved fallows. The gender-disaggregated data, moreover, show women face no additional constraints limiting their adoption of improved fallows.

The future prospects for improved fallow systems in two heavily-population regions of Africa (southern Malawi, western Kenya) would thus appear to be poor. Even if information was disseminated about the use and management of trees and bushes in fallow systems, farmers would still need to have land available to place into fallow. And with population growth rates among the highest in Africa, that is something unlikely to occur in both southern Malawi and western Kenya.

#### EASTERN ZAMBIA: THE EXCEPTION THAT PROVES THE RULE?

Our initial ethnographic results in African locations prior to 1998 were discouraging, as they showed women farmers tend *not* to adopt agroforestry innovations such as biomass transfers, hedgerow intercropping, and improved fallows. Why? Their main limiting factors were lack of knowledge of the new technology, lack of access to seeds or seedlings, and cash or credit to acquire them. Yet structural factors -- lack of land and labor -- were also limiting women's adoption, and in our judgment, they posed more serious problems to adoption prospects than the factors more amenable to policy intervention such as lack of knowledge or seedlings. Moreover, they were much more severe for women than men, and even more severe for female-headed households. We were therefore discouraged about the chances of agroforestry innovations replacing inorganic fertilizers as women's soil fertility amendments in the near future.

But could we extend these results to all of sub-Saharan Africa? In a word, no. Conditions in Africa are so diverse, so location-specific, so dependent on historical contingencies and socio-economic specificities (note the postmodern influence here) that results that hold in Western Kenya and Malawi cannot easily be generalized to other locations in Africa. Recent research results from ICRAF's on-farm trials of improved fallow systems with *Sesbania sesban* in Eastern Zambia seem to agree.<sup>25</sup> In 1988, ICRAF began to test improved fallow technologies at Msekera Research Station, Eastern Zambia, and in 1992/93 some on-farm trials of the improved fallows began in four villages chosen by ICRAF scientists to be representative of the diverse agro-climatic, socioeconomic conditions in the eastern Zambia region.

Small plots of improved fallows, ranging in size from 10 meters by 10 meters to 30 meters by 20 meters, are planted for two years with nitrogen-fixing tree species (*Sesbania sesban* or *Gliricidia* seedlings or direct-seeded *Tephrosia vogelii* or *Cajanus cajan* (pigeon pea)), and followed by two or three years of maize. By far the most promising, although it may look like a “dinky little tree,” is *sesbania*, grown in a *dimba* nursery three to six weeks before the rainy season. Results over the five year cycle showed improved fallows increased total maize production 87% over unfertilized maize (even without any yield in years one and two); although estimates varied about the advantage of IFs over fully-fertilized maize (with 112 kg N/ha). Kwesiga and Beneist found maize yields following two-year improved fallows approach those of fully fertilized fields,<sup>26</sup> but Franzel et al. found fully-fertilized maize yielded 2.5 times more than IFs over five years.<sup>27</sup> The differing estimates did not matter for farmers, however, because with the rising prices of fertilizer in the Eastern Province, fully fertilized maize was no longer an option. In many cases even partially fertilized maize was not an option because farmers had neither the cash nor the access to credit to purchase fertilizer. By 1997, therefore, the multi-year trials of improved fallow technologies (IF) were a major success story: over 3000 farmers had participated, 49 percent of whom were women farmers. In 1998/99, USAID sponsored an extension project managed by World Vision (WV), an NGO operating in Africa to improve food security. The aim of the five-year WV project was to extend improved fallow technologies to the entire region of eastern Zambia with the aim of reaching 50,000 farmers, not just the farmers in the four villages in which ICRAF was concentrating its on-farm trials. By fall 2001, the WV project had registered 10,000 farmers in the region as participants in on-farm tests of IF technologies.

These numbers suggest that the IF technologies are a major success story at a time when Africa can boast of few success stories. Yet the question still unanswered is: *why* are improved fallows being adopted so readily in Eastern Zambia, especially by women, and not in southern Malawi right across the border? Is their success due to the fact that E. Zambia is a region of lower population density than the other regions so that women farmers have enough land to put some of it in fallow, or is it just a delayed reaction to structural adjustment policies that have raised the price of inorganic fertilizers to levels so high that women farmers have finally “adjusted” by deciding to “grow their own fertilizer” and adopt a substitute soil-fertility amendment? To answer this question, Jen Scheffee Peterson of the UF project, “Gender and Soil Fertility in Africa,” in collaboration with ICRAF and later World Vision, interviewed women farmers who both were and were not testing and expanding their on-farm trials of improved fallows.

