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Malawi's Energy Needs and Agroforestry: Adoption Potential of Woodlots

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Abstract Rapid urbanization and population growth have resulted in increasing demand for fuelwood and higher rates of deforestation in Malawi. Agroforestry fuelwood technology (AFT) offers a sustainable approach to addressing this problem. Adoption levels, however, remain low due to several factors. This study explores the influence and interactions among these factors based on analyses of data collected from a large-scale extension effort using binary regression and interaction tests. The results show AFT adoption throughout the country is influenced positively by factors such as farming groups and education; further, labor availability and landholdings are important in the relatively less fertile South. While increased levels of individual income were found to mediate positive influences on adoption, environmental governance was found to moderate negative influences. Based on our results, we suggest closer monitoring of lead farmers, targeted training, promotion of environmental governance, and increased emphasis on due diligence during extension planning.

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Keywords Sub-Saharan Africa · Malawi · Fuelwood · Food Security · Energy Security · Moderation · Mediation · Communal and Individual Woodlots · Environmental Governance

Abbreviations

AFSP	Agroforestry Food Security Program
AFT	Agroforestry Fuelwood Technology
CWL	Communal Woodlot
ICRAF	World Agroforestry Centre
IWL	Individual Woodlot

Introduction

Malawi, a relatively small country, is the fifth most densely populated in Africa and ranks among the lowest on the Human Development Index (UNDP 2015). Like much of sub-Saharan Africa (SSA), agricultural expansion to feed the growing urban centers is a leading cause of deforestation (Rudel 2013). As agriculture, the mainstay of the population, has grown to occupy over 70% of the land area, forest area has dwindled (Yaron *et al*. 2011). This has left only 25% of Malawi forested and most of the forest remnants severely degraded (MARGE 2009). Despite conservation attempts, fuelwood collection strains these remaining forests and hinders their regeneration (May-Tobin 2011). Together, these pressures perpetuate a self-destructive cycle that can lead to drought, flooding, biodiversity decline, and other natural disasters that have detrimental effects on Malawi's people (Specht *et al*. 2015).

As fuelwood becomes increasingly scarce women, who traditionally collect it, have to spend more time doing so (Cooke *et al*. 2008). This not only leaves less time for income generating activities, child care, and education, but for food production and preparation (Kiptot and Franzel 2011). In addition, because preparation of traditional Malawian foods requires varying levels of heat (Makungwa *et al*. 2013), fuelwood scarcity can govern dietary choices (i.e., nutrient consumption; Brouwer *et al*. 1997). Moreover, some types of wood produce more harmful smoke than others. This is especially troubling given that women and children often spend long periods in poorly ventilated kitchens (Chikoko 2002). Thus fuelwood scarcity, through both dietary influences and increased carcinogen contact, contributes to reduced immune system capacity and the spread of infectious diseases (Schaible and Kaufmann 2007). A steady supply of cleaner burning fuelwoods could help provide energy while combating deforestation and reducing health concerns, in-turn increasing income potential and labor availability (Cooke *et al*. 2008).

The potential of agroforestry to contribute to smallholder farmers' wellbeing through increased fuelwood supply is well documented (Fabe *et al*. 2014). Coppicing of trees meant for boundaries, fertilizer, or fodder can alleviate some of the demand on surrounding forests and produce fuelwood of varying quality as by-product (Iiyama *et al*. 2014). Given the characteristics of the species suitable for each of these tasks, this allows a degree of control for carcinogen and heat levels (Ndayambaje and Mohren 2011). Directly applicable, however, is the intentional growing of such trees specifically for providing a steady supply of cleaner burning fuelwoods, known as Agroforestry Fuelwood Technology (AFT).

This work contributes to the understanding of why AFT, despite its documented benefits and applicability to the energy and environmental crises facing Malawi, is not more widely adopted by Malawi's smallholder farmers. It also explores the role of environmental governance and personal finances in influencing such decisions. Data concerning smallholder farmers' perceptions were gathered during a 2013 impact study of an Agroforestry Food Security Program (AFSP) and analyzed through binary logistic regression and interaction tests.

Methods

Study Context

In light of the bleak environmental and institutional outlook in Malawi, the World Agroforestry Centre (ICRAF) has sought to improve food security, income, and livelihood opportunities for rural communities by increasing agroforestry adoption (Beedy *et al*. 2012). This was to be done through provision of fertilizer, fruit, fodder, and fuelwood trees (Table 1) and training concerning appropriate application of each (Ajayi *et al*. 2010). The AFSP combined these tested agroforestry practices with informed policies and effective partnerships, including Malawi's Forestry Service and Agriculture Department, as well as Non-Governmental Organizations. Together they targeted over 200,000 farmers in 11 districts throughout three administrative regions (Northern, Central, and Southern).

