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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 in Ghana as a viable land use option to reduce dependence on natural forest for wood fuels. To align the design and introduction of bamboo agroforestry to the needs of farmers, information on the determinants of bamboo acceptability and adoption is necessary. It is, therefore, the aim of this study to determine how socioeconomic factors, local farming practices and local knowledge on bamboo may influence its acceptability and adoption as a component of local farming systems. Data were collected from 200 farmers in the dry semi-deciduous forest zone of Ghana using semi-structured questionnaire interviews. The results show that farmers' traditional knowledge on bamboo including its use for charcoal production and leaves for fodder are influential determinants of bamboo adoption. Among the demographic characteristics of farmers, age and gender are the most significant predictors. It is also evident that the regular practice of leaving trees on farmlands and type of cropping system may influence bamboo integration into traditional farming systems.

Keywords: adoption; land-use; deforestation; food security; renewable energy

1. Introduction

Deforestation emanating from excessive wood extraction for wood fuels continues to be a major agent of land degradation. The rate of deforestation in Ghana stands at 112.54 km^2 per annum, largely attributed to expansion of agriculture [1,2]. According to Afrane [3], about 73% of rural and 48% of urban households in Ghana depend on firewood and charcoal, respectively, for domestic and industrial use. Charcoal supply predominantly comes from savanna zones, and with lesser amount from deciduous and rainforests. Charcoal production is the next most dependent livelihood of the dry semi-deciduous forest zone (DSFZ) after farming and used as a secondary activity to support income from farming activities [4].

Owing to the increased sourcing of wood biomass from primary forests for charcoal production, government and scientists are advocating for 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 has increased in Ghana. This notwithstanding, monoculture bamboo plantations on agricultural lands may impact adversely on food security unless integrated systems with arable crops and/or livestock are given due consideration. In many parts of Asia, the integration of bamboo on croplands 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.

Currently, the International Bamboo and Rattan Organization (INBAR) is piloting a bamboo agroforestry system as a land use option for food security and renewable energy production in the DSFZ of Ghana. As an innovative development-oriented project, filling knowledge gaps on the determinants of bamboo use and adoption as a component of traditional farming systems is imperative to achieve large scale landscape adoption. In addition, knowledge on adoption determinants of bamboo will help in designing a bamboo-based agroforestry system that is tailored to the needs of farming communities. It was therefore the aim of this study to determine how socioeconomic factors, local farming practices and local knowledge on bamboo may influence its acceptability and adoption as a component of local farming systems.

Conceptual Framework of the Study

Several analytical frameworks have been used for the analysis of adoption of agroforestry technologies. Biot et al. [6] grouped these approaches into three major types: top-down interventions, populist or farmer-first, and neoliberal approaches. Stemming from the concept of farmer-first and sustainable livelihood principles, Shiferaw et al. [7] developed a wider conceptual framework for analyzing factors stimulating the successful adoption and adaptation of smallholder technologies. Given the focus of this study, the conceptual framework developed by Mercer [8] and modified by Zerihun et al. [9] is considered appropriate. The framework focuses on the adoption of already existing agroforestry technologies. However, this framework could be seen as very broad and complex to analyze the adoption rate and institutional setup of agroforestry technologies synchronously 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. Specifically, we modeled the interaction of explanatory variables, such as farmer characteristics, cropping systems, farming practices, bamboo ethnobotany, to predict the potential adoption of bamboo agroforestry in the DSFZ (Figure 1). These interactions facilitate farmer decision making processes and culminate in either adoption or non-adoption of technologies.

