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Socioeconomic Indicators of Bamboo Use for Agroforestry Development in the Dry Semi-Deciduous Forest Zone of Ghana

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Abstract

Bamboo agroforestry is currently being promoted as a viable land use option to reduce dependence on natural forest for wood fuels in Ghana. To align the design and introduction of bamboo agroforestry in conformity with farmers' needs, perceptions, skills and local cultural practices, information on its acceptability and adoption potential among farmers is necessary. It is therefore the objective of this study to (1) describe bamboo ethnobotany and (2) assess socioeconomic factors that affect the acceptability and adoption of bamboo and its integration into farming practices. Accordingly, information has been collected from 200 farmers in the dry semi-deciduous forest zone of Ghana. The study identified the socioeconomic risks and uncertainties as well as biophysical factors that are likely to influence the potential adoption of bamboo agroforestry in the study region. Gender, age, farmers' known uses of bamboo, the practice of leaving trees on farmlands, farmers' networking and access to extension services, land availability and ownership by farmers were identified as suitable predictor variables for the adoption of bamboo agroforestry. It is envisaged that bamboo agroforestry is a good bet in the DSFZ though there is the need to explore domestic energy (fuelwood) provision and substitution potential in order to have a broader picture of the technology.

***Keywords*: adoption; land-use; degradation; ethnobotany; networking; agroforestry; dry semi-deciduous**

1.0 Introduction

Deforestation emanating from excessive wood extraction for wood fuels continues to be a major agent for land productivity decline as well as environmental degradation world-wide [1, 2]. In Ghana, deforestation rate stands at 112.54 km^2 per annum largely attributed to expansion of agriculture and wood harvesting for charcoal production. According to Ghana Population & Housing Census [3], about 73% of rural households and 48% of urban households used firewood and charcoal, respectively, for cooking. It is also estimated that 79% of the country's charcoal supply comes from ecologically more fragile savanna zones, 15% from the semi-deciduous zones and only 6% from the rain forest. Charcoal production is the next most dependent livelihood of the dry semi-deciduous forest zone (DSFZ) after farming [4]. Farmers engage in charcoal production during the lean farming season to support income from farming activities.

Recently, government and scientists are advocating the production and use of bamboo to reduce pressure on the major commercial timber species sourced as fuelwood. Due to development initiatives, such as the Bamboo and Rattan Development Programme (BARADEP), bamboo plantation establishment increased in Ghana. These bamboo monocropping systems, however, may impact adversely on food security if integrated systems with arable crops and/or livestock are not given due consideration. In Asia, the integration of bamboo within agricultural systems is confirmed a suitable approach for increased productivity of food crops and non-food biomass [5]. In Ghana, science-based bamboo agroforestry systems are limited and data to prove their suitability are lacking. The International Network for Bamboo and Rattan (INBAR) is currently piloting a bamboo agroforestry system as a land use option for food security and renewable energy production in the DSFZ of Ghana. In view that bamboo agroforestry is new in Ghana; there are no data that provide information on its acceptability and adoption potential among farmers in the region. However, such information is necessary to better align the design and introduction of bamboo agroforestry in conformity with farmers 'needs, perceptions, skills and local cultural practices. It is therefore the objective of this study to (1) describe bamboo ethnobotany and (2) assess other socioeconomic factors that affect the acceptability and adoption of bamboo and its integration into local farming practices in the DSFZ of Ghana.

2.0 Conceptual framework of the study

Different frameworks and approaches have been used for the analysis of adoption of agroforestry technologies. [6] grouped these approaches into three major types: *top-down* interventions, *populist or farmer-first*, and *neoliberal approaches*. Building from the farmer-first and sustainable livelihood principles but extending and incorporating important elements from various theories and practical realities, [7] have developed a broader conceptual framework for the analysis of factors conditioning the adoption and adaptation of smallholder natural resource management technologies in general. Given the focus of this study, the conceptual framework developed by [8] and modified by [9] is appropriate. The framework focuses on the adoption of already existing agroforestry technologies. However, such a framework is too broad and complex to analyze the adoption behavior and institutional setup of agroforestry technologies concurrently because institutional arrangements other than farmers were not directly evaluated to see their impact on adoption. Again this study explored the willingness of farmers to accept bamboo agroforestry in the face of current wood energy needs and diversified income expectations of farmers in the DSFZ. This present study incorporates the interaction of explanatory variables such as farmer characteristics, cropping systems, livestock keeping, farming practices, bamboo ethnobotany, farmers' networking and access to extension, land tenure system and labour availability to predict the potential adoption of bamboo agroforestry in the DSFZ (Figure 1). These interactions facilitate farmer decision processes and culminate into either adoption or non-adoption of technologies.

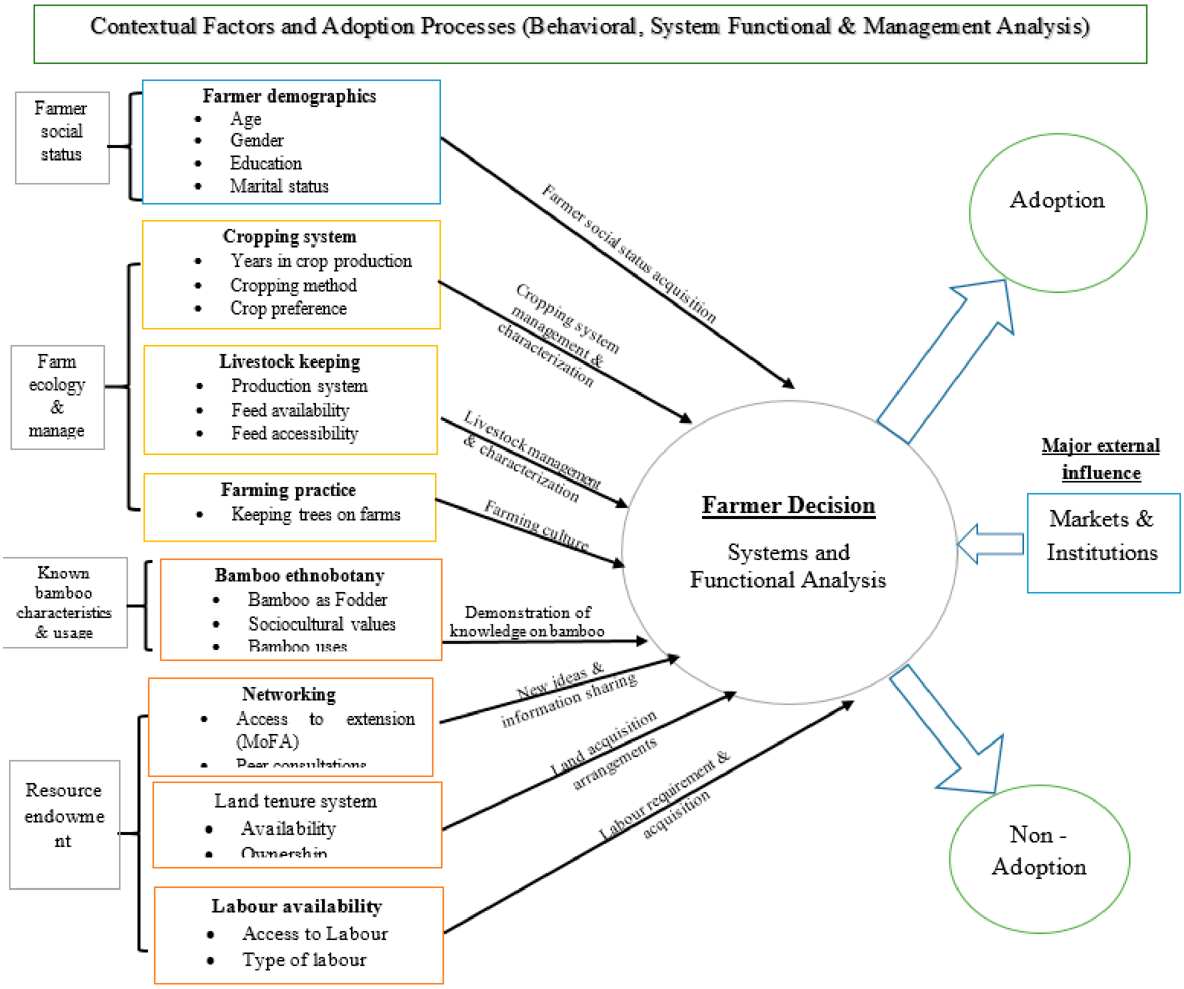

Figure 1. Conceptual framework for the analysis of potential bamboo agroforestry adoption Source: Adapted and modified from Zerihun *et al.* [9]