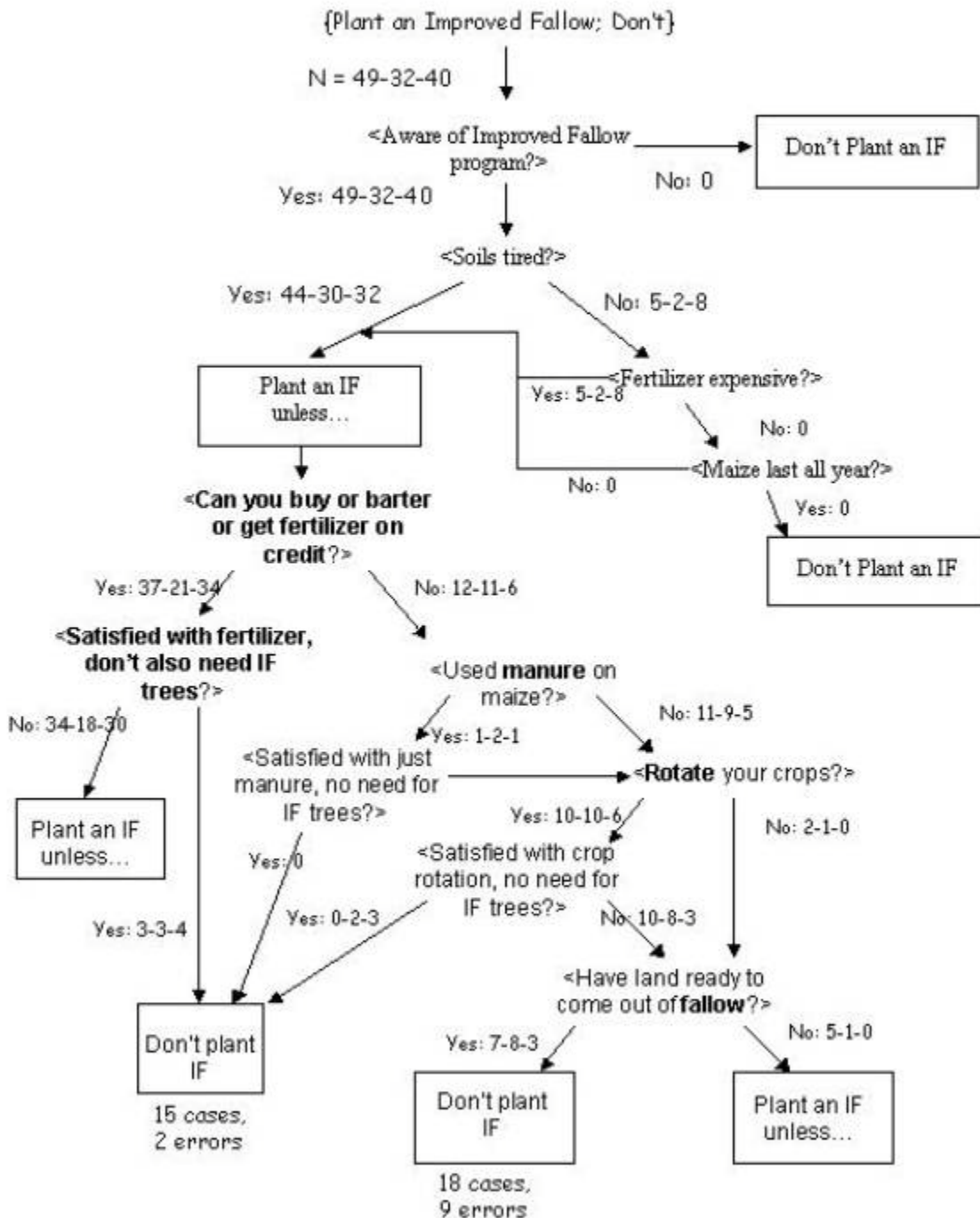
To elicit decision criteria from them, men and women adopters and non-adopters were interviewed in 1998 using open-ended eliciting techniques described by cognitive anthropologists, first by Peterson with three women in each of the four villages targeted by ICRAF with on-farm trials of improved fallows since 1992/93. Profiles of each farmer and stories about each farmer’s adoption process were then formulated, and an initial “composite model” was built to represent the decision process of the group of 12 farmers interviewed. Gladwin and Peterson then jointly refined Peterson’s initial composite model during another 18 interviews in June, 1998, and designed a questionnaire so that Peterson could test the revised decision model (figures 2 and 3) during personal interviews with another test sample of 81



women farmers and 40 men farmers who also resided in the camps surrounding ICRAF's four target villages.<sup>28</sup> Women in both FHHs and MHHs were interviewed, as well as men so that there were three sub-samples. The samples were chosen, after discussions with Steven Franzel and Donald Phiri of ICRAF, such that half the sample of each gender would be *testers*, who planted at least one improved fallow plot, and half *non-testers*, who did not plant even one improved fallow plot. Half of the sample of testers would be *testers-expanders*, who planted at least two improved fallow plots, and half *testers-non-expanders*, who planted only one improved fallow plot.<sup>29</sup>

Different versions of the adoption decision model were tested first by Peterson using an Excel spreadsheet, and then by Gladwin using simple SPSS syntax programs, by including different criteria elicited from different decision makers. Different orderings of the decision criteria were also tested, although the order of the criteria does not usually affect the prediction rate of a simple {Plant an IF; don't} model.<sup>30</sup> The different orders and criteria generated different decision trees, some of which are presented elsewhere.<sup>31</sup> For brevity, only the model with the best fit to these data is included here. The model in figures 2-3 is a close approximation to the first model elicited by Peterson and Gladwin, so that it has "descriptive adequacy," meaning it matches informants' statements about how they decided to plant an improved fallow. It differs from the model first elicited in minor ways, however, by the inclusion of other criteria, which upon testing were shown to "cut" the sample of decision makers into adopters and non-adopters.