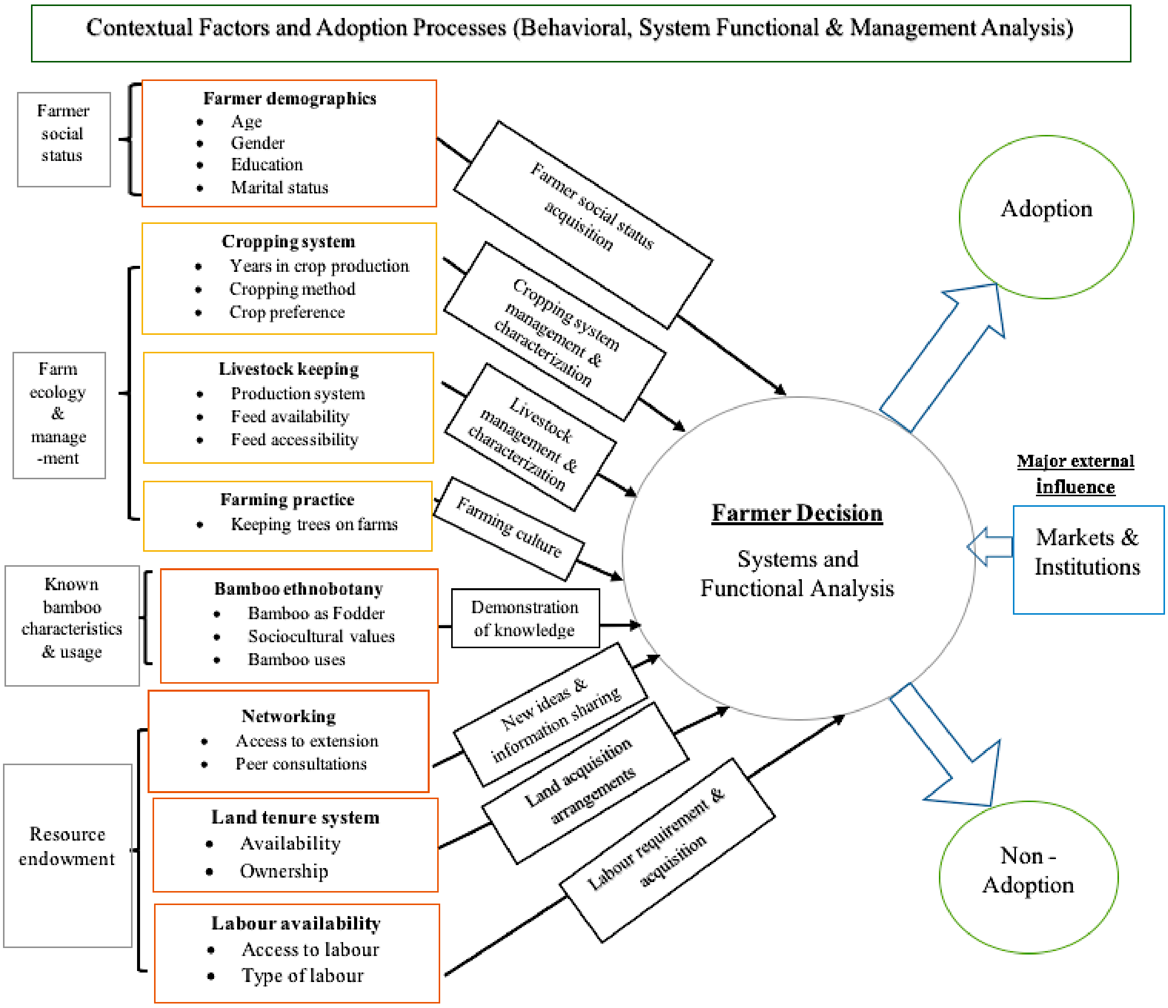

Figure 1. Analytical framework for modeling adoption potential of bamboo agroforestry. Source: Adapted from Zerihun et al. [9].

2. Materials and Methods

2.1. Study Area Description

The study was conducted in the Mampong, Ejura-Sekyedumase Municipals and Sekyere Central, Kumawu-Sekyere and Sekyere-Afram Plains Districts of Ghana (Figure 2). These areas are located within the dry semi-deciduous forest zone of Ghana (DSFZ), with a characterized bimodal rainfall pattern (with an average annual rainfall of 1270 mm). The major rainy season starts in March and peaks in May. There is a minor dint in July and a peak in August, ending in November. December to February is the drier season, which is warm and dusty (in the driest period). Mean annual temperature is 27 °C with variations in mean monthly temperature ranging between 22 °C and 30 °C throughout the year. The soil type of the study site is sandy loam (Ejura—Denteso Association). The study area falls within the zone, considered as the major food basket of Ghana and has the highest production of charcoal and fuelwood from natural sources.

Subsistence agriculture is the major economic activity employing about 65% of the population. The bulk of agricultural production is from manually cultivated rainfed crops. Major crops include: maize, cowpea, cassava, yam, and plantain. The DSFZ was chosen because of its unique characteristic features which combine those of the forest and savanna zones.