An "Impact Survey," the results of which are the basis of this study, was conducted in 2013 in order to understand the reasons participants adopted or continued to use agroforestry. Six study areas were considered: two from the Northern region (Karonga and Mzimba), two from the Central region (Salima and Ntceu), and two from the Southern region (Mulanji and Chikwawa). Due to its broad reach and focus, the AFSP provided a suitable infrastructure for interacting with smallholder farmers who faced an AFT adoption decision.

Data Collection

Participants were selected from a rapid census which catalogued the current levels of agroforestry participation by individuals involved in a baseline study (2009). Using stratified random sampling, a total of 501 households from 44 villages were selected. Data collection consisted of a standardized survey via face to face interviews conducted by trained enumerators during July to August 2013. The Southern and Central regions were considered together in the analysis (and are hereafter referred to simply as the "South") given the environmental and sociological similarities between them and their differences from the Northern region.

Study Location

Malawi is a landlocked country in the southeast of Africa containing five main landform areas that range in altitude between 300 and 3000 m above sea level. The majority of the rains (90%) occur between December and March. Some areas receive very little rain and others are prone to flooding, with annual rainfall varying between 800 and 2400 mm (for a map of climate and market access conditions see Toth *et al.* 2017). The most moderate and favorable regime occurs in the North. Perhaps related, the northern region of Malawi, with its relatively small population, is not afflicted with the same level of fuelwood shortages as the southern and central regions and subsists primarily on timber production. About 80% of the North is under some form of tree cover (mainly homogenous plantations) and smallholder farmer landholdings average 1.2 ha (NORAD 2014). The central region has a large population density and is also the largest area under intensive agriculture, including tobacco and sugar production. In the southern region, which has the greatest population density, highest rate of fuelwood consumption, and lowest percentage of tree cover, fuelwood extraction rates exceed supply

Table 1 Characteristics of Trees and Shrubs used as Fuelwood Species in Malawi

Species	Other Uses	Characteristics	Specific Gravity Calorific Value
Alnus acuminata	Soil improver, terracing, timber, forage	Tree - fast growth, wide tolerance, 20 yr. rotation annual fuel yield 10–15 cubic m/ha, good even burning	0.34–0.6 4600 kcal/kg
Acacia angustissima	Forage, green manure, improved fallow	Shrub/Tree - utilized as fuelwood but its combustion characteristics can vary	0.7–0.85 N/A
Cajanus cajan	Shade, vegetable, timber, intercrop, soil improver	Shrub - important household fuel in many areas that grows rapidly	N/A 3500 kcal/kg
Calliandra calothyrsus	Shade, timber, hedge, erosion control	Shrub - yields 15–40 t/ha (after year 1) with coppice harvests for 10–20 yrs.	0.51–0.78 4720 kcal/kg
Gliricidia sepium	Timber, hedge, erosion control	Tree - wood burns slowly with little smoke and no sparking, easy coppicing	0.5–0.8 4550 kcal/kg
Grevillea robusta	Timber, shade, charcoal	Tree - rotations of 10–20 yrs. and annual volume increments of 5–15 cubic m/ha	0.54 4900 kcal/kg
Leucaena leucocephala	Timber, hedge	Shrub - excellent firewood, little smoke, few sparks and produces less than 1% ash	0.45–0.55 4600 kcal/kg
Leucaena pallida	Timber, hedge, green manure, terrace boundary	Tree - excellent firewood, coppices well	0.55–0.61 4400 kcal/kg
Sesbania grandiflora	Hedge, seed, timber, shade	Tree - wood is light, not valued as a fuel, smokes excessively with high ash content	0.3–0.42 4280 kcal/kg
Sesbania sesban	Green manure, post, shade, improved fallow	Shrub/Tree - soft, relatively smokeless and quick kindling	0.40–0.45 4350 kcal/kg
Tephrosia candida	Hedge, fodder, intercrop, soil Simprover	Shrub/Tree - suitable once it becomes woody with age	N/A N/A

Source: (ICRAF 2016)

(especially near urban centers; MARGE 2009). There, smallholder farmer landholdings average 0.7 ha (NORAD 2014).

Variables

Given that limited literature is available concerning AFT in Malawi, variable determination was based upon research concerning general sustainable technology adoption in SSA, including the works cited in the preceding sections and Table 2.

In addition, direct questions were asked regarding which type of AFT respondents adopted. Most relevant to Malawi is the AFT of woodlots. These are areas, either on individual farms ("individual woodlots:" IWL) or located in a common / communal place ("communal woodlots:" CWL), set aside specifically for multipurpose trees that produce fodder, fuelwood, and/or timber, with typically high stocking densities relative to their surroundings (Nair 1987). While both IWL and CWL represent the use of AFT (and are therefore used as dependent variables in this study), it is useful to distinguish between them to allow for more accurate analysis, especially when attempting to determine adoption factors across varying institutional and geographic settings. Factors within these settings (here the North and South of Malawi) may be more conducive to one type of woodlot adoption, necessitating their division in the analysis.