3.0 Materials and methods

3.1 Study area

The study was conducted in the Mampong, Ejura-Sekyedumase Municipals and Sekyere Central, Kumawu-Sekyere and Sekyere-Afram Plains Districts of Ghana (**Figure 2**). The study area falls within the dry semi-deciduous forest zone of Ghana (DSFZ). It is characterized by a bimodal rainfall pattern with an average annual rainfall of 1,270 mm. The major rainy season starts in March with a peak in May. There is a minor dint in July and a peak in August, ending in November. December to February is the dry season, which is warm and dusty (in the driest period). The area is characterized by a mean annual temperature of 27 ºC with variations in mean monthly temperature ranging between 22 ºC and 30 ºC throughout the year. The soil type of the study site is sandy loam (Ejura – Denteso Association).

Subsistence agriculture is the major economic activity employing about 65% of the population. The bulk of agricultural production is from manually cultivated rain fed crops. The intercropped range of crops vary with greater potentials for maize, cowpea, cassava, yam and plantain. The DSFZ was chosen because of its unique characteristic features which combine those of the forest and savanna zone and is the transition between the two zones.

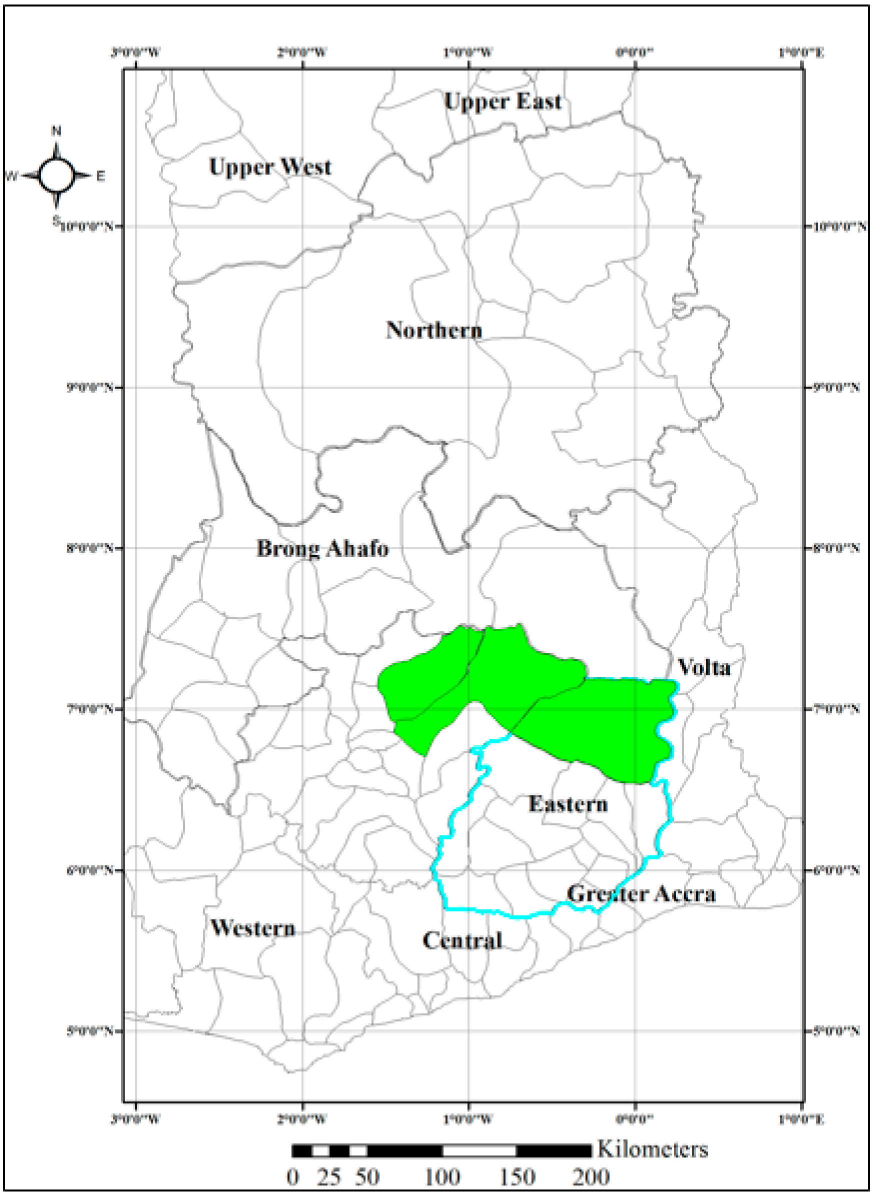

Figure 2: District Map of Ghana Showing the study zone (green) in the DSFZ.

3.2 Data collection, sampling procedure and analysis

A systematic purposive sampling method was adopted to select 200 households with farming as their primary occupation. Farmers (specifically, vegetable, yam, beans, and maize and cassava farmers) from 20 communities of five districts (4 from each district) were selected for a semi-structured questionnaire survey. The number of households interviewed in each community was estimated according to the recommendations of [10]:

$$n = \frac{N}{1+N\,(e)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where n is the sample size, N is the population size, and e is the level of precision equal to 0.05 at 95% confidence level.

A semi-structured questionnaire was administered during the survey to obtain information on the socio-economic variables that are likely to influence adoption of bamboo agroforestry. Behavioral Differential Model fits for the present study and dichotomizes the potential adoption of bamboo agroforestry by assigning a value of 1 if the farmer is willing to plant bamboo on-farm (potential adopter) and 0 if unwilling to plant bamboo on farm (potential non-adopter).

Primary data collected were analyzed in descriptive statistics such as frequencies, means standard errors, cross tabulations and a dichotomous logistic model technique [11] was used to regress adoption of bamboo agroforestry on a set of explanatory variables namely, age of the farmer, education level, extension service contact, farmer networking system, community labour availability, size of family labour force, gender, land availability, land tenure system and arrangement, bamboo ethnobotany and agronomic practices (cropping system patterns, farming practices) at 5% level of significance using Statistical Package for Social Sciences (SPSS ver. 20.0) to establish the socio-economic profile of the area under study. Results from logistic regression analysis are presented in **Appendix 1**.

3.3 Logit model specification and working definitions

Adoption of agroforestry technology was conceptualized as a function of farmers' characteristics. The decision to adopt agroforestry technologies is a behavioral response arising from a set of alternatives and constraints facing the decision maker as shown by [11] in the Behavioral Differential Model.

