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Full Length Research Paper

Adoption of agro-forestry technologies among small-holder farmers: A case of Zimbabwe

C. Parwada[1*], C. T. Gadzirayi[1], W. T. Muriritirwa[1] and D. Mwenye[2]

[1]Department of Agriculture, Bindura University of Science Education, P. Bag 1020, Bindura, Zimbabwe.
[2]International Centre for Agro-forestry, Zimbabwe.

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The objectives of this study were to assess and compare the levels of adoption of agro-forestry technologies between trained and untrained farmers, and identify specific factors that affect adoption of technologies. Data from 300 smallholder farmers selected by snowballing from villages where change agents had been trained by the International Center for Research in Agro Forestry was collected using structured questionnaires. The data were analyzed using the Statistical Package for the Social Science and Microsoft Office Excel. The results showed that there was low level of awareness of agro-forestry technologies among farmers. Formally trained farmers adopted agro-forestry technologies more than informally-trained farmers. Logit regression results showed that the likelihood to adopt live fence was influenced significantly by land ownership, awareness, training, drought, labour and local institutions (p<0.05). Adoption of trees for nutrition was influenced by belonging to a farming group, awareness, training, land size and local institutions (p<0.05). Adoption of improved fallows was influenced by employment status, belonging to farm group, awareness and land size (p<0.05). Factors that influenced adoption of fodder banks were employment status, awareness and training (p<0.05).

Key words: Adoption, agro-forestry technologies, change agents, logit regression.

INTRODUCTION

Land degradation and siltation of rivers are major environmental concerns that tend to drastically reduce yields (Rasto, 1996). Adoption of agro-forestry is an alternative to high-cost inputs such as chemical fertilizers, herbicides, insecticides and pesticides since it offers opportunities of improving the quality of life of resource-poor farmers, while ensuring the sustainability of the natural resources base and the environment (Govere, 2003).

Adoption of agro forestry can lead to improved crop and livestock production because agro-forestry practices are less costly, more affordable and because inputs for fodder and soil amendments are readily available to small-holder farmers. Besides, agro forestry also offers a number of service functions. The major service function of agro forestry is its role in soil management, including control of erosion and maintenance and improvement of soil fertility (Young, 1997). Other service functions include shade, reduction of wind speed, weed control and fencing. Adoption of agro-forestry therefore has the potential to halt land degradation, improve soil fertility and solve fodder problems among smallholder farmers. The key factor is that when trees are properly managed and integrated into farming systems, they improve agricultural productivity and maintain environmental integrity (Hoekstra, 1983).

Many research projects aimed at identifying and domesticating tree species for various soil fertility replenishment practices and developing agro-forestry management principles for improved fodder supply have been widely carried out in the southern part of Africa (NEPAD, 2006). Furthermore, research has also been conducted to identify and test promising indigenous and exotic live fence tree species across a wide range of biophysical conditions and making promising species available for increased farm productivity and cash income

*Corresponding author. E-mail: crparwada@yahoo.com.

(Neupane et al., 2002). In the research done in some provinces in Cameroon, it was found that adoption of agro-forestry technologies is affected by gender of the farmer, household size, level of education, farmer's experience, membership within farmers' associations, and contact with research and extension services. Other significant factors identified were security of land tenure, agro-ecological zone, distance of the village from the nearest town, village accessibility and income from livestock. If fully adopted, agro-forestry technologies have the potential to improve rural livelihoods and reduce the rampant environmental degradation associated with most communal areas in the region.

It is within this context that the World Agro-forestry Centre (ICRAF) and many other developmental institutions have initiated projects on scaling up of agro forestry technologies and innovations among small-holder farmers. ICRAF has been carrying out such scaling up activities in pilot scale up areas (PSUAs) in Zimbabwe (Mwenye, 2003). Training and distribution of germplasm, promoting the establishment of tree fertilizers, fodder for livestock, living fence, biomass transfer, woodlots, trees for nutrition (NEPAD, 2006) have been part of the scaling up activities.