**Figure 2. Model 1 Tested with ICRAF 4-Village Data, 1998, 121 cases (49 FHHs-32 MF-40 MHH)**



### Motivations to Plant Trees

The motivations to plant an improved fallow plot came from the very first interviews by Peterson, as nearly all women say they plant an improved fallow because their soils are tired

(*nthaka yosira/yoguga*), fertilizer is too expensive (*wodula ngako*), and their maize harvest does not last all year until the next harvest. The model in figure 2 says that any one of these reasons is enough for a farmer to consider planting an improved fallow; and thus sends them (i.e., their data) to the outcome, "Plant an improved fallow unless." Note that in the E. Zambian sample, every farmer has at least one of these reasons to plant an improved fallow, and thus the whole sample passes on to the first set of "unless conditions" – conditions or constraints which will block a farmer from planting an improved fallow, even though she or he has a good reason to.

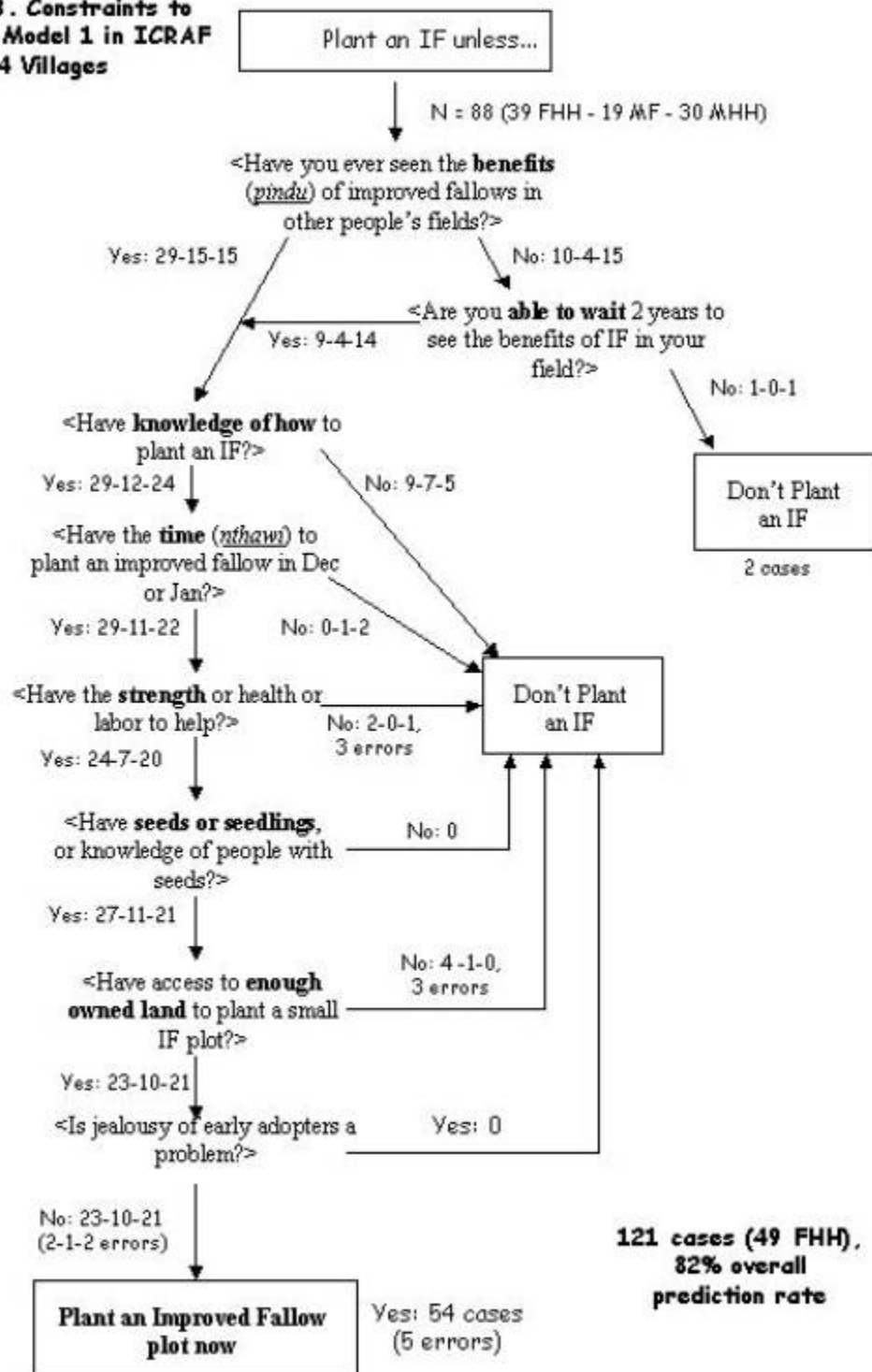
### Constraints to Planting an Improved Fallow

Figure 2 also lists the first set of constraints. It is a subroutine asking farmers if they are already satisfied with their soil fertility amendments so that they do not also need to plant an improved fallow. Farmers are sent to the outcome, "Don't plant an improved fallow," if they can buy fertilizer, or barter for it, or get it on credit, and they're satisfied with the amount acquired; *or* they have used manure on field maize in the recent past, and they're satisfied with manure; *or* they rotate crops in the field, e.g., groundnuts with maize with cotton, and they're satisfied with their crop rotations; *or* they have land ready to come out of a natural fallow now.