For purposes of this study, adoption of bamboo agroforestry shall mean the affirmation to the question "Would you plant bamboo on your farm?" Bamboo ethnobotany shall mean the knowledge of the characteristics (physiology) of bamboo, known benefits or uses of bamboo. The socio-economic factors influencing the potential adoption of bamboo agroforestry technology were analyzed using maximum likelihood estimation of a logistic regression model. The factors hypothesized to predict bamboo agroforestry adoption are analyzed by grouping the factors into eight categories. The categories of the explanatory variables to predict bamboo agroforestry are: *farmer demographics*, *cropping system*, *livestock keeping*, *farming practice*, *bamboo ethnobotany*, *farmers' networking and access to extension*, *land tenure system* and *labour availability*. The modeling approach considers adoption as a dichotomous dependent variable, which takes '1' if adoption is present and '0' otherwise. The model produced in logistic regression is nonlinear and the outcome variable, Y, is the probability of having one outcome or another based on a nonlinear function of the best linear combination of predictors, with two possible outcomes. As specified in [12, 13] and adapted from [9] the simple logistic regression model has the form:

$$ln\left(\frac{\pi}{1-\pi}\right) = \log(odds) \rightarrow \log Y = \alpha + \beta X \ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{2})$$

Taking antilog on both sides of equation (1), then the probability of the occurrence of the outcome of interest can be predicted as shown by equation (2) below:

$$\pi = P(Y) = \frac{e^{\alpha+\beta x}}{1+e^{\alpha+\beta x}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (\mathbf{3})$$

Where 'π' is the probability of the outcome of interest ($Y = 1$); 'α' is the Y intercept (constant of the equation); 'β'represents the coefficients of the explanatory variables (i.e. vector of coefficients to be estimated); 'e' represents a set of predictors and it is the base of the system of the natural logarithms. Taking the log of equation (2), the logit model for estimating coefficients can be derived as:

$$ln\left(1+\frac{P(Y=1)}{P(1-P)}\right) = \alpha * +\beta 1 * X1 + \beta 2 * X2 + \ldots \beta n * Xn, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (\mathbf{4})$$

Equation (4) was estimated using statistical software to find the best linear combination of predictors to maximize the likelihood of obtaining the observed outcome frequencies. In binary regression models, goodness of fit (R^2 values) is not important. The important feature is the expected signs of the regression coefficients and their statistical and/or practical significance. Therefore, the interpretation focuses on statistical significance, direction of the regression coefficients (either positive or negative), and the odds ratios [Exp (β)]. The omnibus test shows whether the explained variance is statistically higher than the unpredicted variance. The Wald test is used to determine the statistical significance for each of the independent variables. The pseudo R-squared statistics (Cox and Snell R^2 and Nagelkerke R^2) are used to predict the significance of the independent variables to the model. The higher the R-square statistics, the better the model fits the data and accounts for a significant amount of the variation.

The main limitation of the questionnaire survey was that it could not obtain all information required for the causal analysis of bamboo integrated farming system problems, because bamboo agroforestry is yet to be practiced. In view of this limitation, detailed information on traditional farming practices adopted by farmers and their bamboo ethnobotany, energy (fuelwood) needs and crisis, labour needs and management, soil fertility and management and crop yield trend were collected through short group discussions held with farmers to validate the answers in the questionnaires.

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4.0 Results and discussion

4.1 Respondents' demographic information

Descriptive statistics of age characteristics of the respondents show that the majority were in the age group of 31-45 years (39.5%, n = 79), 30% (n = 60) accounted for those in 45-60 years, above 60 years and 18-30 years recorded percentage distributions of 22.5% (n = 45) and 8.0% (n = 16) respectively. Gender analysis shows that males dominate with 80% (n = 160; females: 20%, n = 40) in the current study. Moreover, 54% (n = 108) of the farmers had obtained only primary education, 18.5% (n = 37) accounted for those who had secondary education and 1.0% (n = 2) had obtained tertiary education. However, 26.5% (n = 53) respondents had not obtained any formal education. Most of the respondents are married (83%, n = 166), divorced or widowed accounted for 6% (n = 12) each respectively whilst 5% (n = 10) of the total respondents are singles.

4.2 Farming practices as indicator for adoption of bamboo agroforestry.

The omnibus tests of model coefficients indicate that the model containing all the predictors is significant (X^2 = 116.085, df = 2) at 5% level and gives 79.2% correct predictions (Table 1). The model indicates that keeping of trees on farms (1.02 $\pm$ 0.01) and the type of tree species left on farms (1.00 $\pm$ 0.02) are statistically significant at 5% level. Keeping trees on farms had a significant correlation on adoption of bamboo agroforestry. The study shows that out of the 194 farmers who leave trees on their farms, 168 (84.8%) are potential adopters and 26 (13.1%) are potential non-adopters. However, all the farmers (4) who do not leave trees on their farms are potential adopters (n = 4, 2%). Trees species left on farms (**Figure 3**) include: *Ficus exasperata* (30%, n = 60), *Milicia excelsa* (12%, n = 24), *Triplochiton scleroxylon* (18%, n = 36), *Terminalia superba* (8%, n = 16), *Ceiba pentandra* (15%, n = 30), *Nesogodonia papaverifera* (8%, n = 16), *Pycnanthus angolensis* (9%, n = 18). The farmers asserted the reasons for leaving trees on farms are for economic reasons, shade, soil and water conservation, fodder and fuelwood provision. Trees maintain and improve soil fertility as they contribute to nitrogen fixation and nutrient uptake from deep soil horizons [14]. Also, trees improve the structural properties of the soil due to their rooting systems which lessen compaction, reduce surface runoff and erosion, and improve water permeation [15]. Alavalapati and Nair [16] recounted that farmers mostly implement agroforestry systems to provide household needs such as food, fodder, and fuelwood. This system may not be imperative to the conventional agroforester such as social benefits or community acceptability of the system [17, 18].

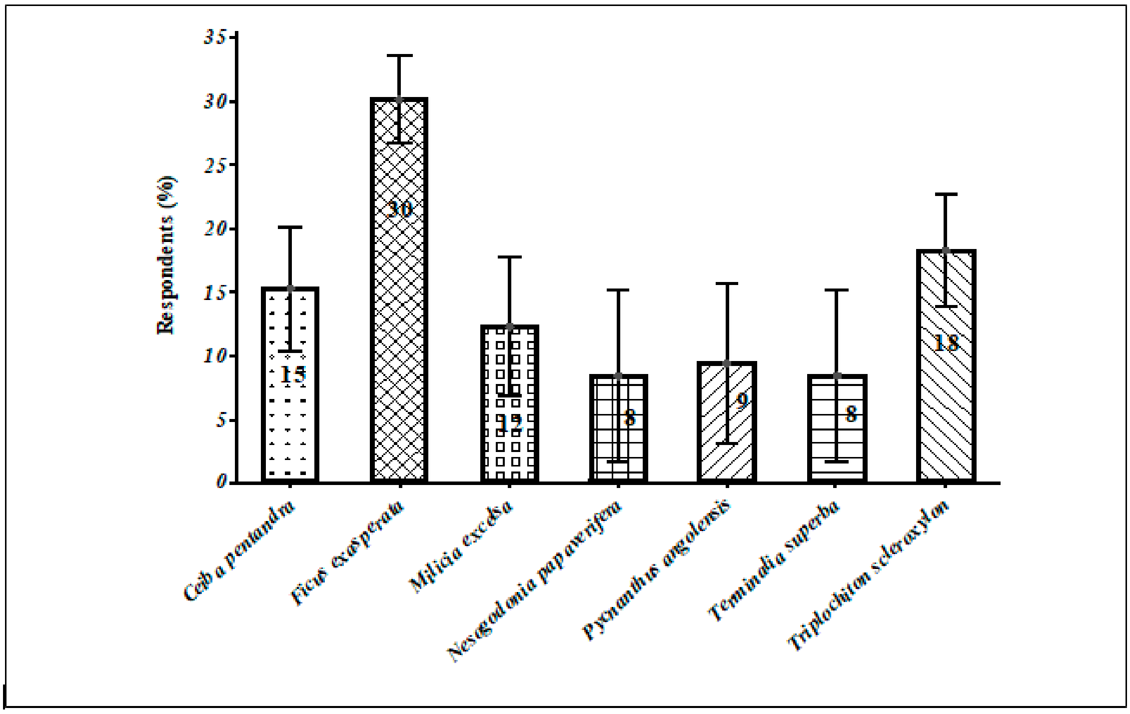

Figure 3. Preferred tree species left on farms by respondents

4.3 Farmers' bamboo ethnobotany as a predictive variable for adoption of bamboo agroforestry

The test of model coefficient shows significant ($X^2 = 12.932$, df = 11) results and gives 88.92% correct predictions (Table 2). Farmers' readiness to try bamboo fodder on their livestock (1.22 $\pm$ 0.033), readiness to incorporate bamboo cultivation on farms for fodder (1.27 $\pm$ 0.035), the visibility of bamboo by farmers (1.06 $\pm$ 0.017), personal planting of bamboo ((1.97 $\pm$ 0.011), had personally used or seen someone using bamboo (1.20 $\pm$ 0.028) and farmers' readiness to produce bamboo charcoal are statistically significant at 5% level. Out of the 186 farmers, 164 (82.8%) are potential adopters and 22 (11.1%) are potential non-adopters.