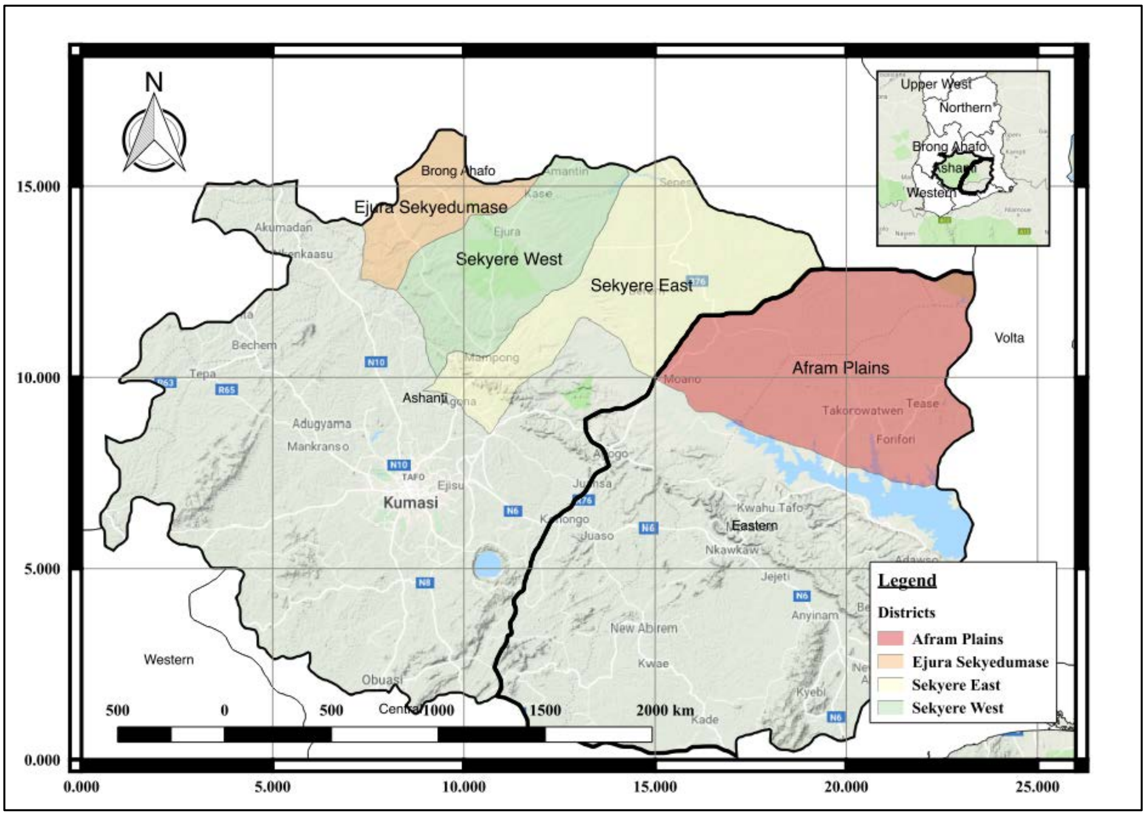

Figure 2. District map of Ghana showing the study sites in the DSFZ (map overlaid on Google satellite scene (2018) of Ghana).

2.2. Data Collection, Sampling Procedure and Analysis

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

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

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 household survey to obtain information on the socio-economic variables that are likely to influence adoption of bamboo agroforestry. We modeled the potential adoption of bamboo agroforestry by designating a value of 1 if the farmer is willing to plant bamboo on his/her farmland (potential adopter) and 0 if the farmer is unwilling to plant bamboo on his/her farmland (potential non-adopter).

Primary data collected were analyzed using binary logistic regression as recommended by Masangano [11] to model adoption of bamboo agroforestry on a set of predictive variables from farmer characteristics (age, education level, gender, marital status), bamboo ethnobotany (knowledge and use), and agronomic practices (cropping system patterns, farming practices) at a 5% probability level using Statistical Package for Social Sciences (SPSS ver. 20.0). The best set of model predictors were evaluated using the log-likelihood criterion, significance of the Chi-square test statistic and the overall model performance adjudged by the stronger power of coefficient of determination (R^2).

Therefore, the interpretation of results focused on statistical significance, the direction of the regression coefficients (either positive or negative), and the odds-ratio [Exp (β)]. Cross-tab analyses were also conducted to estimate the proportion of potential adopters and non-adopters of bamboo agroforestry.

The main limitation of the survey was that it could not acquire all information needed for the pragmatic diagnosis of bamboo integrated farming system problems, because bamboo agroforestry is yet to be practiced with no field demonstrations existing in all sampled communities. As a result, detailed information on traditional farming practices adopted by farmers and their bamboo ethnobotany, energy (fuelwood) needs and crisis, soil fertility and management, and crop yield trends were collected through focus group discussions with farmers to validate the answers in the questionnaires.