As the survey was primarily intended to capture participant's perceptions, "adopted" was self-defined. This means that if a respondent noted that they have a functioning IWL, are part of a CWL, or have taken any steps that they consider using the technology, then they practice AFT and are an adopter. Moreover, levels of adoption (i.e., the degree to which the technology is utilized) and the stage of woodlot growth (i.e., its size and density), are not considered or taken into account.

Treatment

Based on this background and preliminary statistical testing, we created a model of influences on AFT use divided by region, given the distinct institutional and geographic difference between the North and the South. We ran this model twice for each region, once with each type of woodlot (IWL or CWL) as the dependent variable, where 0 = "non-use" and 1 = "use." This was defined as growing multipurpose trees specifically for fuelwood and represented AFT adoption as:

$$\ln[(P_i/(1-P_i))] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \ldots + \beta_K X_{Ki} \quad (1)$$

The framework was then tested against independent variables in four categories:

- *Sociological* (X_1 through X_7): "Age," "Education," "Female Head," "Lead Farmer," "Married," "Group Member," and "Patrilocality;"

Table 2 Variable explanations and expected relationships with AFT use in Malawi

Variables	Meaning	Relation	References
Sociological			
Age	Younger farmers are more open to new tech	Inverse	Blatner et al. 2000
Education	Education instills openness to experimentation	Direct	German et al. 2009
Female HH	Female Household Head in matrilocal village	Direct	Meijer et al. 2014
Lead Farmer	Perceives close relationship with lead farmer	Direct	
Married	Lives with spouse	N/A	
Patrilocal	Male Household Head in patrilocal village	Direct	
Geographic			
Upland Plus	Number of hectares above regional average	Direct	Sirrine et al. 2010
Lack Land	Perceive insufficient land area for testing	Inverse	Pattanayak et al. 2003
Tree Death	Perceive tree death rate as high in area	Inverse	
Financial			
Business	Family member owns a business	N/A	Kwesiga et al. 2003
Employed	Family member makes money outside of farm	N/A	Thangata and Alavapati 2003
Labor	Can afford employee or has large family	Direct	
Land Tenure	Feels secure in ownership of land	Direct	
Extension			
AFSP	Received visit from extension service	Direct	Franzel et al. 2014
Conflict Subsidy	Received subsidy for a non-agroforestry tech	Inverse	Pattanayak et al. 2003
Group Member	Belongs to a farming group	Direct	
Lack Seeds	Perceives required seeds as possibly inaccessible	Inverse	

- *Geographic* (X_8 through X_{10}): "Upland plus," "Lack Land," and "Trees Die;"
- *Financial* (X_{11} through X_{12}): "Available Labor" and "Land Tenure;"
- *Extension* (X_{13} through X_{15}): "AFSP," "Opposing Subsidy," and "Lack Seeds."

Data Analysis

We applied binary logistic regression to the model. The basic regression model, based upon the widely accepted work of Mendenhall and Sincich (1996), was developed with the response "y" measured as 0 or 1 (the latter indicating a positive or "yes" response), and analyzed the relationship between this response and the independent variables (x_1, x_2, ..., x_k) using SPSS 22. Tests for independency (including frequency analysis and means tests when applicable) were carried out for each ordinal variable and corresponding response variables. In addition to binary regression, interaction tests (mediation and moderation) were carried out in order to determine if working with the AFSP, a Farmer Group, or a Lead Farmer, reduced the effects of the negatively influential variables or impacted the influence of external income.

Mediation is a form of interaction in which one independent variable is responsible for another's relationship with the dependent variable (i.e., it is said to "explain" the relationship between them; Fig. 1). Here, mediation tests were carried out following Baron and Kenny (1986) and confirmed in accordance with Sobel (1982). Essentially, to determine if a variable is a mediator, three steps are followed: 1) an independent variable is tested against the dependent variable and found to be significant; 2) a variable suspected of being a mediator is tested against the dependent variable (without the noted independent variable in the model) and found to be significant; and 3) the model is run again with both the independent variable and the suspected mediator present. If the result is

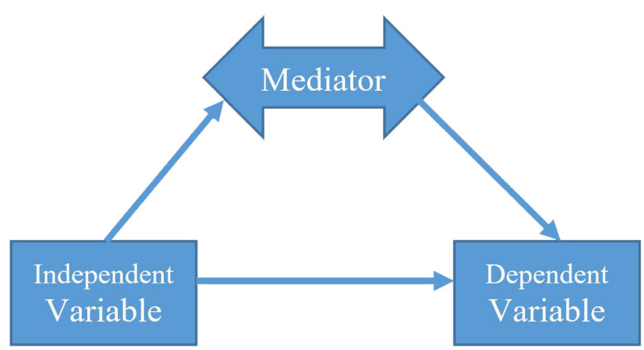

Fig. 1 Mediation Conceptual Diagram: the mediator is responsible for the relationship between the independent variable and the dependent variable

a reduction in the significance of the independent variable's relationship with the dependent variable, and the suspected mediator remains significant, a mediating effect is confirmed.