Results of testing this subroutine of the model show that most farmers can either buy or barter or get fertilizer on credit; but whereas women (especially female headed households) are mostly bartering for fertilizer, men are mostly buying fertilizer. Almost no one gets credit for fertilizer in E. Zambia. Almost no one is satisfied with the amount of fertilizer that is acquired, as usually it is a big decrease from past use. In addition, almost no one uses manure on maize; it is saved for garden vegetables grown in the *dimba* in the dry season, not usually used on field maize. Finally, almost everyone rotates their crops as a soil fertility measure, but that does not satisfy their need for more soil fertility. Results further show there are a lot of errors with the fallow criterion, "Have land ready to come out of fallow now?"; but when we omit it (by running another version of the model without it) there are more errors in the model (29 vs. 21). We thus conclude that with these data, the fallow criterion clearly helps the prediction rate, so that it belongs in the model.<sup>32</sup>

If the farmer is satisfied, he or she – really his or her data -- is sent to the outcome [Don't plant an IF now]. If the farmer is not satisfied, and also feels a need for the soil fertility amendment of IF trees, he or she is sent to the outcome, [Plant an IF plot unless...], meaning the farmer must pass another set of constraints in order to go to the outcome [Plant an IF]. The latter constraints in figure 3 start with a benefits criterion, ("Have you ever seen the benefits of IFs in other people's fields?"). If yes, farmers are asked if they can wait two years to see the benefits. Because of the intense work of ICRAF in these four villages, most farmers have either seen the benefits of IF plots on their or their neighbors' land, so most can wait the two years until the maize harvest after the improved fallow.

**Figure 3. Constraints to IFs with Model 1 in ICRAF 4 Villages**



The model thus tells us that farmers will plant an improved fallow: if they have a reason to plant one (their soils are tired, fertilizer is too expensive, or their maize harvest does not last all year) and they have seen the benefits of an improved fallow for themselves or can wait two

years to see the benefits on their own plots, and they know how to plant one (planting the nursery, transplanting the seedlings, or direct-seeding tephrosia), and have the time the strength and health to do it, as well as access to seeds or seedlings and a small plot of land to experiment on.

Results show most (86) farmers in this sample proceed to the other constraints: lack of technical knowledge of *how* to plant the improved fallows (planting the nursery, transplanting the seedlings, or direct-seeding tephrosia), lack of time to plant an IF, lack of strength and health, lack of access to seeds or seedlings, and lack of land. In addition, farmers were asked if their only access to land was borrowed land (so they would not plant an IF), or if villagers' jealousy of early adopters of IF might be a problem. Results show only 54 of 86 farmers pass *all* these latter constraints and are predicted to adopt. The most important limiting factor (for 21 farmers) is lack of technical knowledge of *how* to plant an IF. Of the 86 farmers who make it down the tree to this constraint, lack of technical knowledge is a limiting factor for more married women (37%) than FHHs (24%) than men (17%). This gender difference is expected, based on previous WID literature showing women receive less extension training than men.<sup>33</sup> Women's lack of knowledge does affect adoption: this model predicts adoption for only 31% of the married women in MHHs compared to 47% of the FHHs and 52% of the men in MHHs. There are 22 total errors of the model, meaning the model successfully predicted 82% of farmers' choices.