3. Results and Discussion

3.1. Farmers' Characteristics/Demographics as Indicator for Adoption

Table 1 summarizes model results on using farmer characteristics as predictive variables for agroforestry adoption. The best set of model predictors are statistically significant ($p < 0.001$) with 87% correct prediction at the 5% level. The results show that gender and age of farmers can significantly predict the potential adoption of bamboo agroforestry. The odds ratio for age is 1.092 with a positive coefficient of 0.088 signifying that adults have larger potential to adopt bamboo agroforestry than the youth. The study found the majority of respondents within the ages of 31–45 years (40%). Within the ages of 31–45 (27%) are potential adopters whilst 24 (12%) are potential non-adopters. This age-influenced adoption trend could be attributed to the perception of young farmers; most of them see farming as a secondary occupation and use it to supplement their monetary income relative to older farmers whose major source of livelihood is farming and thus have a stronger likelihood to accept new farming technologies. This finding is inconsistent with reports by Rogers [12] and Ajayi [13], which highlight a decreasing potential of agroforestry technology adoption with increasing age. The effect of age on technology adoption has been well studied and reported to be context-specific. For instance, while Rogers [12] and Ajayi [13] found age could influence agricultural technology adoption, Waswa [14], Ndiema [15] and Njuguna et al. [16] found no relationship between age and technology adoption On the other hand, other researchers have found age to be positively correlated with technology adoption [17–21] citing people between the ages of 18–43 as more active and ready to take risks by adopting new technologies.

Table 1. Parameter estimates of modeling farmers' characteristics for predicting bamboo agroforestry adoption.

Variables [1]	Coefficients	Std. Error	*p*-Value	Exp (β)
Age	0.088	0.065	0.000	1.092
Gender	0.002	0.028	0.030	1.002
Education level	−0.853	0.090	0.059	0.426
Marital status	0.006	0.041	0.102	1.006
Constant	−1.889	0.210	0.000	0.151

[1] The best set of model predictors (−2 Log-likelihood = 95.9) was significant (Chi-square test value = 58.04, $p < 0.001$) and overall model predictions on adoption of 87.4%. Std. error is the standard error and Exp (β) is the odds-ratio representing the likelihood of adoption.

Gender analysis is also significant to the adoption model with men found to be more likely to adopt bamboo agroforestry than women. Majority of the farmers are males (80%) of which potential adopters are 136 (68%) and 24 (12%) estimated as potential non-adopters. Female farmers numbered 40 with 38 (19%) characterized as potential adopters whilst only 2 (1%) were non-adopters. Although the female respondents constitute a smaller percentage of respondents, majority of them shows keen interest in adopting bamboo agroforestry. Nevertheless, the decisions on the choice of new technologies by women farmers are strongly dependent on their husbands as male household heads tend to have more access to land. This is in agreement with Scherr [22] who found in her studies on economic factors influencing farmer adoption of agroforestry that females are not permitted to make decisions to adopt agroforestry technologies without consulting the family head (mostly males). This adds to the growing concern of gender inequalities on household decisions and access to farm resources. The lower proportion of sampled women-farmers in the study area could be linked to situations where women do not have headship to land and tree tenure due to the largely patrilineal inheritance systems [23]. Issues of gender in agricultural technology adoption have been explored over the years, and studies report mixed evidence concerning the different roles females and males play in the adoption of technology [24]. In comparing these facts, Morris and Doss [25] report no significant relationship between gender and probability to adopt improved maize in Ghana. Conversely, other studies have shown differences in gender norms and culture play significant roles in technology adoption [26–28]. In Nigeria, Obisesan [29] found gender to be a significant determinant of the adoption of improved cassava production approaches. Similarly, Lavison [30] also reports male farmers are more likely to adopt organic fertilizer as compared to their female colleagues.

Unlike age and gender, the study shows that the level of education and marital status are not significant determinants of bamboo agroforestry adoption. Although this contradicts the assertion that education (formal and informal) or training increase the rate of technology adoption [31], it may be context-specific. Other studies, such as Amudavi [32] and Ndiema [15], also found that the educational status of a farmer was not a significant indicator of technology adoption. The results of the current study suggest that, in the study region, the kind of education or training that can facilitate the adoption of an innovation might be the education on the innovation itself and how well farmers are exposed to the innovation; and not necessarily academic education [33–38].