Moderation is a form of interaction in which the value of a suspected moderator affects ("systematically modifies") the relationship between an independent variable and the dependent variable (Sharma *et al*. 1981; Fig. 2). Essentially, the relationship between an independent variable and the dependent variable is analyzed along with different levels of a suspected moderating variable. If the significance or direction of the relationship between the independent variable and the dependent variable change when differing levels of the suspected moderator (e.g., low, medium, and high) are included individually (i.e., in absence of the other levels) in the model, a moderation effect is concluded to exist. In order to test for this, ordinal variables must be constructed.

For the South and North samples the dependent variables consisted of three levels: no woodlot use, CWL or IWL use, and CWL and IWL use (0, 1, and 2 respectively). The AFSP variable used the number of years respondents had been part of the program (0 through 5). The Farmer Group variable consisted of 10 levels: 0 representing not being in a group and the numbers 1 through 9 (representing the presence (1) or lack thereof (0) for each of the factors commonly understood to create successful environmental governance: participation (Bulkeley and Mol 2003), communication, clear rules and objectives, equal power and information access (Tarrant *et al*. 1997), legitimacy (Roberts *et al*. 2009), and sanctions and monitoring (Papadopoulos 2011).

Next, the significant negative influences within each sample were combined to create a measure specific to it. For example in the South IWL sample, the significant negatively influential variables included Lack Land, Lack Seeds, and Conflict Subsidy. These variables were combined to create an ordinal negative influence variable that ranged from zero (indicating the respondent did not consider any of these influences to be present) to 3 (indicating the respondent considered all three influences to have been present). Likewise, the significant negatively influential variables present in the other

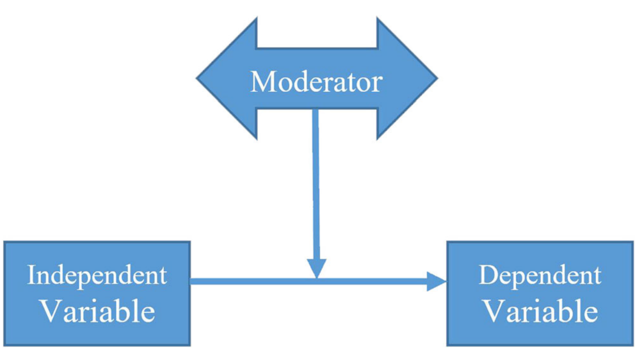

Fig. 2 Moderation Conceptual Diagram: the moderator influences the relationship between the independent variable and the dependent variable

samples were used to create new ordinal variables specific to those samples. Once the variables were constructed, analysis was conducted according to Hayes (2013) utilizing the associated SPSS PROCESS add-on tool.

Results

Individual Woodlot Adoption

In the South, three factors were found to positively influence adoption of IWL: Upland Plus (2.18 / $p < 0.05$), Farmer Group (2.78 / $p < 0.01$), and Lead Farmer (2.59 / p < 0.05). Two constraints were significant: Lack Seeds (0.07 / $p < .001$) and Lack Land (0.05 / p < .001). One factor was found to negatively influence IWL: Conflict Subsidy (0.28 / p < .001) (Table 3). Also worth noting for the South is that Labor (i.e., more than 5 family members and/or employees able to work) was nearly significant and had a positive effect on IWL adoption (1.65 / $p < 0.1$).

In the North two factors were found to positively influence adoption of IWL: Farmer Group (2.46 / $p < 0.05$) and Education (2.59 / $p < .05$). Two constraints were found to be significant: Lack Land (0.07 / $p < .001$) and Lack Seeds (0.14 / $p < 0.01$) (Table 3). Moreover, one factor was nearly significant and negatively influential: Lead Farmer (0.36 / p < 0.1). Finally, when variables concerning outside sources of income (Business or Employed) were tested in this model the significance of being in a farming group was removed while all other significant variables remained unaffected. This was the only model in which this occurred and led to follow up tests concerning interaction (discussed further below).

Communal Woodlot Adoption

In the South, only being in a Farmer Group was found to positively influence adoption of CWL (1.77 / p < 0.05). Constraints upon CWL adoption included: Lack Seeds (0.39 / p < .001) and Trees Die (0.27 / $p < .01$). Moreover, Lead Farmer (0.52 / p < 0.01) and Conflict Subsidy (0.42 / p < .001) were negatively related to CWL adoption (Table 4). In the North, participation in a Farmer Group (2.62 / p < 0.05) significantly and positively influenced CWL adoption, and one constraint was determined: Lack Seeds (0.42 / $p < .05$). There were also two negative influences on CWL in the North: Female HH (0.07 / p < .01) and being Married (0.10 / p < .01). Worthy of note is that the constraint of Trees Die was nearly significant (0.26 / $p < 0.1$).