This implies that holding other factors in the model constant, farmers (n = 5, 2.5%) who have planted bamboo before have more than 8.364 times likelihood of adopting bamboo agroforestry than farmers (n = 193, 97.5%) who have not personally planted bamboo before at 5% level of significance. Farmers (2.5%, n = 5) who have planted bamboo before are potential adopters. However, those that have not planted bamboo before have 167 (84.3%) potential adopters and 26 (13.1%) potential non-adopters. Similarly, farmers who are ready to produce bamboo charcoal have the likelihood to adopt bamboo agroforestry. Moreover, from the total 159 farmers, 137 (69.2%) are potential adopters and 22 (11.1%) are potential non-adopters. From the 39 farmers who have not used or seen someone using bamboo, 35 (17.7%) are potential adopters whilst 4 (2%) are potential non-density. Ancillary results show that bamboo is used for mounting television poles, props in building, construction of garden fences and storage barns as well as roofing of houses **(Figure 4)**.

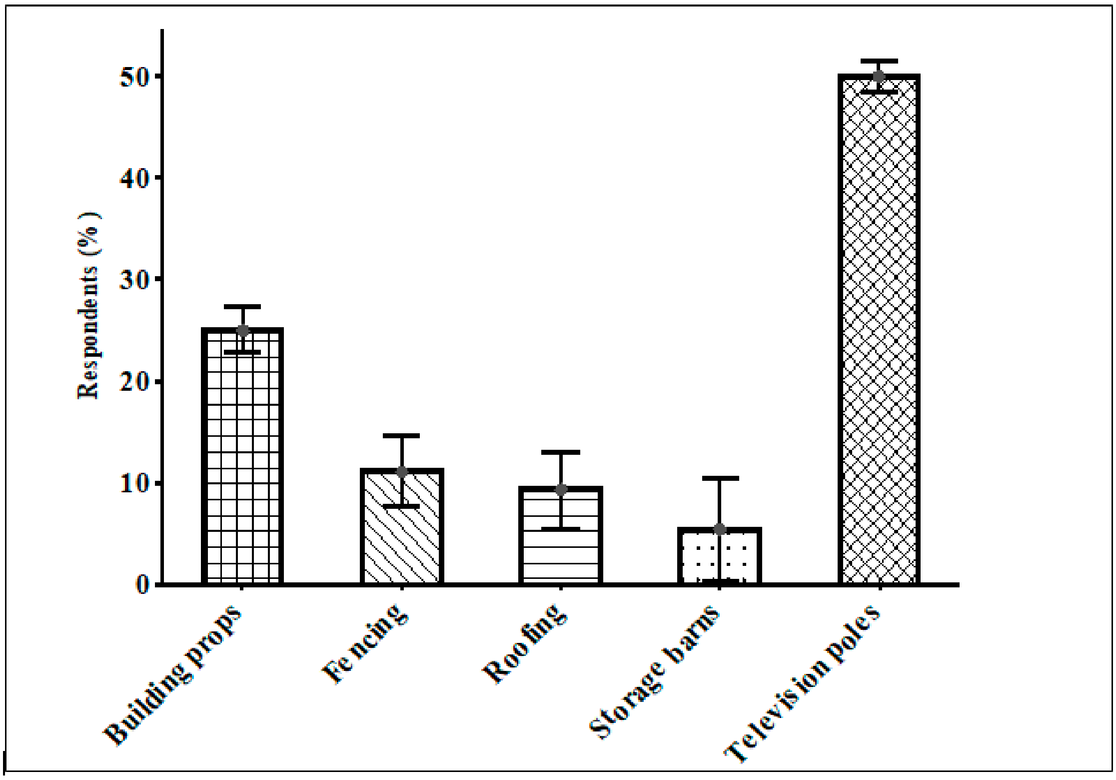

Figure 4. Variations of respondents' known uses of bamboo

Cross-tab analysis shows that 124 (77.5%) farmers are ready to try bamboo fodder whilst 36 (22.5%) are not ready to use bamboo fodder. Out of the 124 farmers, 107 (66.9%) are potential adopters and 17 (10.6%) are potential non-adopters. However, the 36 farmers who claimed they are not ready to try bamboo fodder are potential adopters (22.5%). It is also argue that schemes to inspire tree planting on farms need to be centered on farmers' comprehension of tree management in the perspective of household livelihood strategies, stressing that information about farmers' perceptions of the significance of trees and the constrictions they face in increasing tree resources are rare [19]. A study by [20] reports that rural people are mostly accustomed to tree growing but have divergent attitudes towards trees and this could affect the establishment of trees on farms.

4.4 Socioeconomic indicators of bamboo acceptability and adoptability

4.4.1 Use of farmers' characteristics/ demographics as indicator for adoption.

Table 3 summarizes the logistic regression results on the explanatory variable (farmer characteristics) as a function to predict potential bamboo agroforestry adoption. The omnibus test of model coefficients indicates that the model containing all the predictors are statistically significant (X^2 = 58.041, df = 6) with more than 87.4% correct predictions at 5% level. The results show that age (2.67 $\pm$ 0.065) and gender (1.20 $\pm$ 0.028) of farmers can significantly predict the potential adoption of bamboo agroforestry. The maximum likelihood estimate of the odds ratio [Exp (β)] for age is 1.092 with a positive coefficient of 0.088 signifying that being an adult within the ages of 31-45 years (39.5%, n = 79) increases the likelihood of potential adoption of bamboo agroforestry by 1.092 units than those within the age group of 18-30 years (8%, n = 16) at 5% level, holding other factors constant. Within the ages of 31-45, 53 (26.8%) are potential adopters whilst 24 (12.1%) are potential non-adopters. Also, within the age group of 18-30, 14 (7.1%) are potential adopters whilst 2 (1%) are non-adopters. This is probably because the younger farmers have or see farming as their secondary occupation and use that to supplement their monetary income relative to older farmers whose major source of livelihood is farming and thus likely to adopt agroforestry technologies. This finding is inconsistent with previous studies (Nyirenda *et al*., 2001; Adesina *et al*., 2001), which report that adoption decreases with advanced age.

