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Factors Influencing Adoption of Bamboo *(DEDROCALAMUS ASPER)* for Agro Forestry in Selected Subcounties of Nyandarua County, Kenya

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Abstract— **Bamboo (*Dedrocalamus asper*) is a very fast growing, extensive, low-cost plant in the family of grasses with great potential in environmental conservation and poverty alleviation. It has over 1500 documented uses. However, with the present crisis of land in Kenya especially in high potential areas where bamboo is grown, there is a need to identify options of cultivating bamboo as an agroforestry crop. Therefore, the main objective of the study was to establish factors influencing uptake of bamboo for agroforestry in selected Sub Counties in Nyandarua County, Kenya. The specific objectives were; to investigate the agroforestry systems in the selected Sub Counties of Nyandarua County, to establish the factors influencing the adoption of bamboo for agroforestry in selected sub counties of Nyandarua County and to examine the problems faced by farmers cultivating bamboo in selected sub counties of Nyandarua. Closed and open-ended questionnaires were administered to 132 bamboo farmers as the targeted population. The data collected was analyzed using Statistical Package for Social Statistics (SPSS) version 23 for data analysis. Likert Chi-square tests were run to establish the relationship between the rate of bamboo adoption and problems encountered, the agroforestry system practiced and the social economic factors. From the results home gardening was the main type of agroforestry system practiced. It was revealed that, monthly household income (χ^2 = 29.87 and χ^2 =20.053, P = 0.014 and 0.021), size of land (χ^2 =1.433, and χ^2 =4.633, P value = 0.031 and 0.009), income from crops intercropped with bamboo (χ^2 □ 14.173 and χ^2 □ 25.243; P = 0.004 and p= 0.000) influenced the rate of adoption of bamboo (χ^2 □ 14.173 and χ^2 □ 25.243; P = 0.004 and p= 0.000) for Ol'kalou and Ol'jororok Sub Counties, respectively). The study recommended more research on crops suitable for intercropping with bamboo as an agroforestry crops.**

Index Terms*— *Agroforestry, Bamboo, poverty, potential

I. Introduction

Bamboo is a fast-growing non- woody forest produce that is common in forest ecosystems of the world (Kigomo, 2007). Bamboo species grows naturally on the mountains and highland ranges of eastern African countries and in the medium lowlands of other countries of Africa. There are more than 87 genera and 1500 bamboo species in the world playing vital role in the industrial and domestic economies of China, Japan, Thailand, Combodia, India, and Vietnam (Divakaraet al., 2001). Only one species is native to Kenya, the species Yushania alpine covers about 150,000 ha growing in pure or mixed stands in montane forest of Kenya (Kigomo, 2000). Pure bamboo comprises about 30% of the vegetation types of the Aberdares forest in Kenya (KFS, 2010).

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Bamboo plays a critical role in the protection of the soil and water resources in forested catchment areas in Kenya (KFS, 2010). Kenya has less than 20% high potential land against growing human population (Kinyanjui, 2009). Increased population, economic development and increased energy needs has resulted to reduction of other forest resources leading to bamboo being explored for commercial value addition (Muchiri and Muga, 2013). Bamboo has been and continued to be a material of choice for construction and traditional uses throughout Africa. These uses of bamboo make a major contribution to rural income and employment, although the unsystematic clearing of natural forests and the lack of priority in its development join forces to erode bamboo status.

Due to rapid growth in human population, gregarious flower, irregular farming and widespread forest fires the bamboo its natural growth and on farms has decreased. This has led to decrease in bamboo cover since most of the land that used to grow bamboo is instead utilized for human settlement and overexploitation especially in the more easily reached forest areas. The Kenyan and Ethiopian government in the Eastern African region recognized the deteriorating bamboo and formulated policies to encourage sustainable management of bamboo as renewable resources (Hidalgo-Lopez and Oscar, 2003).

Amongst the major forest goods, bamboo has continued to gain credit. Long time, bamboo was regarded as a weed but today it is considered as a multiple use plant and as a valuable timber substitute (Banerjee et al., 2009, Kant et al., 1992). Bamboo is used in ornamental flower farming, wood curving, fencing and cottage industries. In Kenya bamboo is gaining a lot of interest in the energy sector, textile and construction sector (Kigomo. 2007).