### Testing The Same Decision Model on Another Sample

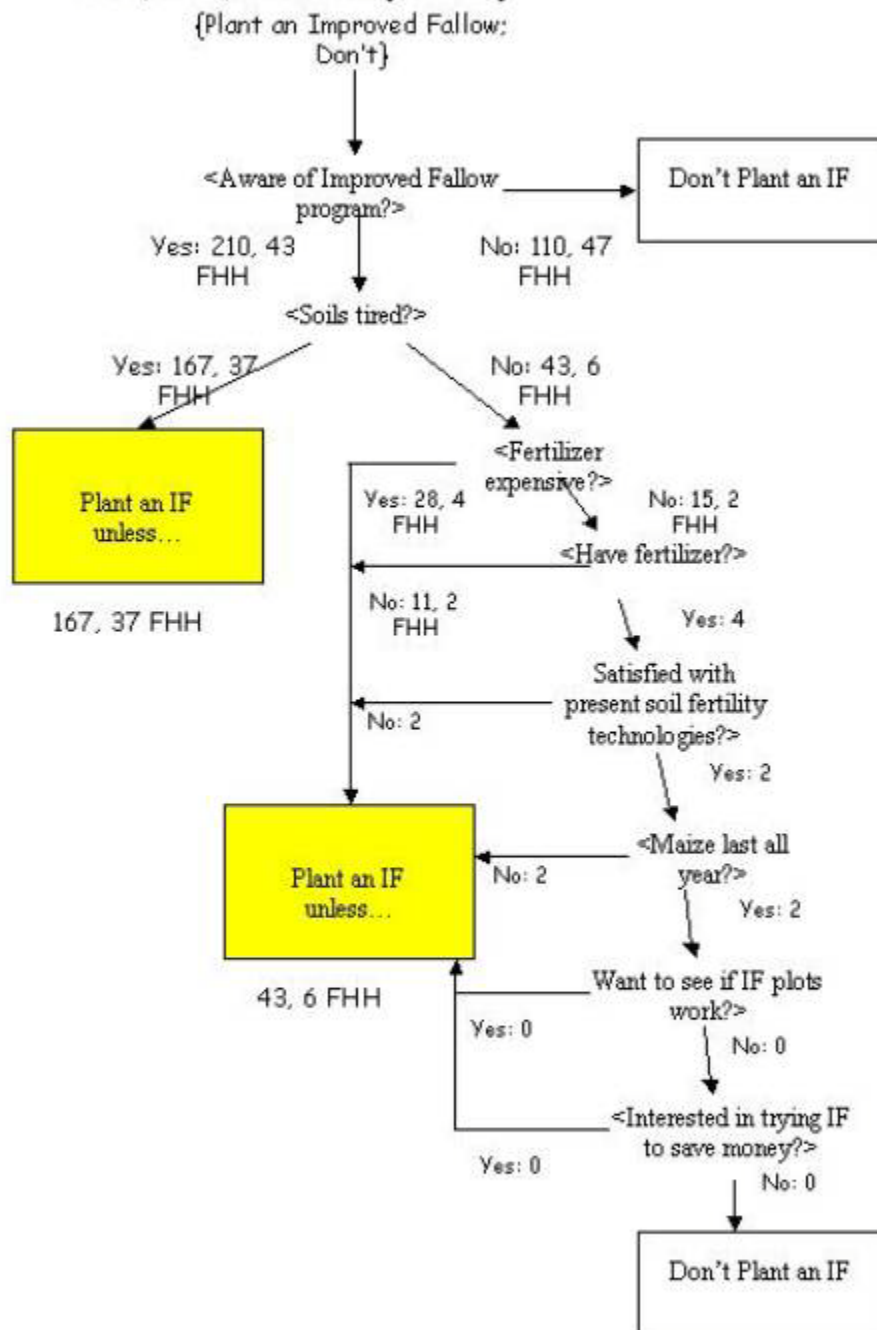
Some of the results of testing this model were as expected from the WID literature, e.g., that men adopt more than women in MHHs or FHHs. Other results were unexpected, e.g., women in FHHs adopt improved fallow technologies more than women in MHHs. These results were a surprise – although a welcome surprise – because results of the other studies done as part of the “Gender and Soil Fertility” project, seen in other papers in this issue, were quite dismal about the possibility of reaching FHHs with soil fertility improvements. For example, Uttaro's study in southern Malawi shows FHHs do not buy small bags of fertilizer; they are usually bought for mens' fields and/or “dimba” cash crops, even if bought by women in local shops. Neither do FHHs grow grain legumes as soil fertility amendments, because the legumes are eaten as food rather than turned under “green.” Sullivan's Senegalese study, for another example, shows that the only women apt to adopt credit for fertilizer use on hybrid rice would be older married women in extended-family households. Similarly, Gough's Malawi study shows that grants and vouchers for grants of fertilizer benefit FHHs, but only minimally: women's disposable cash incomes increase less than 10% from Malawi's starter pack program. Even cash crops in women's farming systems have minimal benefit to them, because women tend to skim the fertilizer received on credit for the cash crop and apply some of it on the food crop. As a result, they find they receive little cash income from the cash crop when it is sold and the credit repaid. Compared to these findings that do not paint a promising picture of government's being able to reach FHHs with soil fertility technologies, these results of FHHs' adoption of improved fallow technologies stand out as a remarkable successful story.



Fortunately we were able to further test these surprising results, because the World Vision extension project conducted a baseline survey in 1999 by Peterson et al.,<sup>34</sup> before it began an ambitious project to diffuse improved fallows technologies from four villages to the entire eastern Zambia region. We thus included questions to test the decision model in figures 2 and 3 with survey data from 320 farmers (230 MHHs and 90 FHHs) living in 20 villages (called camps) spread across the eastern Zambia region, including districts of Chadiza, Chipata North, Chipata South, Katete, and Mambwe. In this target area, only 4% of the households – and only 2% of the FHHs – interviewed had enough maize to last all year from the 1997/98 farming season, and 50% of the households ran out of maize by December.<sup>35</sup> Household food insecurity was thus considered a major community problem in all the villages, and mentioned as the number one problem in 45% of the villages sampled. Fifty-eight percent (158/273) of the respondents described their soils as being depleted, while 22.5% considered them “moderate,” and only 19% described them as good.<sup>36</sup> Here, there were some gender differences: 69% FHHs described their soils as depleted, compared to 54% MHHs. Ninety-four percent of the farmers surveyed had some knowledge of fertilizer use, although only 41% of those who had some knowledge actually used it, because of lack of cash. Similarly, 84% of the farmers had knowledge of manure, but only 40% of those with knowledge of manure actually applied manure in their fields or gardens (*dimbas*). The number practicing improved fallow technologies was even lower: 66% of farmers had heard of improved fallows before the last planting season, but only 21 farmers – 10% of those with knowledge, and 7% of all farmers interviewed – had planted an improved fallow.<sup>37</sup> Therefore, outside of the four villages where ICRAF concentrated its on-farm research, there was relatively little adoption of improved fallow technologies at the start of the World Vision extension project in the entire region of eastern Zambia.