It is seen from the results that gender had a significant role in adoption of a technology. Majority of the farmers are males (80%, n = 160) of which potential adopters are 134 (67.7%) and 24 (12.1%) are potential non-adopters. Female farmers are 40 and out of these, 38 (19%) are potential adopters whilst only 2 (1%) are non-adopters. Although the female respondents constituted a smaller percentage of respondents, a lot of them show interest in adopting agroforestry technologies. Their decisions, however, depend on the males because the farm lands to a larger extent belong to the male counterparts. This is in agreement with Scherr [21] who found in a study of economic factors in farmer adoption of agroforestry that females are not permitted to make decisions to adopt agroforestry technologies without consulting their husbands perhaps due to the gender-equity issues in the introduction of technology to farmers. The lower agroforestry adoption by women can be attributed to the fact that in the study area, women still do not have headship to land and tree tenure due to the largely patrilineal inheritance systems [22]. This finding is inconsistent with a previous study by [9], which reports that being a male-headed family reduces the likelihood of adopting agroforestry technologies. Education level (2.00 $\pm$ 0.090) and marital status (2.13 $\pm$ 0.041) were not statistically significant at 5% level. This finding is inconsistent with [23, 11], that education is positively associated with probability to adopt agroforestry technologies. They base their argument on the fact that formal and informal training have the potential to increase the rate of adoption by directly increasing awareness, imparting skills and knowledge of the new technology.

Many new practices stemming from a top-down approach and overlooking socio-economic realities often produce disappointing results for executing agencies [24]. However, the comprehension of existing social context can positively influence the acceptance and commitment to local and introduced technologies [25]. Therefore, studies on agroforestry adoption is becoming increasingly important to researchers. It is therefore imperative to monitor the trends in socio-economic research in agroforestry to delineate strengths and weaknesses in the current state of knowledge and to foster guidance for further investigation and more productive feedback loops between researchers and practitioners [26].

4.4.2 Characterizing farmers' cropping systems as a predictor for adoption.

The results in Table 4 show a significant relationship for the model containing all the predictors at 5% level of significance and give a correct prediction of 86.9% per the results from the omnibus tests of model coefficients (X^2 = 35.221, df = 7, p<0.05). The logistic regression results show that farmers' primary objective for growing crops (3.58 $\pm$ 0.049), influences of crop preference (2.65 $\pm$ 0.110), regular cropping method (2.07 $\pm$ 0.106) and meeting of their

crop production target (1.75 $\pm$ 0.031) are statistically significant at 5% level. Farmers who grow crops for subsistence and commercial with priority on commercial are 131 (65.5%) of which 120 (60.6%) are potential adopters and 11 (5.6%) are potential non-adopters **(Figure 5)**.
The study shows that the reason of market value (59%, n = 118) mostly influences farmers' preference of crops. Out of this, 103 (52%) farmers are potential adopters and 15 (7.6%) are non-adopters. Other reasons are duration to maturity (13.5%, n = 27) with potential adopters of 25 (12.6%) and 2 (1%) are non-adopters, sociocultural reasons (11%, n = 22) with 15 (7.6%) potential adopters and 7 (3.5%) non-adopters, easiness of establishment (9%, n = 18) with 16 (8.1%) farmers as potential adopters and 2 (1%) as potential non-adopters, high demand (6%, n = 12) and less production inputs (1.5%, n = 3) as shown in **Figure 6**.

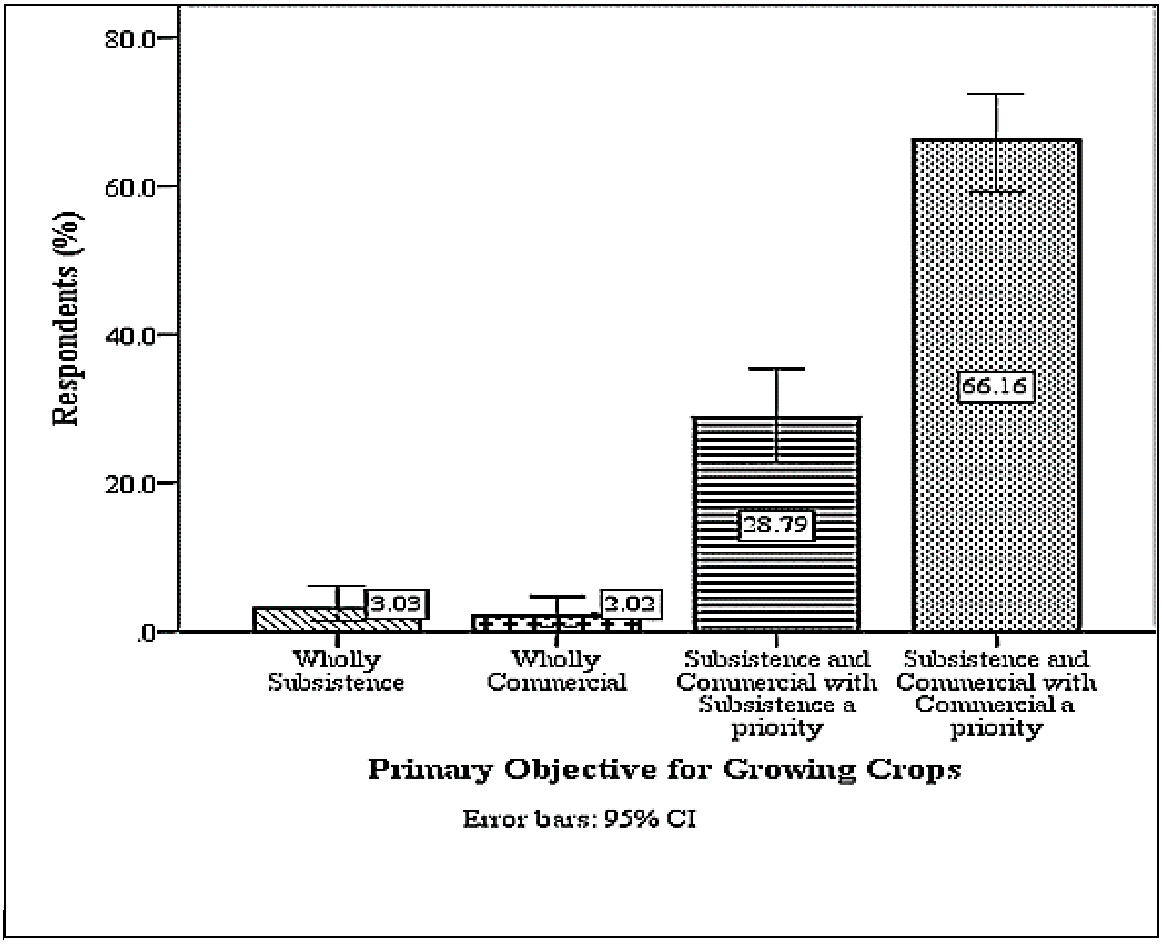

Figure 5: Respondents primary objectives for crops cultivation

Farmers (13%, n = 26) with no regular cropping method reduces the likelihood of potential adoption of bamboo agroforestry than those who have regular cropping pattern (86.9%, n = 172) at 5% level of significance, holding other variables constant. Descriptive analysis **(Figure 7)** show that majority of the farmers practice mono-cropping (54%, n = 108) as their cropping pattern and out of this, 90 (45.5%) are potential adopters and 18 (9.1%) are potential non-adopters; mixed cropping (19.5%, n = 39) with 37 (18.7%) potential adopters and 2 (1%) potential non-adopters; 35 farmers practiced intercropping representing *17.5%.* Out of this, 31

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(15.7%) are potential adopters and 4 (2%) farmers are potential non-adopters. Crop rotation accounted for 16 farmers representing 8%. Fourteen (14) farmers representing (7.1%) are potential adopters and 2 (1%) farmers are non-adopters.

The other explanatory variables: number of years spent by farmers in crop production (3.67 $\pm$ 0.047), soil fertility (1.24 $\pm$ 0.031) and access to fertilizer (1.30 $\pm$ 0.033) are statistically not significant at 5% level. The findings are inconsistent with previous study by [9], who reported that good soil fertility have a decreasing effect on household agroforestry adoption. This implies that the unwillingness of farmers to integrate bamboo in their farming practices cannot be based on the fact that bamboo may exhaust soil nutrients. However, the possible adoption of bamboo integration in farming systems might not be necessarily for soil fertility improvement but for other reasons such as fuelwood needs.