Interaction Tests

In the South IWL sample, increasing presence of the factors determined to contribute to effective environmental

Table 3 Regional Statistics and Binary Logistic Regression of Malawi *Individual* Woodlot Use

Variables	*SE*	South_(*n* = 324)			OR	OR	North (*n* = 177)			*SE*
		Freq.	%	Use IWL			Use IWL	%	Freq.	
Farmer Group	.432	218	68	27%	2.78**	2.46*	29%	64	113	.469
AFSP	.446	246	76	23%	0.90	1.39	27%	78	138	.508
Lead Farmer	.461	54	17	35%	2.59*	0.36~	23%	18	31	.605
Conflict Subsidy	.410	94	32	16%	0.28***	0.86	27%	9	11	.822
Lack Seeds	.643	66	21	5%	0.07***	0.14**	6%	19	33	.704
Trees Die	xxx	21	7	0	xxx	0.14	8%	7	13	1.20
Upland Plus	.425	216	67	26%	2.18*	1.98	31%	75	132	.538
Lack Land	.663	81	25	4%	0.05***	0.07***	5%	23	41	.790
Land Tenure	xxx	16	5	0	xxx	2.38	30%	6	10	.888
Labor (Fam. Size)	.456	200	62	26%	1.65~	0.81	26%	65	115	.438
Patrilocal	.387	116	36	22%	0.76	1.16	30%	69	122	.504
Married	.788	237	73	24%	2.57	0.41	30%	73	130	.987
Female Head	.734	91	28	18%	2.36	0.27	17%	23	41	1.03
Education	.698	36	11	11%	0.77	2.59*	42%	25	45	.487
Age	.013	50[1]	16	*NA*	1.01	1.01	*NA*	18	50[1]	.012
Intercept	1.26				0.04**	0.30				1.28
X^2					100***	54***				

[1] Age, being a continuous variable, is presented with the mean and standard deviation

OR odds ratio, *SE* standard error, *Freq.* frequency, % percentage of entire sample, Use WL = percentage of each variable that also used Individual Agroforestry Woodlots

Two tailed:

~*p* < .10

*p < .05

**p < .01

***p < .001

governance within a group was found to moderate (reduce) the combined effects of the significant constraints (Lack Land, Lack Seeds, and Conflict Subsidy). As levels of the elements of environmental governance within the group increased, the "buffering" of these negative effects increased. Specifically within farmer groups, low levels of environmental governance (1.58) reduced the influence of the combined negative factors 19%, at medium levels of environmental governance (5.59) the influence was reduced by 32%, and at high levels of environmental governance (9.0) the influence was reduced by 43%.

In the North IWL sample, the presence of the Farmer Group variable was found to mediate the significance of the variables concerning income external to the farm (i.e., Business and Employed). When these external financial variables were placed in the model, they had a combined significance of 0.02 and the significance of the farming group variable went from 0.05 to 0.10, while the overall significance of the model went from 54 ($p < .001$) to 60 ($p < .001$). The mediation test revealed that the Farmer Group variable was responsible for 36% of these variables' relationship with IWL use at a significance of $p < 0.01$ (Sobel Z value of 2.85).

Discussion

Individual Woodlots

The odds of adopting IWL in South Malawi significantly increased when smallholder farmers had: average or above area of highlands (3.25 ha), an average or above number of family members (5), membership in a farmer group, or close association with a lead farmer. For North Malawi, education (25% of the sample) and membership in a farmer group (64% of the sample) were associated with increased adoption of IWL. The odds of IWL adoption in South Malawi were negatively impacted by the constraints: lack of land, lack of seeds, and conflicting subsidies. Lack of seeds and land also negatively affected adoption of IWL in the North.

Farming Groups

Farming groups had the most significant and largest positive relationship with IWL adoption within the South sample and the second most significant relationship with IWL in the North.

Table 4 Regional Statistics and Binary Logistic Regression of Malawi *Communal* Woodlot Use

Variables	*SE*	South_(n = 324)			OR	OR	North (n = 177)			*SE*
		Freq.	%	Use CWL			Use CWL	%	Freq.	
Farmer Group	.267	218	68	57%	1.77*	2.62*	35%	64	113	.420
AFSP	.291	246	76	54%	0.87	1.25	33%	78	138	.449
Lead Farmer	.325	54	17	44%	0.52*	0.92	36%	18	31	.523
Conflict Subsidy	.271	94	32	43%	0.42***	0.60	27%	9	11	.762
Lack Seeds	.264	68	21	43%	0.40***	0.42*	27%	19	33	.376
Trees Die	.459	21	7	33%	0.27**	0.24~	15%	7	13	.883
Upland Plus	.272	216	67	51%	0.67	0.70	33%	75	132	.412
Lack Land	.263	81	25	63%	0.87	0.53	29%	23	41	.414
Land Tenure	.586	16	5	56%	1.31	2.73	50%	6	10	.783
Labor (Fam. Size)	.285	200	62	56%	0.89	0.94	31%	65	115	.377
Patrilocal	.271	116	36	50%	0.77	0.82	30%	69	122	.408
Married	.490	237	73	55%	1.27	0.07**	30%	73	130	.907
Female Head	.480	91	28	53%	1.10	0.10**	32%	23	41	.921
Education	.418	36	11	56%	1.05	1.43	38%	25	45	.429
Age	.009	50[1]	16	*NA*	0.99	1.00	*NA*	18	50[1]	.011
Intercept	.831				4.05	4.86				1.16
X^2					41***	25*				