Objectives of the study

The study sought to

(i) Assess the level of awareness of farmers to the introduced agro-forestry technologies.
(ii) Compare the levels of adoption of agro-forestry technologies between farmers trained by ICRAF and other untrained small holder farmers.
(iii) Identify specific factors that influence adoption of the agro-forestry technologies among small holder farmers.

LITERATURE REVIEW

The level of diffusion of agro-forestry technologies has generally lagged behind scientific and technological advances attained in such technologies thereby, reducing their potential impacts (Mercer 2004). The experience with regards to the adoption of agro-forestry technologies in Zimbabwe has not been too different from the global trend. Although agro-forestry is financially profitable and there has been an increasing trend in the uptake of the technologies by farmers, the widespread adoption of agro-forestry technologies by many more smallholder farmers is nonetheless constrained by several challenges such as local customs, institutions and policies at the national level (Masangano and Miles, 2004).

The uptake of agro-forestry technologies is more complicated than those of annual crops (Mercer, 2004; Scherr and Müller, 1991) because of the multi-components and multi-years through which testing, modification and uptake of the technologies takes place. As a result, a precise definition of the "adoption" of agro-forestry often poses a challenge. Some authors (for example, Adesina and Zinnar, 1993; Franzel et al., 1999) distinguished between "testers", "experimenters" and "adopters". Other authors [for example, Ajayi et al. (2003)] regard the uptake of agro-forestry technologies as a continuum and posit that farmers can be assigned positions in the continuum based on the extent of uptake of the different components of the technology.

The biophysical performance and the relevance of the agro-forestry technologies in Southern Africa have been well demonstrated in the past one and half decades (Kwesiga and Coe, 1994; Mafongoya et al., 2003; Kwesiga et al., 2003). Research and development activeties on agro-forestry have expanded to include questions on farmer uptake, adoption and impact of the technologies. Farmer adoption and the impact of new farm technologies on adopters are some of the key measures of the overall success or otherwise of such innovations. In a strict sense therefore, different degrees of "adoption" of agro-forestry technologies can be identified. A recent study in Zambia (Ajayi et al., 2006) reveals that the key criteria that farmers themselves use for assessing the level of "adoption" of agro-forestry technologies are as follows: good management (timely weeding and pruning) of agro-forestry fields, density and mix of trees species planted, number of years of continuous practice of agro-forestry and size of the land area that a farmer assigns to agro-forestry.

Some local customary practices and institutions prevailing in the sub-region, incidence of bush fires and browsing by livestock during the dry season, and absence of perennial private right over land limit the widespread uptake of some agro-forestry technologies (Phiri et al., 2004). Animals destroy the trees after planting either by browsing the leaves and removing the biomass or by physically trampling over the plants. Community's institutional regulations for fruit collection, land and tree tenure all affect the individual farmer's decision to invest in establishing an indigenous fruit tree orchard. Land ownership is also likely to influence adoption if the investments are tied to the land and the benefits of these investments are long term (Fernandez-Cornejo et al., 1994).

Tenants are less likely to adopt technologies that require high investments on the land and whose benefits are long term because the benefits of adoption do not necessarily accrue to them. However, agro-forestry institutions have been working in collaboration with traditional rulers, government officials, community-based organizations, NGOs and national partners to resolve these institutional bottlenecks (Ajayi and Kwesiga, 2003).

Agro-forestry technologies are generally incipient technologies and relatively new phenomenon compared with conventional agricultural practices that farmers have known, been used to and have received training for a much longer period. Unlike annual crop production technologies and conventional soil fertility management options, fertilizer trees systems require skills in terms of management of the trees. Capacity for doing this need to be built at the national level (Ajayi et al., 2003), the costs of providing information greatly decrease over time, but they are critical when helping farmers get started with the practice.

One of the greatest constraints of some agro-forestry technologies is the lack of access to quality seeds (Thangata and Alavalaparti, 2003). Unlike the seeds of annual crops in which established institutions exist to promote them and private sector organizations have been engaged in their multiplication and distribution, there is little or no institutional structure to make the seeds of agro-forestry available “off the shelf”.