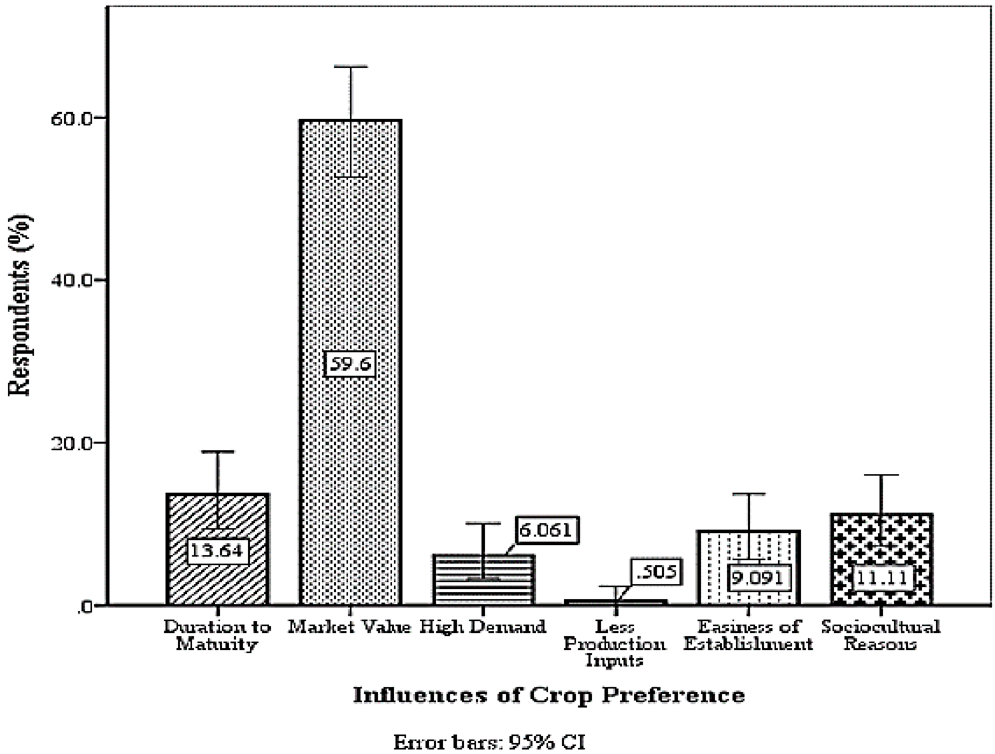

Figure 6: Influences of crop preference for cultivation

4.4.3 Livestock production indicators for adoption of bamboo agroforestry.

In table 5, five variables of livestock keeping are regressed with the dependent variable "will you plant bamboo on your farm" to predict potential adoption of bamboo agroforestry.

The omnibus tests of model coefficient indicate that the model containing all the predictors is statistically significant (X^2 = 41.314, df = 5, $p<0.05$) at 5% level and gives 82.01% correct predictions.

In this model, rearing of animals (1.33 $\pm$ 0.033), the kind of animals reared (1.99 $\pm$ 0.079) and livestock production system (2.45 $\pm$ 0.058) are statistically significant at 5% level. Out of the 131 farmers, the 16 (11.3%) farmers who keep animals under the intensive system are all potential adopters. This might be attributed to the intensity of deforestation in the study region that has aggravated the difficulties in sourcing for feed stocks for livestock and farmers see the need to plant bamboo for fodder production to feed their livestock. Farmers keeping animals under the extensive system are 46 (32.4%) with 37 (26.1%) potential adopters and 9 (6.3%) non-adopters. Semi-intensive system accounts for 80 farmers of which 78 (54.9%) are potential adopters and 2 farmers (1.4%) are potential non-adopters.

Out of the 133 farmers who keep livestock, 122 (61.6%) are potential adopters and 11 (5.6%) are potential non-adopters. Farmers who do not keep livestock have 50 (25.3%) potential adopters and 15 (7.6%) potential non-adopters. It was observed that most of the farmers rear goats (33.5%, n = 67) representing 40.8% (58) as potential adopters and 9 (6.3%) potential non-adopters; others keep poultry (23.5%, n = 47) with all as potential adopters (33.1%); sheep (8.5%, n = 17) with all the farmers as potential adopters (12%) and cattle (5.5%, n = 11) with 9 (6.3%) as potential adopters and 2 (1.4%) as potential non-adopters.

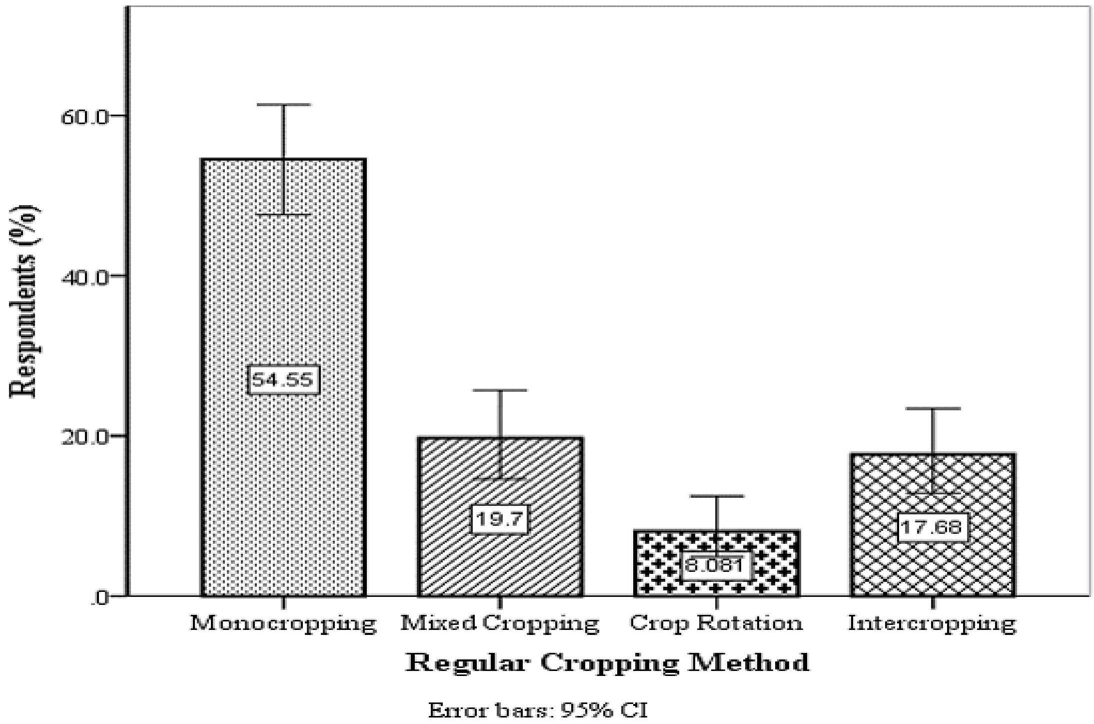

Figure 7: Variability of farmers' regular cropping method

4.4.4 Farmers' networking and access to extension services

The omnibus tests of model coefficient show that the model containing all the explanatory variables is significant ($X^2 = 77.645$, df = 1, p<0.05) and gives 60.1% correct predictions (Table 6). Majority of the farmers (62.5%, n = 125) admitted that they make consultations with colleague farmers on the choice of crops to grow and the cropping pattern whilst 73 others representing 36.5% said otherwise. Out of the 125 farmers, 109 (55.1%) are potential adopters and 16 (8.1%) potential non-adopters. However, out of the 73 farmers who do not make consultations on choice of crops and cropping pattern, 63 (31.8%) farmers are potential adopters whilst 10 (5.1%) are potential non-adopters. Extension services are also active in the study area and are mostly provided by Ministry of Food and Agriculture and other food/ commodity groups such as Purchase for Progress (United Farmers' Association Group, Freedom Farmers' Association, Kasapa Food Farmer's and Marketing Cooperative Society