The decision tree model to adopt improved fallows (IF) in figures 2-3 was tested again with this sample (heretofore called the World Vision sample), via questions on the baseline survey that correspond to the criteria in figures 4-5. As before, farmers must have at least one reason or motivation to adopt an IF in figure 4, and have to pass all criteria or constraints to reach the outcome [Plant an IF] in figure 5. As before, results of testing the model are disaggregated by gender of household head.

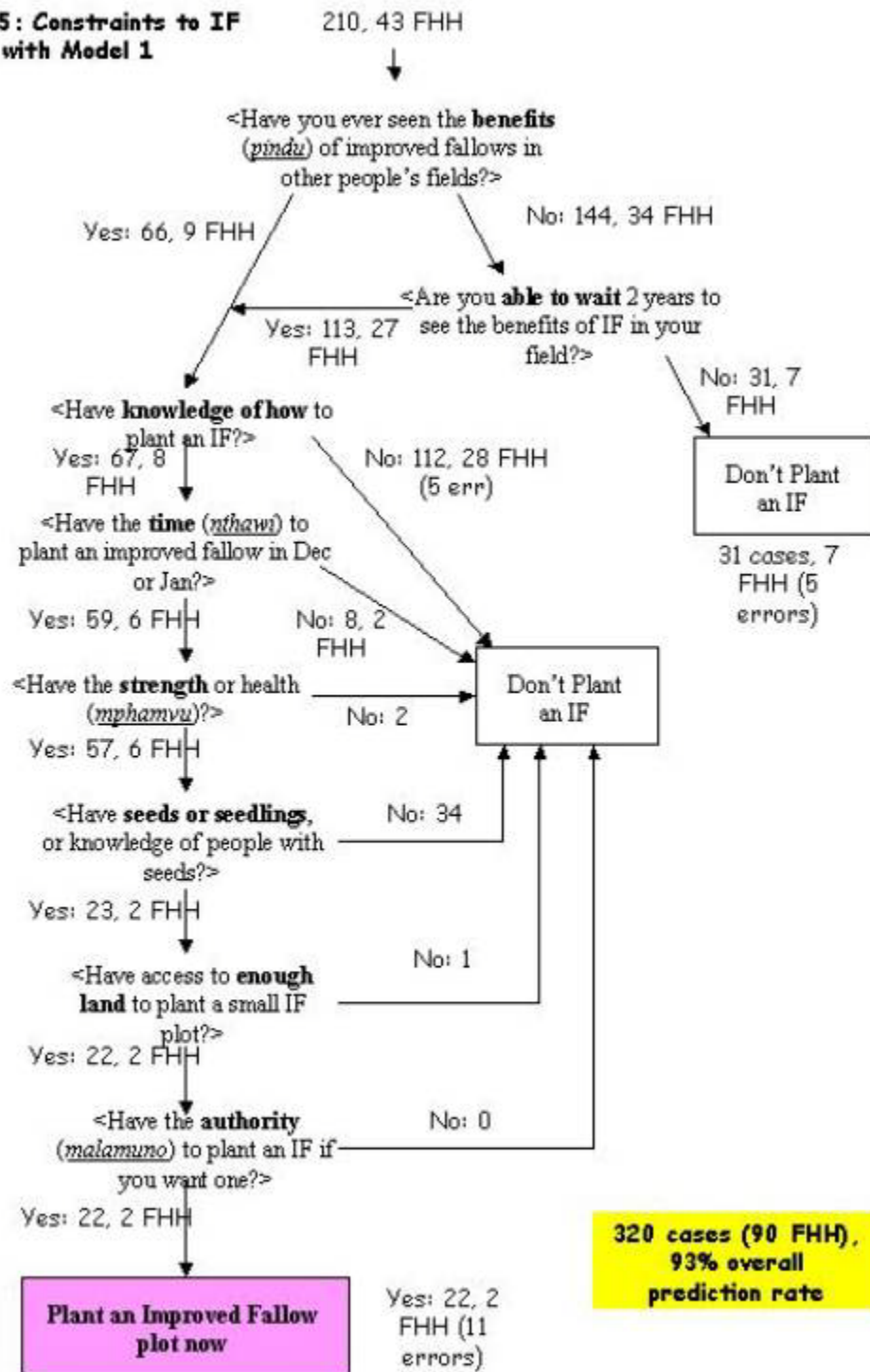
**Figure 4: Model 1 Tested with World Vision Baseline Data, 1999, 320 cases (90 FHHs)**



What is different about the results in figures 4-5, now that the sample of decision makers is dispersed over the entire eastern Zambia region rather than being concentrated in the four villages ICRAF was planting on-farm trails in, is that one-third of the sample (110 of 320

farmers) and half of the FHHs (47 of 90 FHHs) are not aware of the ICRAF improved fallow program (criterion 1). They therefore go to the outcome [Don't plant an improved fallow (IF)], with no errors on this path. Again, it is expected that disproportionately more FHHs than MHHs lack awareness-knowledge of improved fallow technologies.

Only 210 farmers, including 43 FHHs, proceed down the tree to consider the reasons to plant an IF, such as "Soils tired?" (criterion 2), "Fertilizer expensive" (criterion 3), "satisfied with present soil fertility technologies" (criterion 5), "Maize last all year" (criterion 6). In addition to these figure-two criteria, Peterson et al. (1999) also asked farmers if they wanted to see if an improved fallow plot would work (criterion 7) and if they were interested in trying an improved fallow just to save money (criterion 8). Results in figure 4 show no farmer made it down the tree to process the latter two criteria; all farmers who passed the awareness-knowledge constraint in criterion 1 had a reason to plant an improved fallow, and thus they (i.e., their data) were sent on to the constraints in figure 5.