Dendrocalamus asper and Dedrocalumus giganteus are grow naturally in tropical Asia at low altitudes and up to

1500m above sea level. They thrive at 400-500m above sea level in areas with average annual rainfall of about 2400mm. They also grow in any type of soil but prefer heavy soils with good drainage. It does well on sandy and acidic soils. The most preferred method of propagation is rhizome offsetting which is highly effective but highly labor intensive. It can also be propagated through culm cutting.

The economic analysis of bamboo-based agroforestry was studied in Asia and India (Dhyani et al., 2015, Banerjee et al., 2009, Nath et al., 2008, Kant et al., 1992). Intercrops of bamboo, rice, pigeon peas, ground nuts, turmeric and cowpeas were carried out in Asia. According to the findings, it was found that growth attributes of bamboo plants irrespective of species were significantly higher when grown with intercrops than sole plantation (Banerjee et al., 2009). Returns on both crops and bamboo were higher compared to mono-cropping. Leguminous crops showed a better compatibility with bamboo (Banerjee et al., 2009, Nath et al., 2008).

Bamboo growing has been studied in Kenya, (Katumbi et al., 2017, Karanja et al., 2015, Kibwage et al., 2008). Studies of Bambusa vulgaris and Dendrocalamus giganteus in Nyanza province have shown that bamboo can be grown by farmers and produce better returns compared to tobacco growing (Kibwage et al., 2008). Bamboo shoots from Bambusa Vulgaris, Yushania alpine and Dedrocalamus giganteus have also been studies in Kenya for their potential food source. Results showed that the type of bamboo that grow well in Kenya and are wealthy in critical major-nutrients comparable to edible varieties grown in countries such as China and India (Karanja et al., 2015). Studies from biomass resource of Yushania alpine and its ability for sustainable utilization in aberdare forest in Kenya showed that the available bamboo in this area is a model source of energy and would achieve an even flow of biomass attainable over five years sustainable management program (Katumbi et al., 2017).

Studies of intercropping bamboo with food crops have not been done in Kenya. From other studies it is clear that there are agricultural crops that enhance bamboo growth (Banerjee et al., 2009, Nath et al., 2008). There is therefore a need to identify suitable crop for intercropping with bamboo for its maximum growth.

A. Objectives

The specific objectives of the study were:
1. To investigate the types of agroforestry systems in the selected sub counties of Nyandarua County.
2. To establish the factors influencing the adoption of bamboo for agroforestry in selected sub counties of Nyandarua County
3. To examine the problems faced by farmers cultivating bamboo in the selected sub counties of Nyandarua County

II. LITERATURE REVIEW

A. Bamboo for agroforestry

Globally, bamboo grows on different niches like natural forests, riverbanks, dam sites and lake boundaries. Bamboo is also planted along farm boundaries reduce soil erosion, shelterbelts for homesteads and in degraded land to improve regeneration. In India, at its early stages' farmers intercrop bamboo with agricultural crops and when the stand establishes the bamboo is managed as a pure stand for collection of bamboo shoots for food (Katumbi et al., 2017)

Agroforestry systems with bamboo species lead to a sustainable land use option in different countries such as in Northern Vietnam at the Doge catchment (Krioshnaakutty, 2004). In India, it was observed that growing of soya beans as an intercrop of bamboo during the first six years is economically viable (Ahmed, 2004). Results revealed that, after profitability and cost benefit analysis bamboo held the second position in productivity among cropping groups in mixed home gardens (Krioshnaakutty, 2004). In China and Bangladesh mushrooms are raised in bamboo stands (Rai, 2004).

Additionally, at different heights and growth characteristics bamboo may be used as windbreaks thereby protecting other agricultural crops systems from demining effects of other environmental factors (Nath et al., 2009). Nonetheless according to Kibwage et al., 2008, bamboos play a critical role in providing forage to livestock during the dry season. Maih and Hussain (2001) in Bangladesh revealed that animals can consume both twigs and leaves of bamboo. Leaf and twigs are also used highland bamboo are also used for animal feed during dry season when there is shortage of feed (Yeshambel et al., 2011).