[1] Age, being a continuous variable, is presented with the mean and standard deviation

OR odds ratio, *SE* standard error, *Freq.* frequency, % percentage of entire sample, Use WL = percentage of each variable that also used Individual Agroforestry Woodlots

Two tailed:

~p < .10

*p < .05

**p < .01

***p < .001

These high levels of influence were obtained despite only 15% of group members in both regions participating in the AFSP. This is because groups increase the reach of extension agents by providing a central means for information dissemination (Kiptot *et al.* 2007). Providing information to a few trusted group members and allowing the members to inform one-another (and even those outside the group) is also a good means of evading the distrust of outsiders common in SSA (discussed below). The potential for this dissemination facilitation is tied to a group's level of environmental governance (Agrawal 2005). In essence, a group's ability to attain its goals improves if the distribution of power and information is perceived as balanced throughout its membership (Ashley *et al.* 2006). To this end in the South, 82% of group members claimed their group had at least eight of the nine relevant environmental governance characteristics, while in the North 69% of group members claimed the same.

Lead Farmers

Arguably, lead farmers can be considered sociological influences rather than elements of extension. This is because, although lead farmers are given implements and intensive training by extension agents in order to pass them on to others, they typically are already considered elites within their community (thereby arriving at this privilege in the first place) or become elevated in status as a result (Alinyo and Leahy 2012). As the gate-keepers for resources and knowledge, they can direct benefits toward their closest associates. Indeed, the potential for lead farmers to have a high impact within a limited range was observed, mentioned by respondents, and noted in other studies. For example, Kiptot and Franzel (2013) found that across agroforestry technologies, distance dictates who is able to frequent lead farmers and that this frequency significantly influences adoption. Franzel *et al.* (2015) also found the lead farmer extension model to be of limited reach but high impact. Our results confirm these findings.

In the South, lead farmers increased the odds of AFT adoption by over 150%, but only reached 17% of the sample (compared to 76% for extension agencies). A nearly equal percentage claimed to have lead farmer access in the North (18%). As in the South, this level of interaction also had a significant influence. The primary difference was that, unlike the South, lead farmer interaction was negatively influential in the North. This highlights a shortcoming of the lead farmer model of extension: there is limited control over what lead farmers actually teach to others.

Lead farmers may not teach a technology correctly due to deficiencies in the manner they were trained, more pressing demands on their time, or any number of other reasons. For example, there is the potential for conflicting subsidies to take lead farmers' focus away from sustainable technologies (Kiptot *et al*. 2007). Such subsidy may come from other extension efforts or even the government, the latter frequently taking the form of coupons for chemical fertilizers (Brazys *et al*. 2015). However, in the North IWL sample, the lack of significance of the conflicting subsidy variable likely rules out the possibility of this "cooption by subsidy." Indeed, over three times as many participants in the South as in the North received subsidies conflicting AFSP efforts. Knowing this allows for focus on other potential causes. For example, geography may play a role beyond simply dictating convenient access to these farmers.

The ecological setting of the North, with its abundance of tree plantations and 75% of the sample rating their soil quality as good, would have less need for fertilizer subsidies. Also, due to the good soil quality, frequenters of lead farmers would likely see, at least in the short term, success with any agricultural method being offered (be that something other than IWL or even improper IWL implementation). If the lead farmer was not teaching IWL correctly, long term results likely wouldn't differ from the other techniques. As such, the extra effort and land commonly perceived as required by IWL would not be justified in the minds of the farmers. This would contribute to negative perceptions of the technology.

Other Variables

Finally, while many farmers view fuelwood collection as extremely time consuming, they can perceive IWL as requiring extra labor and crop space (Thangata *et al*. 2002). For example, studies conducted in Kenya estimate collecting fuelwood off-farm consumes 130 h per year, compared to 36 h spent by those who harvest fuelwood from their own farms (Kiptot and Franzel 2011). However, in our study, the significance of the larger than average family size variable (Labor) attests to the perception that extra labor is required to conduct AFT appropriately. Also, the significance of the larger than average area of fertile highlands (Upland Plus) variable confirms the crop and tree trade-off apprehension (i.e., having greater amounts of fertile upland reduces spacing concerns). While future extension efforts cannot promote changing the size of one's family or land holdings, greater promotion of CWL may indirectly address both issues.