Over several years, there have been structural shifts towards “quick fixes” and technologies that render immediate benefits (Ajayi and Kwesiga, 2003). The opportunity of agro-forestry technologies to provide some medium and long term benefits to individuals and the public simultaneously is not as yet well communicated to many stakeholders.

The human capacity, infrastructures and institutional supports for agro-forestry are not as well developed as for annual crop technologies (Gladwin et al., 2002). Such missing support include well developed input and output market to enhance access of small-holder farmers to ensure that they get the price premium for their crop produce. Labour intensive innovations will likely be adopted by households with high access to farm and off-farm labour. Fernandez-Cornejo et al. (1994) identified another type of farm labour that influences technology adoption, that is, the labour provided by the farm operator him/herself. This kind of labour is often called operator labour and is thought to have a positive impact on level of adoption of agro-forestry technologies because the technologies have a high requirement of operator’s time.

In general, the factors which influenced farmers’ adoption decision with regards to agro-forestry technologies fall within four broad categories. These are those which exert (1) positive influence on farmers’ adoption decisions, (2) negative impacts (3) ambiguous or no direct effect (4) systemic influence on all types of households in a given community and spatial locations (Place and Dewees, 1999; Place, 1995).

RESEARCH METHODOLOGY

Information of the trained agro-forestry change agents was obtained from Agricultural Research and Extension Services (AGRITEX). A change agent team consisted of 30 people, 2 local extension agents, 4 political leaders and 24 farmers drawn from the five wards. The change agents were drawn from at most four villages per ward from which two villages were randomly chosen and these constituted a sub-population of the study. From each of these villages, 30 farmers were sampled using snowball sampling technique. Snow ball sampling was used to identify farmers trained by farmer trainers in the five wards. Random sampling of farmers was done when the snowballing ends. The villages had at least one trained change agent. The training was either from ICRAF, other organizations or farmer to farmer training.

Thirty farmers were interviewed using structured questionnaires. The first farmer to be interviewed in a village was a trained change agent and then the next target was obtained by snowballing. Random picking was done in cases where the snowballing ended before the 30 farmers were interviewed. Trained and untrained farmers were purposefully selected and interviewed. A total of 300 farmers, which approximately represented 3.45% of all smallholder farmers in the district were interviewed in this study.

Data from the questionnaires was analyzed using Statistical Package for the Social Science (SPSS) and Microsoft Office Excel 2003. Frequencies of responses graphs were obtained and cross-tabulations were done to determine the relationships among variables. Logistic regression ($P = 0.05$) was done to find factors that predicted the likelihood to adoption of the agro-forestry technologies.

RESULTS AND DISCUSSION

Level of farmer awareness on agro-forestry technologies

Three criteria, that is, able to remember, describe and state use of a technology were used to assess awareness among farmers. A farmer was therefore regarded as being aware of an agro-forestry technology when he/she was at least able to remember the technology.

Based on these criteria, three levels of awareness were assessed as follows:

1. High awareness: able to remember, describe and state use of a technology.
2. Medium awareness: able to remember and describe only.
3. Low awareness: able to remember only (Figure 1 and Table 1).

Adoption of agro-forestry technologies

A farmer was considered as having adopted an agro-forestry technology when he/she has practiced it for at least 3 years in a row and the level of adoption was based on land size under a technology. According to this land size, two levels of adoption were classified as follows:

1. Low adoption - 0- 0.01 hectares (area under a technology)
2. High adoption - > 0.01 hectares (area under a technology) (Table 1 and Figure 2).