Many new practices stemming from a top-down approach and overlooking socio-economic realities often produce disappointing results for implementing agencies [39]. However, understanding the prevailing social values can positively influence the adaptation and commitment to both existing and introduced technologies [40]. In addition, studies on agroforestry adoption are becoming increasingly important to researchers. It is therefore essential to monitor socio-economic concepts in agroforestry to delineate strengths and weaknesses in the current state of knowledge and to foster guidance for further investigation and optimal decision making through productive feedback loops between researchers and farmers [41].

3.2. Farming Practices as Indicator for Adoption of Bamboo Agroforestry

Farming practices such as keeping trees on farms and the type of tree species left on farms had significant effect and explained 79.2% of the adoption potential of bamboo agroforestry (Table 2).

Table 2. Farming practices to predict bamboo agroforestry adoption in the DSFZ.

Variables [1]	Coefficients	Std. Error	*p*-Value	Exp (β)
Keeping trees on farms	1.866	0.010	0.001	0.155
Type/preferred tree species	−1.021	0.020	0.04	1.200
Constant	−1.889	0.210	0.000	0.151

[1] The best set of model predictors (−2 Log-likelihood = 158.4) was significant (Chi-square test value = 116.09, $p < 0.05$) and overall model predictions on adoption of 79.2%. Std. error is the standard error and Exp (β) is the odds-ratio representing the likelihood of adoption.

For the 194 farmers who kept trees on their farms, 168 (85%) were potential adopters and 26 (13%) were potential non-adopters. However, all the farmers (4) who do not leave trees on their farms were potential adopters (2%). Figure 3 shows preferred trees left on farmlands for economic and environmental benefits. The farmers report several reasons for leaving trees on farms such as economic gains, shade, soil and water conservation, fodder, and fuelwood provision. This implies that farmers would most assuredly accept to plant any woody perennial on their farm if they knew the ecological and economic functions of such woody perennial. It could be further deduced that farmers' decision for keeping trees on their farmlands have ecological justifications and importance since trees maintain and improve soil fertility through processes of nitrogen fixation and nutrient uptake from deep soil horizons [42]. Furthermore, trees improve the structural properties of the soil with their rooting systems by reducing soil erosion and increasing soil water infiltration [43]. Alavalapati and Nair [44] 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 [39,45]. Technology adoption has many policy implications on agricultural and agroforestry development and technology-specific attributes have been shown in the past to significantly determine farmers' decision to adopt a technology [46]. The economic value of woody perennials is a key factor in farmers' adoption of a technology [22]. According to Glover et al. [47], environmental or ecological potential of a woody perennial is critical in influencing an adoption decision.