Communal Woodlots

The odds of adopting CWL in South Malawi significantly increased when smallholder farmers have membership in a farmer group. For North Malawi, membership in a farmer group (64% of the sample) was also associated with increased adoption of CWL. The odds of IWL adoption in South Malawi were significantly negatively impacted by the constraints: lack of land, tree death, and conflicting subsidies. Lack of seeds and tree death also negatively affected adoption of CWL adoption in the North, along with being married and having a female headed household.

Farming Groups

Similar to the IWL results, farming groups had significant positive impacts on CWL adoption in both the North and the South, and conflicting subsidies were only significantly influential in the South. Unsurprisingly, lack of land and labor were not issues, as CWL use requires no space on the adopter's farm and greatly reduces both the labor hours required to find fuelwood and to tend to AFT requirements (as they are shared communally). Replacing these factors was the issue of tree death. However, the lack of the Trees Die variable's significance in the IWL samples of both regions attests to the suitability of the trees for these areas, allowing for focus on other causes.

One explanation for why tree death was an issue in CWL and not IWL is that, despite the best efforts of the groups managing such lots, overharvesting still occurs. While not quite reaching tragedy of the commons proportions, overharvesting appears to be affecting enough trees in CWL to make tree death a significant influence on the decision to adopt the technology. This could be addressed by including more information regarding the degree to which certain species can be coppiced and the importance of closer monitoring in extension efforts targeting groups and other potential CWL adopters. In the South those in the latter category might be identified by a lack of overall farm area, as 63% of CWL adopters in that region shared this characteristic (the highest percentage in any sample).

Lead Farmers

Another difference between the South CWL and IWL samples was the opposite influence of lead farmers. Southern CWL respondents were negatively influenced by interaction with a lead farmer, while southern IWL smallholder farmers were positively influenced. The proposed reasons for the negative lead farmer influence in the North IWL sample (i.e., improper training or co-option) can be ruled out in the case of the South CWL sample by the significant positive influence of the variable in the South IWL sample (i.e., showing they had not been co-opted and knew how to pass on the training they received). This points to three South specific possibilities: a potential AFSP training preference for IWL, a conscious choice by lead farmers to focus on IWL, or a regional/cultural aversion to CWL at the farmer level.

These possibilities are highlighted by comparison of a few rates: 1) awareness levels of CWL were roughly the same in the North and the South (25% and 30%, respectively); the same percentage of farmers use IWL in the North as they do in the South (approximately 28%); and 3) adoption of CWL differs greatly between the two regions (57% in the South and only 35% in the North). Given that AFT awareness levels and IWL use were so similar in the North and South, the disparity in CWL adoption rates stands out. Notably, two issues were negatively influential in the North CWL sample that were not present in the South CWL sample: marriage and having a female household head.

Other Variables

Divorce rates in Malawi are some of the highest in Africa (65%; Cherchye *et al*. 2016). Moreover, "polygamous" is the most common marital status in northern Malawi, which also has the highest level of polygamy in the country (Kerr 2005). Given the noted sociological differences between the North and South an increased level of spousal distrust may contribute to a preference for IWL in the North (e.g., not wanting a significant other to frequent a group setting as this represents an opportunity to invest in potential extra/post - marital options; Telalagic 2015). While this concept was noted in interviews, the significance of the marriage and female headed household variables within this context requires further investigation. Nonetheless IWL focused extension may be more appropriate in such settings until more research is conducted.

All Adoption Models

Given that the AFSP was an intensive extension effort (reaching 78% of the sample), increases in AFT use were expected (i.e., a goal of the program). While the AFSP variable itself was not significant, lead farmers were supplied and trained through the AFSP and farming groups served as points of contact for AFSP agents (the high significance of these variables highlighting an indirect effect). Combined with the fact that regional awareness of AFT increased dramatically during the course of the AFSP (90% in the North and 94% in the South) it is reasonable to assume that a general "extension environment" was created that affected even those not directly contacted by AFSP agents (Toth *et al*. 2017). Specifically, dissemination through farmer groups and, in some instances, lead farmers effectively drove the advancement of project goals by increasing community wide knowledge levels (a phenomenon discussed in Kiptot *et al.* 2007).

Beyond issues of physical access to lead farmers and farmer groups, regional sociological differences could lead to certain settings being more conducive to these means of extension. For example, distrust of government and organizations considered to be associated therewith, are commonly noted in SSA (Cho and Kirwin 2007). In general, this phenomenon contributes to the success of the lead farmer model and would explain why farmer groups and lead farmers were both more influential than direct AFSP extension (i.e., they benefited from higher levels of trust in their respective communities).

Interaction Tests

In the South, farmer groups moderated the influence of the significant IWL adoption constraints. In essence this means southern farmer groups weaken the negative effect these constraints have on IWL adoption decisions. In the North, farmer groups mediated the influence of external sources of income (i.e., owning a business and/or being employed). In essence this means northern farmer groups help create a positive relationship between having such sources of income and IWL adoption. While in both scenarios farmer groups were ultimately related to increased IWL adoption, the mechanisms by which this occurred were different. We began investigating this difference comparing the significant IWL constraints from each region.