Level of adoption of the agro-forestry technologies among farmers

Live fence had the highest number (15.6%) of farmers

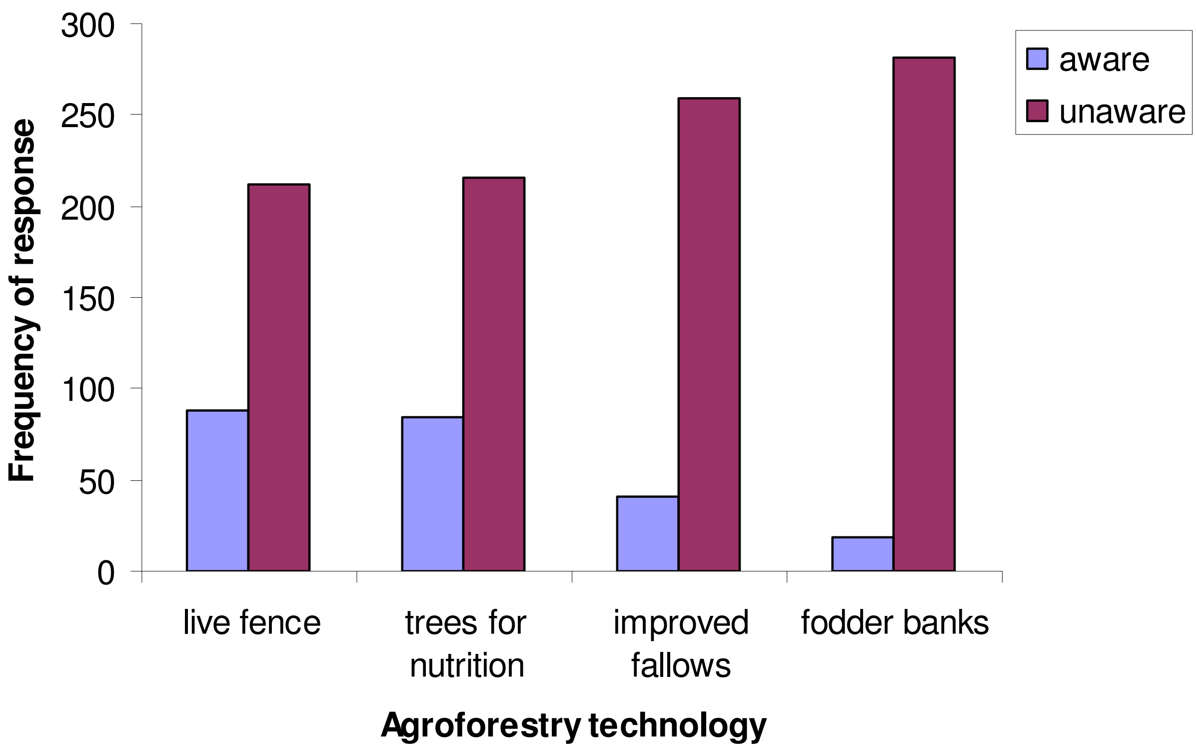

Figure 1. Frequency response on awareness to agroforestry. None of the four technologies had at least 50% of the respondent who indicated awareness.

Table 1. Households' frequency (%) response to visit by agro-forestry change agents.

Technology	Yes	No
Live fence	36	64
Trees for nutrition	34.7	65.3
Improved fallows	24	76
Fodder banks	11.7	88.3

Most farmers indicated that they had been visited by agro-forestry change agents on live fence while least number was visited on fodder banks.

who indicated high level of adoption and fodder banks had the least number (2%) of farmers. Highest number (24.3%) of farmers with low level of adoption was on trees for nutrition, while improved fallows had the least number (3%) of farmers (Figure 2).

Level of adoption between trained and untrained farmers

More of trained farmers had both lowly and highly adopted than untrained farmers on all the four technologies and non-adopters were more on untrained farmers than on trained farmers (Table 2).

Factors influencing adoption of agro-forestry technologies

Logit model

The likelihood of observing the dependant variable (P_i) was tested as a function of variables which include sex, age of house hold head, household size, marital status, occupation, decision marker, permanent land tenure, belonging to a farming group, level of formal education acquired, awareness to AF, training on AF technologies, seed shortages, drought, tree adaptability to local conditions, existence of prohibitive local institutions and labour intensiveness of the technologies. Therefore:

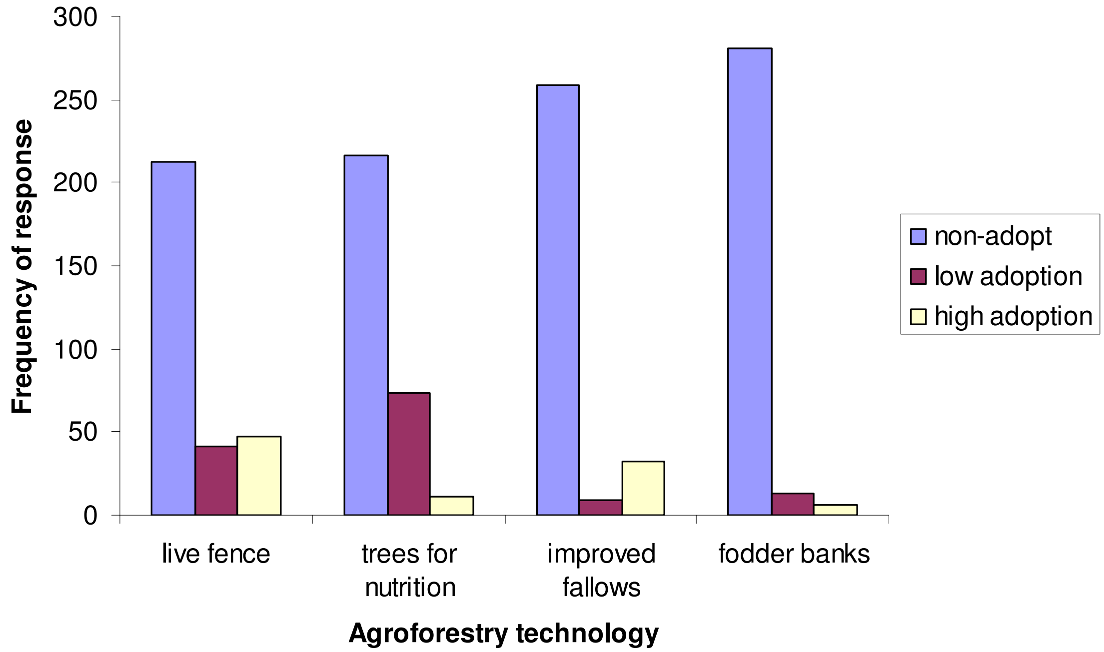

Figure 2. Frequency response on level of adoption on the technologies.

Table 2. Household (%) response on level of awareness to agro-forestry technologies.

Technologies	Level of awareness			
	Unaware	Low	Medium	High
Live fence	64	8	9	19
Trees for nutrition	65.3	8.7	10	16
Improved fallows	76	4.6	6.6	12.7
Fodder banks	88.3	9.7	1.3	0.7

$P_i = F(Z_i) = F(a + BX_i) = 1 / \{1 + \exp(-Z_i)\}$ …………… [1]

Where: $F(Z_i)$ = the value of the standard normal density function associated with each possible value of the underlying indexes Z_i. P_i = the probability of observing a specific outcome of the dependant variable (adopting an agro-forestry technology such as improved fallows) B = regression parameters to be estimated. X_i = set of explanatory variables. a = regression intercept. BX_i = linear combination of independent variables so that:

$Z_i = \text{Log}\{P_i / (1-P_i)\} = B_O + B_1X_1 + B_2X_2 + \ldots + B_nX_n + U$………………..[2]

Where: i = 1, 2, … ,n are the observations. B_0 = constant. B = the regression parameter to be estimated. BX = linear combination of independent variables. Z_i = the log odds of choice for the i^{th} observation. P_i = the probability of observing a specific outcome of the dependent variable (adoption). X_n = the n^{th} explanatory observation. U = the error term.

The dependant variable, Z_i in [2] above is the natural logarithm of the probability that a particular choice (adoption of agro-forestry technology) would be made (Field, 2005).

Awareness was statistically significant ($p < 0.05$) on all the four agro-forestry technologies introduced in Buhera, while other variables were peculiar to some technologies (Table 3). Besides awareness, adoption of live fence was significantly predicted by land ownership, training, drought, labour and local institutions, while trees for nutrition was predicted by employment status, belonging to farm group, land size, training, labour and local institutions. In addition, adoption of improved fallows was predicted by employment status, belonging to farm group

Table 3. Household frequency (%) on adoption of the agro-forestry technologies.