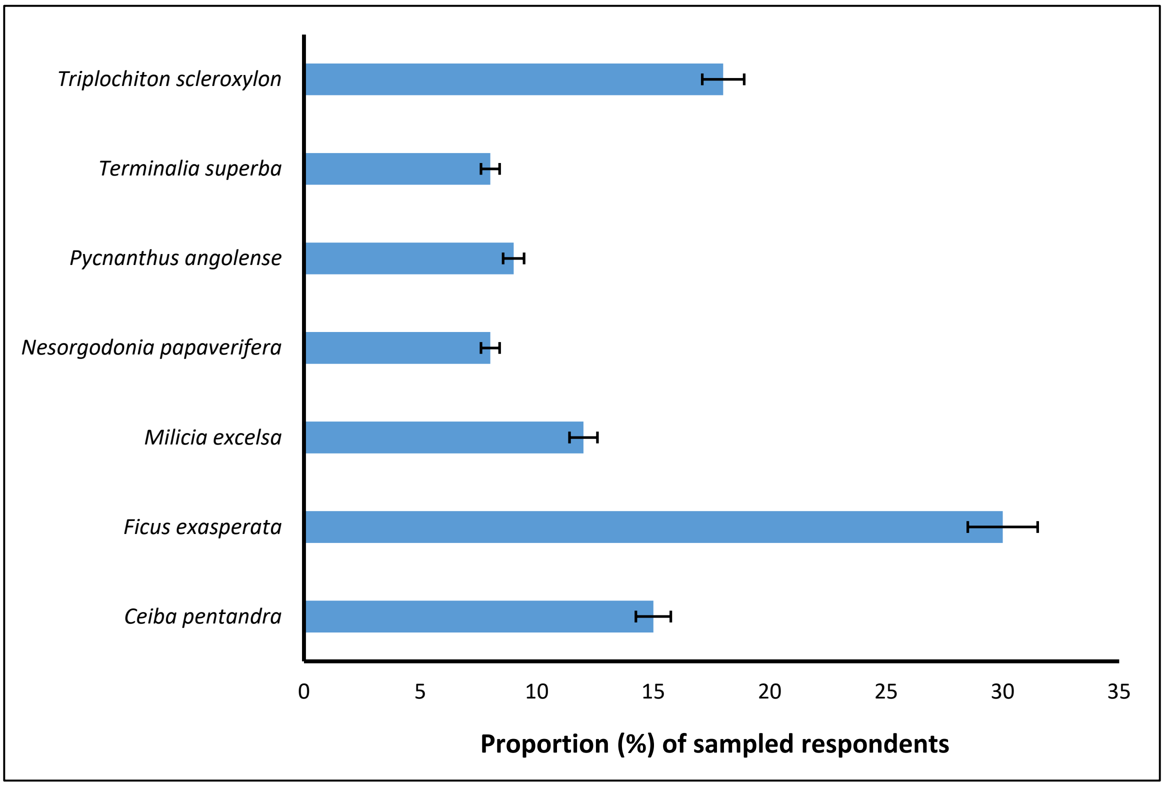

Figure 3. Preferred tree species left on farms by respondents. Error bars show percentage (5%) deviation of sampled respondents.

3.3. Characterizing Farmers' Cropping Systems as a Predictor for Adoption

The set of predictors such as crop production objective, crop preference and cropping method which characterize cropping systems in the study area were found to be significant ($p < 0.001$) determinants of bamboo agroforestry adoption (Table 3). It was observed that most (67%) of the sampled respondents were farmers who grow crops mainly for commercial purposes. Out of this, 61% were potential adopters and 6% were potential non-adopters. With recent climate change and land degradation impacts on crop yields and poverty trends especially in sub-Saharan Africa (SSA), most farmers are shifting from the traditional subsistence farming to become more commercially-oriented. Such farmers are keener to explore innovations that seek to increase production and farm incomes [48–50]. Other findings have also supported the assertion that capital or economic situation of a farmer influences technology adoption [31,51,52]. In SSA, bamboo-based agroforestry systems are now developing, but literature on their economic feasibilities is limited. However, with livelihoods in SSA mostly tied to agriculture and forestry, investments in bamboo-based agroforestry systems may contribute to rural poverty reduction and improved livelihoods in the region [53]. Like most agroforestry systems, bamboo-based agroforestry systems are expected to open new income streams by diversifying agroecosystems and offering multiple economic benefits from the sale of grains and vegetables from short-duration crops (integrated with bamboo), supply of fodder for livestock, and the sale of processed bamboo culms as wood fuels, charcoal, timber or industrial raw materials [54]. In most of SSA, it is common for rural households to diversify income streams as a pathway to reduce vulnerability to the failure of their primary income generating activities [48,55].

Table 3. Parameter estimation of farmers' cropping system in predicting bamboo agroforestry adoption.

Variables [1]	Coefficients	Std. Error	*p*-Value	Exp (β)
Number of years in crop production	−0.273	0.047	0.961	0.761
Primary objective for growing crops	17.368	0.049	0.02	0.031
Crop preference	1.357	0.110	0.01	3.886
Regular cropping method	−1.537	0.106	0.03	0.754
Meeting crop production target	1.637	0.031	0.02	5.142
Challenges with soil fertility	1.959	0.031	0.084	7.091
Access to fertilizer	−0.708	0.033	0.490	0.493
Constant	−25.382	0.024	0.998	0.000

[1] The best set of model predictors (−2 Log-likelihood = 118.8) was significant (Chi-square test value = 35.22, $p < 0.001$) and overall model predictions on adoption of 86.9%. Std. error is the standard error and Exp (β) is the odds-ratio representing the likelihood of adoption.