Group) sponsored by the Canadian World Food Programme. The uptake of new technologies is often influenced by the farmers' contact with extension services [23]. The study supports the findings of [27, 11], who report that adoption of any innovation, technology or agricultural practice will be accelerated if farmers have an accurate understanding of the cost-benefits accruing from the adoption. The findings support the outcome of studies done by [28] which report that farmers' clubs and cooperative groups positively influence the adoption of agroforestry technologies. It is assumed that to substitute for or balance this lack of information, informal sources of information must be created within farming communities. Farmers who cannot access information from external sources can ostensibly obtain knowledge within their social networks and transfer information through social interactions [29, 30] report that, Social networking which is a method that is most often used to elicit, visualize, and analyse social relations and social networks, is a suitable tool to examine properties of farmer knowledge transfer. The use of diverse farming knowledge is necessary for the maintenance of complex agroforestry technologies. Thus, the resolve of techniques advancement in agroforestry, explicitly through farmer communication and learning linkages, is crucial to comprehend barriers for farmer access to information [31]. Assuming that informal sources of information are rooted within farming communities and are accessible to farmers through social interactions, the analysis of the social structure is a cogent research approach by which to disclose communication patterns. The identification of key actors in the development and transfer of agroforestry technologies can provide valuable acumen into information diffusion and may serve as pathways to a productive land-use [32].

4.5 Indicators based on predictable risks and uncertainties

4.5.1 Use of labour availability to predict bamboo agroforestry adoption.

Analysis on labour availability displays that the omnibus test of model coefficient is statistically significant ($X^2 = 73.470$, df = 1, $p<0.05$) and gives 76.7% correct predictions at 5% level. It was seen that most about 186 farmers representing 93.9% have access to labour. Out of this, 160 (80.8%) farmers are potential adopters whilst 26 (13.1%) are potential non-adopters. However, farmers (n = 12, 6.1%) who do not have access to labour are all potential adopters (6.1%). The findings support the outcome of study done by [28] who report that the availability of labour supply (cheap labour) positively influences the adoption of agroforestry technologies. Large family sizes and hired labour availability have a positive impact on adoption of agroforestry technology. Combining tree resources and food crops on the farm is labour demanding, therefore, families constrained with labour force may not be able to practice agroforestry. Only labor-saving agroforestry technologies will be adopted [22]. Many agroforestry interventions will require some amount of change in either the utilization of, or labour necessity. Under conditions of unemployment, agroforestry may essentially enhance labour efficiency, while in other circumstances shortages may pose serious threats to the adoption of certain technologies such as alley cropping. In heavily populated areas, the commitment of land to agroforestry will possibly require the omission of other activities. Hyman [33] stated that farmers motivated to plant trees often encounter shortage of available labour for crop production. Thus farmers depending on agriculture as their primary source of livelihood might be dispirited to allocate family labour for tree planting activities. Hocking *et al*. [34] has emphasized that large scale farmers tend to plant trees to some degree separated from the homestead. Moreover, farmers frequently compare the expected benefits of tree planting on their lands with the benefits they can realize by using their labour for other farming systems [35]. Studies by Thacher *et al*., [36] pointed out that long-term investment in tree planting is most likely if labour constraints faced by the farmers inhibit alternative economical and viable investments.

4.5.2 Security of land tenure system (ownership and availability) as indicator for adoption

Land ownership and availability of land to plant bamboo was regressed with the dependent variable "will you plant bamboo on your farm" to predict a logit model shown in Table 8.

The omnibus tests of model coefficient show that the model containing all the explanatory variables is statistically significant (X^2 = 71.920, df = 2, p<0.05) and gives 72.8% correct predictions.

The model shows that availability of land to plant bamboo (1.12 $\pm$ 0.032) and ownership of land (1.01 $\pm$ 0.011) are statistically significant at 5% level. From the total of 174 farmers who admitted that they have lands, 163 (82.3%) are potential adopters and 11 (5.6%) are potential non-adopters. However, out of 24 farmers who do not have lands, 15 (7.6%) are potential non-adopters whilst 9 (4.5%) are potential adopters. Similarly, farmers (n = 179, 89.5%) who own lands have more than 4.859 times likelihood of planting bamboo on their farms than farmers (n = 19, 9.5%) who do not own lands at 5% level of significance, holding other factors in the model constant. Out of the 179 farmers who admitted that they own lands, 168 (84.3%) are potential adopters and 11 (5.2%) are potential non-adopters. However, out of 11 farmers who do not own lands, 9 (4.5%) of them are potential non-adopters whilst 2 (1.1%) are potential adopters. This might be attributed to the reason that land acquisition in the study region is by renting and that farmers do not have complete ownership of the land. Farmers decide to adopt a practice that seems most consistent and suitable to achieve their goals or interests [37, 38]. Those decisions are made after assessing farm internal resources such as household composition, farm size and external conditions like incentive policies, and market prices [37]. Internal and external conditions influences the adoption of agroforestry technologies. Pattanayak *et al.* [26] highlighted that demographic characteristics, intra-household homogeneity, resource assets, market incentives, biophysical factors, risk and uncertainty were determining factors for agroforestry adoption. Flower [38] pointed out that attitudes, agroforestry knowledge and farm characteristics had significant contribution to the adoption of riparian buffers and forest farming. Similarly, [39] also reiterated that physical properties of the landscape, such as bank stream erosion, influenced the adoption of riparian buffers. The stimulus of economic motivations, a commonly examined internal factor, is not conclusive in the adoption of agroforestry [40]. Franzel *et al.* [41] proved that the economic benefits of agroforestry had a positive effect in adopting agroforestry while [42] found that they were not a driving factor. Regarding external forces, the value of land for future development was found to be an important element in deciding whether to plant trees or grasses as riparian buffers [42]. When the science of agroforestry focused on the tropics, the most often identified socioeconomic issues critical to agroforestry systems' success in smallholder systems included land tenure, labour, and marketability [43]. It was therefore concluded that, there must be more studies to examine the full range of potential factors that may influence agroforestry adoption [40].

5.0 Conclusion and recommendations

Bamboo-based agroforestry systems hold a high adoption potential in the study region. The study identifies the socioeconomic, cultural and biophysical factors that are likely to influence the potential adoption of bamboo agroforestry in the dry semi-deciduous forest zone (DSFZ) of Ghana as farmer characteristics, cropping system, livestock keeping, farming practice, bamboo ethnobotany, farmers' networking and access to extension, land tenure system and labour availability. These factors hypothesized to predict potential bamboo agroforestry are significant and can positively predict the adoption of bamboo agroforestry. Eighty to ninety percent of the farmers are potential adopters of bamboo agroforestry. There is the need to consider factors such as age, gender, cropping method, crop preferences, primary objective for growing crops such as market availability and early maturity, role of bamboo as fodder plant, other uses and benefits of bamboo, land availability and ownership as well as labour availability in all initiatives towards the introduction of bamboo agroforestry. The major land-use challenge facing the study region are limited output from farmlands (solely agricultural crops) resulting in low income diversity from farming. This situation has a tendency for crop production decline as it presents the only livelihood support to the larger population. Again, vegetation to support fuelwood (which is the major domestic energy source) is declining at a high rate. Vegetation loss and low income diversity conditions, necessitate the introduction of suitable land-use system capable of providing wood energy source as well as supporting agricultural production. Accordingly, bamboo agroforestry is perceived as a good bet in the DSFZ. Although, bamboo agroforestry may seem a best bet, however, there is the need to explore its domestic energy (fuelwood) provision and substitution potential. Also, farmers in the DSFZ need to be sensitized further on social, ecological and economic potential of bamboo. Farmers will also have to be trained in bamboo cultivation. Policy and institutional arrangements would have to be developed to ensure sustainable bamboo cultivation and usage for domestic fuelwood energy supply and other uses to avert further deforestation and land degradation. It would be very much expedient to involve the Ministry of Food and Agriculture (MoFA) as an institutional channel/partner in the introduction of bamboo agroforestry once it has been discovered that farmers consult or receive information from MoFA to help in their decision making processes concerning farming activities. Again, since farmers consult each other very often in their crop production systems, the bamboo innovations have a high potential of spread and adoption. Therefore, it is recommended for the identification or setting up of more farmer groups and cooperative farming or buyer groups in the DSFZ since they can be used on Innovation Development and Transfer Platforms facilitate the introduction of bamboo-based agroforestry systems.