Given that the constraints of lacking seeds and land were similar for both IWL samples, we focused attention on the high level of conflicting subsidies present predominantly in the South (affecting 30% of respondents opposed to 11% in the North). Independence tests showed that in the South, conflicting subsidies were negatively correlated with external sources of income. This makes sense because as subsidies are distributed more widely the impact of having external sources of income is reduced (e.g., the subsidies allow for purchase of agricultural technology in the same manner the extra income might). The difference, however, between these forms of extra purchasing power is that external income can be used more freely (i.e., for IWL adoption or some competing technology) while the subsidies can only be used for a competing technology. Someone who earns both external income and receives conflicting subsidies will use the subsidy to purchase a technology that displaces IWL and spend the external income elsewhere. In this sense farmer groups in the South fight against the negative influence of conflicting subsidies (i.e., moderate their negative influence on IWL adoption).

Absence of the conflicting subsidy in the North means that more of the freely utilized extra purchasing power (i.e., external income) must be spent on agricultural technology. Additionally, independence tests further showed that external sources of income in the North were positively correlated with being in a farmer group (the latter of which we already know positively influences the odds of IWL adoption). This trend increases the odds that some of this external income will go towards IWL adoption. So, while the percentages of group members that are external income earners in the North and South are relatively similar (45% and 50%, respectively), the much lower level of conflicting subsidies in the North allows for more of the extra purchasing power to be applied to IWL adoption. In this sense farmer groups in the North guide investment into sustainable technologies (i.e., mediate the relationship between external income and IWL adoption).

The results suggest that, absent a sustainable influence such as a farmer group, extra purchasing power (i.e., conflicting subsidy or external income) could discourage IWL adoption, or at least makes less labor intensive alternatives (e.g., purchasing charcoal) more affordable. Of course, business ownership and salaried employment should continue to be promoted, but extension efforts must also recognize this phenomenon and adjust accordingly. For example, outreach programs can emphasize how the secondary benefits and increased future gains accrued through agroforestry, including surpluses of fuelwood, allow for sale or barter for other necessities (Cooke *et al.* 2008).

Limitations

A few shortcomings of this study, some of which were noted early, are also worth mentioning here. Other studies at household level have shown that time spent, distance to forest reserves, and wealth are significant factors influencing fuelwood collection choices (Arnold *et al*. 2006; Brouwer *et al*. 1997). Time and distance were not measured in this work, given its focus on perception; however, nearly all participants noted the increasing difficulty of fuelwood collection. Complicating things further, regional sociological differences can be vast, especially with regard to differing perceptions of what wealth and fuelwood shortages actually entail (Ndayambaje *et al*. 2013). Specifically, the ability to substitute fuelwood with alternative materials such as crop stover, dung, twigs, and bark can sometimes prevent recognition of the severity of fuelwood scarcity, and prevent their more efficient use elsewhere (Iiyama *et al*. 2014).

Conclusion and Recommendations

In the context of Malawi's rapid urbanization, population growth, and energy concerns, there is considerable scope and potential for smallholder farmers to utilize agroforestry-based sustainable fuelwood production methods to increase their well-being and income. Our research was designed to investigate how extension efforts may increase their impact in this regard by raising awareness of how influential factors in smallholder farmer agroforestry woodlot adoption decisions are perceived and interact. To this end, our results provide several suggestions.

While generally extremely effective, farmer groups should especially be promoted in areas identified as having high levels of opposing subsidies. This promotion should be accompanied by information regarding the elements of environmental governance that help such groups function efficiently.

Use of the lead farmer model of extension is also highly effective, but only within a limited range. It should be accompanied by vigilant monitoring and research regarding selection of lead farmers in order to ensure proper training and guard against perpetuating social imbalances.

Promotion of communal woodlots should target families with members and landholdings lower than community averages and should emphasize the importance of proper tree-coppicing methods. This will help to dismiss concerns regarding inadequate labor and planting space associated with individual woodlots, as well as prevent the tree death found to be an issue on some communal lots.

Noting marriage / divorce rates and matrilocal / patrilocal traditions could help guide resources in future extension efforts. Focusing efforts on individual woodlot training where high levels of female headed households and polygamy coexist may be beneficial, as efforts to promote communal woodlots in such areas tend to fail.

The indirect and long-term benefits of agroforestry fuelwood use should be instilled during all stages of extension. This should be done in order to decrease the chances of abandonment in latter stages of development or individual increases in wealth. Likewise, due diligence regarding existing policies and potentially competing extension programs could also help guide future efforts. For example, noting the high level of conflicting subsidies in a region prior to program initiation could be cause to shift focus to a farmer group model of extension. Conversely, noting the low amount of conflicting subsidies and a lack of geographic constraints in a region could lead to the concentrating of resources on traditional forms of extension targeting the general community.

Ultimately, future extension efforts should combine their own research regarding these influences and evolving location specific institutional factors to increase their likelihood of success.

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