Although bamboo raw materials have no guaranteed prices in Ghana, potential bamboo farmers have the advantage of benefiting from the emergent and growing bamboo economy and industry in the country. Ghana seems to be on a pathway to advancing bamboo resource development following the increasing market for bamboo products and the presence of the West Africa sub-regional office INBAR in Kumasi. The Government of Ghana and INBAR have collaborated in establishing the Bamboo and Rattan Development Programme (BARADEP). Aside the small-scale traditional bamboo basketry/craft shops and the famous Bamboo Bicycle Producing Company at Toase-Nkawie in Kumasi, there are many other private bamboo initiatives ranging from small cottage to large-scale enterprises including Global Bamboo Products in Anyinam, KWAMOKWA bamboo plantations all in Kumasi, Greater Accra Bamboo and Rattan Handicrafts Association, Brotherhood Cane/Rattan Weavers Association., Links Handicrafts Association., New Vision Handicrafts Association, Pioneer Bamboo Manufacturing Co., Ltd. (Accra, Ghana), Assin Foss and TTom Bamboo Toothpick Processing Company, Tandan. Also, many foreign investors have taken advantage of this initiative, sound political environment and the favorable climatic conditions for bamboo development and have a dozen of large-scale plantations and processing centers in Ghana. One of the most successful of such initiatives is the EcoPlanet Bamboo project, with its vision as a bamboo plantation and processing company that focuses on the provision of a secure and certified source of fiber for timber manufacturing industries and markets globally. Darlow Enterprises is another bamboo company of importance which is also resident in Ghana. With headquarters in Belize and the Philippines, Darlow Enterprises focuses on bamboo charcoal production. All these enterprises present a great market channel for bamboo trade from which potential bamboo farmers could link up and benefit financially through the trading of bamboo products.

3.4. Bamboo Ethnobotany as a Predictive Variable for Adoption of Bamboo Agroforestry

Ethnobotany focuses on how plants have been or are used, managed and perceived in human societies, and it expresses how plants are used for various needs (clothing, conservation techniques, shelter, food, medicine, hunting, magico-religious concepts) as well as their general economic, and sociological importance in societies [56]. From the study, local knowledge on bamboo characteristics and usage record a strong prediction (88.9%) to the model of potential adoption. Farmers' readiness to try bamboo fodder on their livestock, readiness to incorporate bamboo cultivation on farms for fodder, the visibility of bamboo by farmers, personal planting of bamboo, bamboo use, and farmers' readiness to produce bamboo charcoal are statistically significant to the model (Table 4).

Table 4. Model estimates of farmers' bamboo ethnobotany to predict bamboo agroforestry adoption.

Variables [1]	Coefficients	Std. Error	*p*-Value	Exp (β)
Knowledge on bamboo leaves used as fodder	−0.769	0.026	0.067	0.463
Livestock fed with bamboo leaves before	−20.505	0.018	0.098	0.000
Readiness to try bamboo fodder	−1.840	0.033	0.000	0.159
Readiness to incorporate bamboo cultivation on farm as fodder	−1.040	0.035	0.005	0.219
Seen/heard bamboo	3.727	0.017	0.033	1.316
Personally planted bamboo before	2.321	0.011	0.040	8.364
Taboos/beliefs associated with the use or planting of bamboo	−0.603	0.017	0.471	0.547
Knowledge on bamboo charcoal	−0.006	0.023	0.836	0.994
Production of bamboo charcoal before	1.243	0.000	0.060	1.222
Readiness to produce bamboo charcoal	1.456	0.011	0.001	4.562
Personally used/seen someone using bamboo	2.343	0.028	0.004	3.561
Constant	−12.382	0.024	0.998	0.000

[1] The best set of model predictors (−2 Log-likelihood = 11.9) was significant (Chi-square test value = 12.93, $p < 0.001$) and overall model predictions on adoption of 88.9%. Std. error is the standard error and Exp (β) is the odds-ratio representing the likelihood of adoption.

Out of the 186 farmers who appeared to possess some level of knowledge on bamboos, 164 (88%) were potential adopters and 22 (12%) are potential non-adopters. Bamboo use in Ghana is tied to fencing, use as television poles, roofing etc. (Figure 4). Cross-tab analysis also shows that 124 (78%) farmers are ready to try bamboo fodder, whilst 36 (22%) preferred otherwise. It is argued that new or existing interventions to encourage tree planting on farmlands need to be centered or realigned on farmers' comprehension of tree management in the domains of household livelihood schemes, such as fodder needs, energy needs and supplement of income, stressing that information about farmers' perceptions of the significance of trees and the constrictions they face in increasing tree resources are rare [56–60]. In the DSFZ, livestock is mostly kept on free-range systems where prolonged drought limit access to nutritive food materials [61]. As bamboos are drought-tolerant and produce relatively high nutritive fodder, their integration into farming systems can supply supplementary feed materials for livestock [62]. While the increased knowledge and use of bamboo have the potential to support its integration into traditional farming systems, issues of land tenure, labour availability and economic importance have to be critically assessed.