Agro-forestry technologies	Option	
	Adopted	Non-adopters
Live fence	29.3	70.7
Trees for nutrition	28	72
Improved fallows	13.7	86.3
Fodder banks	6.3	93.7

Table 4. Frequency (%) response on level of adoption between trained and untrained farmers.

Agro-forestry technology	Trained and non-adoption	Untrained and non-adoption	Trained and low adoption	Untrained and low adoption	Trained and high adoption	Untrained and high adoption
Live fence	1.7	69	7.3	6.3	8.7	7
Trees for nutrition	2	70	17	7.3	2.7	1
Improved fallows	7.3	79	2	1	9.4	1.3
Fodder banks	9.7	84	3	1.3	1.7	0.3

and land size. The adoption of fodder banks was also predicted by employment status and training (Table 3).

Level of farmer awareness to agro-forestry technologies

The study showed that the awareness to agro-forestry technologies among farmers is low and this could be due to ineffective communication about the long term benefits of agro-forestry technologies between the change agents and other farmers. This agrees with Govere (2003) when he noted that although agro-forestry is an age-old practice, many farmers are yet to receive communication about the technologies. The ineffectiveness in communication could have been due to farmers' attitude towards the agro-forestry technologies; they tended to seek information on technologies with immediate benefits that could not be the agro-forestry technologies. In support of this, Ajayi and Kwesiga (2003) noted that for several years, there have been structural shifts towards quick fixes technologies.

Level of adoption between trained and untrained farmers

The study showed higher adoption of agro-forestry technologies among trained than untrained farmers (Table 2). This could be due to the fact that the training had reduced the perceived complexity among farmers and enhanced the observability and adaptability of the technologies to them. Rogers (1995) found that most people are afraid of adopting new innovations due to the fear of unknown future risks. This could have resulted in the low adoption among untrained farmers.

The farmers who adopted without formal training could have got information during informal group meetings or by seeing the technologies from other farmers and developed interest on them resulting in adoption or this could be spontaneous adoption. This conforms well to Rogers (1995), who noted that a highly visible innovation will be adopted more readily. On the other hand, Snapp et al. (1998) noted that the slow growth of trees make their effects and rewards difficult to observe; this could have resulted in low adoption among informally-trained farmers. Farmers who discontinued with technologies could have discovered that the demands of the technologies were difficult to meet and were not feasible to continue. This was supported by Swinkels and Franzel (1997) when they argued that for an innovation to be adopted, it has to be feasible in order for it to be implemented in a farmer's situation.

Factors influencing adoption

The results showed increased likelihood in adopting the agro-forestry technologies with awareness (Tables 3 and 4) suggesting that since agro-forestry is still a new phenomenon among farmers, communication of the technologies was therefore very important before adoption. This agrees well with Van den Ban and Hawkins (1998) who stated that the initial stage for adoption process is awareness. Govere (2003) also agreed with the need for farmer awareness about agro-forestry technologies through effective communication in order for adoption to take place.

The study revealed increased likelihood to adopt live fence when farmers had permanent land ownership suggesting that since agro-forestry technologies require high investments on land and the benefits normally come after a long time lapse, so farmers needed to be assured that they will enjoy the benefits once they have embarked on such technologies. This is in congruence with Fernandez-Cornejo et al, (1994), who found that land ownerships is likely to influence adoption and tenants are less likely to adopt technologies that require long term high investment on land.

The increased likelihood to adopt live fence and trees for nutrition with the absence of prohibitive local institutions could mean that existence of some national and local institutions discourages farmers from growing trees in their fields. This agrees with Phiri et al. (2004), when they noted that local institutions such as those dealing with incidence of bush fires, browsing by livestock during the dry seasons and absence of perennial private right over land limits the widespread uptake of some agro-forestry technologies.