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Appendix 1

Table 1: Logistic regression estimation of farming practice to predict bamboo agroforestry adoption in the DSFZ.

Variable	B	Std. error	Wald	Df	Sig.	Exp(β)
Keeping trees on farms	1.866	0.010	78.387	1	0.001	0.155
Type/preferred of tree species	-1.021	0.020	12.933	1	0.04	1.200
Constant	-1.889	0.210	32.628	1	0.000	0.151
-2 Log Likelihood			158.401			
Cox & Snell R^2			0.444			
Nagelkerke R^2			0.591			
Omnibus tests of model coefficients						
• Chi-square			116.085			
• Df			2			
• Sig.			0.000			
% Correct predictions			79.2			

Table 3: Logistic regression estimation of farmers' characteristics to predict bamboo agroforestry adoption.

Variable Name	B	Std. Error	Wald	Df	Sig.	Exp(β)
Age characteristics of farmers	0.088	0.065	0.475	1	0.000	1.092
Gender characteristics of farmers	0.002	0.028	0.321	1	0.030	1.002
Education Level	-0.853	0.090	6.084	1	0.059	0.426
Marital Status	0.006	0.041	0.000	1	0.102	1.006
Constant	-1.889	0.210	8.628	1	0.000	0.151
-2 Log Likelihood			95.953			
Cox & Snell R^2			0.254			
Nagelkerke R^2			0.470			
Omnibus tests of model coefficients						
• Chi-square			58.041			
• Df			6			
• Sig.			0.000			
% Correct predictions			87.40			

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Table 2: Logistic regression estimation of farmers' bamboo ethnobotany to predict bamboo agroforestry adoption.

Variable Name	B	Std. Error	Wald	Df	Sig.	Exp(β)
Knowledge on bamboo leaves used as fodder	-0.769	0.026	0.848	1	0.067	0.463
Livestock fed with bamboo leaves before	-20.505	0.018	0.000	1	0.098	0.000
Readiness to try bamboo fodder	-1.840	0.033	4.664	1	0.000	0.159
Readiness to incorporate bamboo cultivation on farm as fodder	-1.040	0.035	7.664	1	0.005	0.219
Seen/ heard bamboo	3.727	0.017	0.359	1	0.033	1.316
Personally planted bamboo before	2.321	0.011	2.362	1	0.040	8.364
Taboos/beliefs associated with the use or planting of bamboo	-0.603	0.017	0.519	1	0.471	0.547
Knowledge on bamboo charcoal	-0.006	0.023	0.043	1	0.836	0.994
Production of bamboo charcoal before	1.243	0.000	1.200	1	0.060	1.222
Readiness to produce bamboo charcoal	1.456	0.011	4.321	1	0.001	4.562
Personally used /seen someone using bamboo	2.343	0.028	2.723	1	0.004	3.561
Constant	-12.382	0.024	4.363	1	0.998	0.000
-2 Log Likelihood			11.905			
Cox & Snell R^2			0.272			
Nagelkerke R^2			0.659			
Omnibus tests of model coefficients						
• Chi-square			12.932			
• Df			11			
• Sig.			0.000			
% Correct predictions			88.92			

Table 4: Logistic regression estimation of farmers' cropping system to predict bamboo agroforestry adoption.

Variable Name	B	Std. Error	Wald	Df	Sig.	Exp(β)
Number of years in crop production	-0.273	0.047	0.079	1	0.961	0.761
Primary objective for growing crops	17.368	0.049	0.000	1	0.02	0.031
Influences of crop preference	1.357	0.110	1.999	1	0.01	3.886
Regular cropping method	-1.537	0.106	2.776	1	0.03	0.754
Meeting of crop production target	1.637	0.031	3.235	1	0.02	5.142
Challenges with soil fertility	1.959	0.031	2.976	1	0.084	7.091
Access to fertilizer	-0.708	0.033	0.476	1	0.490	0.493
Constant	-25.382	0.024	4.363	1	0.998	0.000
-2 Log Likelihood			118.774			
Cox & Snell R^2			0.163			
Nagelkerke R^2			0.301			
Omnibus tests of model coefficients						
• Chi-square			35.221			
• Df			7			
• Sig.			0.004			
% Correct predictions			86.9			

Table 5: Logistic regression estimation of livestock keeping to predict bamboo agroforestry adoption.

Variable Name	B	Std. Error	Wald	Df	Sig.	Exp(β)
Rearing of animals	2.081	0.033	0.032	1	0.001	8.014
Kind of animals reared	1.044	0.079	0.000	1	0.040	2.840
Primary objective for keeping livestock	-18.657	0.085	0.032	1	0.080	0.998
Livestock production system	-1.012	0.058	0.146	1	0.030	0.363
Feed accessibility challenge	-19.255	0.022	0.000	1	0.998	0.000
Constant	-2.470	0.314	6.856	1	0.000	0.085
-2 Log Likelihood			35.924			
Cox & Snell R^2			0.254			
Nagelkerke R^2			0.602			
Omnibus tests of model coefficients						
• Chi-square			41.314			
• Df			5			
• Sig.			0.000			
% Correct predictions			82.01			

Table 6: Logistic regression estimation of farmers' networking and access to extension to predict bamboo agroforestry adoption.

Variable Name	B	Std. Error	Wald	Df	Sig.	Exp(β)
Consultation in choice of cropping and cropping pattern	-1.919	0.034	51.366	1	0.000	0.147
Constant	-1.841	0.340	29.236	1	0.000	0.159
-2 Log Likelihood			72.841			
Cox & Snell R^2			0.324			
Nagelkerke R^2			0.433			
Omnibus tests of model coefficients						
• Chi-square			77.645			
• Df			1			
• Sig.			0.000			
% Correct predictions			60.1			

Table 7: Logistic regression estimation of labour availability to predict bamboo agroforestry adoption.

Variable Name	B	Std. Error	Wald	Df	Sig.	Exp(β)
Access to Labour	-1.817	0.017	34.846	1	0.000	0.163
Constant	0.424	0.360	21.933	1	0.050	0.127
-2 Log Likelihood			107.350			
Cox & Snell R^2			0.419			
Nagelkerke R^2			0.558			
Omnibus tests of model coefficients						
• Chi-square			73.470			
• Df			1			
• Sig.			0.001			
% Correct predictions			76.7			

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Table 8: Logistic regression estimation of land tenure system (Ownership and Availability) to predict bamboo agroforestry adoption.

Variable Name	B	Std. Error	Wald	Df	Sig.	Exp(β)
Land availability to plant bamboo	2.696	0.023	17.890	1	0.000	7.121
Land ownership	1.421	0.011	23.400	1	0.030	4.859
Constant	-0.934	0.452	0.892	1	0.072	0.881
-2 Log Likelihood			115.306			
Cox & Snell R^2			0.552			
Nagelkerke R^2			0.737			
Omnibus tests of model coefficients						
• Chi-square			71.920			
• Df			2			
• Sig.			0.000			
% Correct predictions			72.8			