**Figure 5: Constraints to IF with Model 1**

The list of constraints in figure 5 is identical to figure 3, except for the inclusion of an “authority” (*malamuno*) constraint (criterion 16), which Peterson elicited from women in the four ICRAF villages when reporting back to them about the results of her first personal survey.

At that time, she had asked why fewer married women adopted improved fallows, and the women replied, “malamuno”, i.e., they did not have the authority to plant an improved fallow plot on their household’s land without the husband’s permission. When this criterion is included at the end of the path in figure 5, however, it doesn’t “cut” the sample into adopters and non-adopters: no farmers say no, they don’t have the authority and so do not plant an improved fallow.

Instead, as expected, the main limiting factor to adoption of improved fallows in figure 5 is how-knowledge of the IF technologies, which includes knowledge of how to plant a seedbed, how to transplant, how to prune and harvest the trees, etc. At this juncture in the decision process, 112 farmers, including 28 FHHs, do not know how to use the IF technology and so do not plant an improved fallow. After how-knowledge, the second main limiting factor is lack of seeds or seedlings: 34 farmers are sent to the outcome, [Don’t plant an improved fallow] at criterion 14. Only 22 farmers in the World Vision baseline sample, including only 2 FHHs, are thus sent to the outcome, [Plant an improved fallow now]. There are, however, 11 errors in this sub-sample of “adopters.” These errors may be due to some omitted criteria in this model, or incorrect phasing of the decision-criteria questions by the survey interviewers, or farmers’ lack of understanding of the questions in the survey. Whatever the reason, there is a high error rate on this path.

Nevertheless, the overall prediction rate of farmer adoption behavior is 93 percent (299/320) in this World Vision sample, much higher than the 82% prediction rate of the same model in the ICRAF four-village sample. This difference in prediction rate between the two samples is surprising; we would expect lower prediction rates in tests conducted by third-party interviewers unfamiliar with the decision model, as “the fudge factor” is eliminated. We would therefore expect the World Vision sample, conducted by interviewers trained by Peterson, to have lower prediction rates than in the ICRAF sample. The unexpected high success rate in the World Vision sample, however, may be simply due to lack of variation in adoption behavior in the sample. In the 1999 baseline data sample from the World Vision project, almost no one (7% farmers) adopted improved fallows. In contrast, in the ICRAF sample, half (54%) of the farmers adopted while half (46%) did not. The greater variability in adoption behavior in the ICRAF sample, therefore, might be responsible for the lower prediction rates. Alternatively, the high success rates of the model in the World Vision sample may be due to the fact that for one-third of this sample, there was no awareness-knowledge of improved-fallow technologies and therefore no real choice for these 110 farmers to make. Clearly, the decision model should be tested again, as the improved fallow technologies diffuse, awareness-knowledge grows, and more farmers across the wider eastern Zambia region face a real choice about whether or not to plant improved fallows.

## Conclusion

Results of testing decision tree models of farmer adoption behavior described here present mixed results on the potential of agroforestry technologies, as measured by the extent of farmers’ adoption or acceptance of them as soil fertility amendments. Williams’ 1997 results show adoption of hedgerow intercropping and biomass transfers by women farmers was poor



in western Kenya. Uttaro's 1998 gendered-disaggregated results about the adoption of improved fallows in Zomba, southern Malawi, were similarly discouraging. In contrast, Peterson's 1999 results from eastern Zambia show that *women, especially FHHs, do adopt* improved fallow technologies, because they know their soils are depleted and they are not satisfied with the amount of fertilizer they can now afford to acquire by barter or purchase. Statistical results of estimating logit and ordered probit models presented elsewhere also confirm these results, and show that women in FHHs are *more likely* to adopt improved fallows than are married women or men in MHHs, holding constant other factors such as household size, age and club membership of the household head, and his/her ability to wait two years to see the benefits of an improved fallow.<sup>38</sup>

Taken at face value, therefore, improved fallow technologies appear to be one of the few success stories in sub-Saharan Africa today. Questions remain, however, about whether they will continue to diffuse. Results here suggest they should, as farmers increasingly realize they cannot afford to buy costly imported chemical fertilizers, and are therefore adjusting to the idea of "growing their own." Government policies, however, have a great deal of impact on whether or not improved fallows diffuse.<sup>39</sup> Policy makers who realize they cannot continue to give costly subsidies of either credit or fertilizers to farmers will tend to encourage adoption of improved fallow technologies; while governments who keep their exchange rate overvalued, fearing recurrent devaluations of their currencies, will not. This is because, as the decision models above show, it's the unaffordability of chemical fertilizers -- made more unaffordable with every devaluation of the local currency -- that leads farmers to adopt improved fallow technologies.