During the dry seasons, animals are allowed to move freely in the fields destroying the trees after planting either by browsing the leaves and removing the biomass or by physical trampling over the plants. These could have been a cause for low adoption of some agro-forestry technologies among farmers.

The increased likelihood to adopt trees for nutrition and improved fallows when farmers belonged to a farming group, could suggest that the groups were sources of information about the technologies and moreover, the current extension system emphasizes on the group extension approach (Mwenye, 2003). During the group meetings, farmers had time to interact and share information that they could have discussed on the agro-forestry technologies resulting in awareness leading to adoption.

An increased likelihood to adopt improved fallows and fodder banks with unemployment of farmers could suggest that most of the unemployed farmers in the district have low income, so they cannot afford to buy expensive synthetic fertilizers and feeds. They could only depend on cheaper ways to solve their problems through agro-forestry. On the other hand, employed farmers could afford the prestigious fencing materials since their incomes are higher than the unemployed ones. Therefore, agro-forestry provides affordable means to solve such problems as many authors agreed that agro-forestry technologies offer opportunities of improving the quality of the resource poor farmers (Young, 1997).

Increased likelihood to adoption live fence and trees for nutrition among farmers with no drought occurrence and when labour was unlimited, could suggest that technologies that required high labour are avoided regardless of their benefits. This could be due to the fact that many farmers do not have enough labour to tally with the technological demands since most of the able bodied younger people had migrated to the growth point and big towns for employment. Most of the communal farmers are poor and they could not afford to hire off-farm labour. Under such circumstances, the technologies were incompatible with the socio-economic environment of the farmer and farmer needs and objectives, thus they discontinued or did not try.

Drought prevalence in the district could have deterred the farmers from adopting the technology as it would be difficult to establish the trees under such harsh conditions. Buhera experiences high temperatures for a greater part of the year and this could have created a need to irrigate the trees so frequently, thereby increasing labour and water needs competition between people and trees. The technology should be compatible with the physical environment of the area in which it is introduced. The tree species (*Jatropha carcus*) used for live fence and trees for nutrition (*Cajanus cajan* and *Moringa olifera*) were compatible with the physical environment of Buhera and hence they thrived even during drought periods. This might have motivated the farmers to adopt the technologies better than improved fallows and fodder banks. On the other hand, tree species for improved fallows and fodder, for instance *Acacia anguistissima,* could have proved incompatible to the physical environment of Buhera resulting in better adoption of live fence and trees for nutrition. This was supported by Rogers (1995) and Strong and Jacobson (2006) who concluded that innovations which are difficult to understand and implement are less likely to be adopted than technically simple innovation. Adoption of live fence was high because of the need to protect fields from the stray animals during dry seasons. This would reduce time spent on chasing away animals from trees meant for either improved fallows or fodder banks.

Agro-forestry trees need to be drought tolerant and the technologies must be adaptable to dynamic user's demands. The low uptake of improved fallows and fodder banks could be due to incompatibility and less adaptability of the technologies to farmers' situations; for instance, most small-holder farmers have no cattle, so they could not worry about fodder banks.

Conclusion

The study showed low level of awareness to agro-forestry technologies. Live fence and trees for nutrition were the most practiced technologies and fodder banks were the least practiced technology in the district. Adoption was higher on trained than untrained farmers on all the four practiced technologies.

Land ownership, awareness, training, drought, labour and local institutions influenced adoption of the live fence. Belonging to a farm group, awareness, training, land size and local institutions influenced adoption of trees for nutrition. Employment status, belonging to a farm group, awareness and land size influenced adoption of improved fallows. Adoption of fodder banks was influenced by employment status, awareness and training.

There is need to set well linked communication channels, for example mass media, and provide in service training to agricultural extension officers in order to pass information on agro-forestry benefits to many stakeholders.

It is of paramount importance for donors to capacitate farmers before leaving and set exit strategies in place so as to reduce level of discontinuation among farmers.

Policy markers should consider agro-forestry when formulating policies (national and local institutions) by granting of permanent land ownership to farmers and privatization of livestock during both summer and winter seasons so as to reduce complications to farmers when adopting the technologies.

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