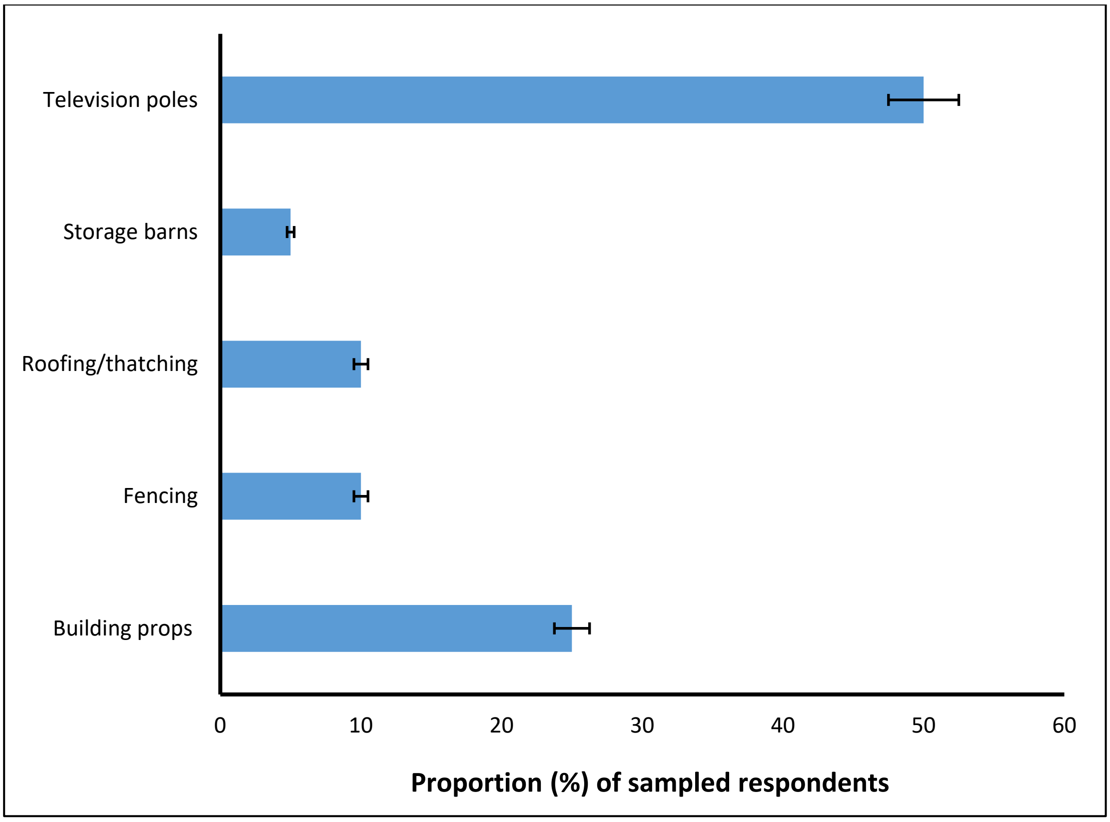

Figure 4. Predominant uses of bamboo known to sampled respondents in the DSFZ. Error bars show percentage (5%) deviation of sampled respondents.

4. Conclusions

The study identifies the socioeconomic factors and farming practices that influence the adoption of bamboo agroforestry in the dry semi-deciduous forest zone of Ghana. Factors found to be statistically significant were: age, gender, cropping method, crop preferences, primary objective for growing crops such as market availability and early maturity, role of bamboo as fodder plant, uses and benefits of bamboo, cropping system and farming practice. The present study provides key contributions for future bamboo-based agroforestry design and some directions for agricultural development policies. The key influential socioeconomic indicators identified in the study may provide a guide for rolling local farmers into the 2016–2040 National Forest Plantation Development Strategy of Ghana which seeks to establish 1000 hectares of bamboo plantations annually; culminating into the agenda to plant 50,000 hectares of bamboo plantations over the next 25 years by employing agroforestry principles. In the quest to develop Ghana's bioenergy sector, bamboo biomass has been included to ensure sustainability of the Ghana Bioenergy Policy initiative. The Government of Ghana may benefit essentially by using this study as a basis for further studies in developing a comprehensive national database to offer more insight into bamboo-socioeconomic implications to enhance the achievement of this goal. There is also the opportunity for Ghana to revitalize the almost 'defunct' national agroforestry policy by drawing lessons from this study by critically considering those socioeconomic indicators identified.

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