Whether or not improved fallow technologies can entirely substitute for nitrogen fertilizers, as suggested by ICRAF and Pedro Sanchez, also remains to be seen. Most observers agree that the verdict is still out for improved fallow technologies, which may take a decade for farmers to test properly. First farmers plant several small plots of different tree species, then they wait three to four years to see the results of each plot. Because the improved fallow cycle takes so long, farmers' adoption or adaptation of this technology takes a lot longer than adoption of an improved seed or a new fertilizer. Until the experiment fails, African farmers -- like most researchers -- are willing to experiment, probably due to the lack of other options available as soil fertility amendments in Africa today. This is especially true for women farmers, even more so for female-headed households whose lack of adult family labor presents them with severe cash and credit constraints. Being good farmers, they know they need to have as many tools as possible in their soil fertility toolbox, so that even if not applicable everywhere, the improved-fallow tool will be used where it is most appropriate.

## Notes

1. Gabre-Madhin and Johnston 1999.
2. Tomich, Kilby, and Johnston 1995.
3. Sanchez et al. 1997.
4. Smaling et al. 1997: 52.
5. Bumb et al. 1996.
6. Pinstrip-Andersen 1992.

7. Jama et al. 1997.
8. Palm et al. 1997.
9. Gladwin and McMillan 1989.
10. Eicher 1982, Eicher 1995.
11. Smale 1995.
12. Rocheleau 1995.
13. Pala-Okeyo 1980.
14. Scherr 1995.
15. The term hierarchical decision models distinguishes decision trees from linear additive models such as linear regression analysis, probit analysis, or logit analysis. The term “hierarchical” refers to the fact that the decision criteria or dimensions are mentally processed in a certain order such that alternatives are compared on each dimension or criterion separately, and criteria or dimensions are ordered so that all of them may not be processed by all individuals. This simplifies the decision process considerably, and saves the individual cognitive energy. A linear-additive model, in contrast, assumes all the criteria or dimensions of each alternative are weighed by the decision maker, and each alternative is assigned a composite score, and the alternative with the highest score is chosen. Much debate about these two types of models of the search-for-information process has occurred between psychologists (Rachlin 1990: 76-77).
16. Gladwin 1976, 1989, 1991, 1992; Swinkels and Franzel 1997, Williams 1997, Peterson 1999, Peterson et al. 1999, Uttaro 1998, D’Arcy 1998.
17. Simon 1979.
18. Gladwin 1976, 1979.
19. David 1992, Shepard et al. 1997, Swinkels and Franzel 1997.
20. Williams 1997.
21. Her research was conducted at various sites in and around Maseno, mainly in Siaya and Kisumu districts, home to mostly Luo and some Luhya people. A typical farm in this area is less than 1 hectare in size; mean household size is 7 people including 3 or 4 adults. Many farms have small coppiced woodlots (about 0.14 ha.) of *Eucalyptus saligna* but indigenous trees such as *Markhamia lutea* and *Sesbania sesban* are commonly found around homesteads, on boundaries, in croplands and in fallows. As mentioned, Luo women are traditionally forbidden to plant trees and although this custom is changing somewhat, men are still expected to make decisions about species type and placement of trees. If a woman takes care of or uses trees around the homestead, they generally still belong to her husband or his family, even after he dies (Rocheleau 1996). However, shrubs (specifically *Sesbania sesban*), are women’s property and women are allowed to plant them in croplands, manage, use, and dispose of them as they see fit. This is also true among Luhya women. Moreover, men and women have different uses for tree products. Although resource use is not absolute and inflexible, in general, men prefer poles, timber and fodder from trees while women want fuelwood and fodder. Although both show interest in soil fertility improvement, women farmers have different sets of concerns regarding their soil fertility management strategies.

22. Williams used two samples of women, one to build the adoption models and one to test them. Both samples included female-headed households (*de jure* and *de facto*), members and non-members of women's groups (high to low resource, newly and well-established), and women generally considered to be of above-average, average, and below-average wealth according to such socio-economic criteria as farm size, house type, numbers and types of livestock etc. The sample of women used to build the models consisted of 25 Luo women while the sample used to test the models was made up of both Luo and Luhya women (10 and 13 respectively).
23. Jama et al. 1997.
24. Uttaro 1998.
25. Franzel et al. 1997, Kwesiga et al. 1997, Peterson 1999, Peterson et al. 1999.
26. Kwesiga et al. 1999.
27. Franzel et al. 1997.
28. Peterson 1999.
29. At first it was planned to find 40 women who began testing improved fallows before 1995/96 in the four target camps. This was impossible, however, as only 28 women tested IFs before 1995/96, because most of the early testers were men. In many instances, however, farmers were so convinced of the success of the technology (especially after having visited farmers in other camps as part of field days or farmer-to-farmer visits) that they did not wait until they harvested their first IF before they planted another. Of the 81 women in the ICRAF sample, Peterson interviewed 40 non-testers, 23 tester-expanders, and 18 tester-non-expanders; of the 40 men, she interviewed 15 non-testers, 16 tester-expanders, and 9 tester-non-expanders (Peterson 1999:4).
30. Gladwin 1989: 72.
31. Gladwin et al. 2002.
32. However, a more complicated subroutine may have to replace the simple criterion used here which assumes natural and improved fallows are substitutes for each other, e.g., add an additional constraint, "Do you have time and strength to clear this land?"
33. 33 Staudt 1975.
34. Peterson et al. 1999.
35. Peterson et al. 1999: 89.
36. Peterson et al. 1999: 65.
37. Peterson et al. 1999: 68.
38. Gladwin et al. 2002.
39. Place and Dewees 1999.

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