In Nigeria, bamboo is planted in an agroforestry system called the taungya system; where farmers plant bamboo together with agricultural crops at the initial stages of its bamboo growth. Once the bamboo establishes and grows taller, the farmer shifts to grow their agricultural crops elsewhere (Muzari et al., 2012). However, land shortage caused farmers to grow the bamboo in hedgerows, alley cropping and as windbreakers. Annuals such as vegetables intercropped with bamboo have been beneficial to the Nigerian farmer both economically and ecologically. In Kenya bamboo for agroforestry has not been fully exploited, there is therefore a need for establishing the factors influencing its adoption for agroforestry.

B. Factors influencing adoption of new agricultural technologies

Agriculture plays a critical function in food security, economic growth, poverty eleviation and rural development. Small holder farmers 'agriculture has been identified as a vital development tool for achieving millennium development goals (World Bank, 2008). Most smallholder farmers rely on traditional methods of production which has lowered the level of production (Muzari et al., 2012).

Generally, these farmers obtain low crop yield because the local varieties commonly used have low potential yield (Muzari et al., 2012). Increase agricultural productivity is essential to meet rising demand for food which triggers more research on methods of increasing production and sustainable agriculture.

Agricultural technologies include all kinds of improved techniques and practices which affect growth of agricultural output. Among such technologies and practices is agroforestry (Loesvinsohn et al., 2013). By virtue of improved input and output relationship, new technology tends to raise output and reduces average cost of production which in turn results to substantial gains in arm income (Challa, 2013).

Adopters of improved technologies however increase production, leading to constant social-economic development. Such adoption is also associated with higher earnings, lower poverty, improved nutrition, lower staple food prices, and increased employment opportunities. Nonetheless, adoption of improved technologies has led to the success of green revolution in many western countries (Kiarie, 2014).

A lot of literature exists on the factors that affect adoption of agricultural technologies. Farmers' choice on how and whether to adopt a new technology is dependent on active interaction between characteristics of the technology, array conditions and circumstances (Loevinsohn et al., 2013). An understanding of the factors influencing this choice is important for economic study of determinants of growth, and generator and disseminators of those technologies (Kinyanjui et al, 2009).

Social-Economic Factors

Access to credit facilities as an economic factor has been reported as an essential aspect in technology adoption (Ayesha & Mohammed, 2012). Credit accessibility promote the acceptance of risky technologies through reduction of the liquidity constrains and boosting household risk bearing ability (Ahmed, 2004). In some countries, access to credit facilities have been found to be discriminative especially on households headed by females thus affecting the ability of women to engage in yield-raising technologies (Muzari et al., 2013). Kenya economy promotes women and youth involvement in new technologies by providing activities that provide free interest on loan to them (UWEZO fund).

Nevertheless, size of the land plays a major role in adoption of new technology. Land size can affect and in turn be affected by the other factors influencing adoption (Bandera & Rasul, 2002). Most studies have reported a positive relation between farm size and the adoption of agricultural technology (Ahmed, 2004; Uaine et al., 2009; Mignouna et al., 2011). In consideration to total firm size and not the crop acreage on which the new technology is practiced, overall adoption could be influenced more by the consideration of crop acreage with the new technology.

Individual preference is a factor that determines the adoption rate of a technology. Taste and cultivation practice will affect how profitability is perceived in a household (Muzari et al., 2013). Technologies from other regions may have different flavors and textures than local substitutes and may not be adopted even if they increase yields and income (Challa, 2013). Evidence shows that amount income earned by individuals determines the investments the person can venture in (Challa, 2013). The size of the household is stated as a key factor for the amount an individual is willing to let go for a certain good or service (Muzari et al., 2013). Social normality is significant for technologies where individual adoption decisions generate cost and benefits from both the profitability of technology (Mignouna et al., 2011).

Institutional Factors

Being in a social group enhances social capital allowing trust, idea and information exchange (Mignouna et al., 2011). Farmers within a social group learn from each other the benefits and usage of a new technology. Uaine et al., (2009) suggested that social networks effects are important for individual decision. In a study by Kiarie (2014) in Nigeria, it was noticed that farmers who participated in most of the community-based organizations were likely to engage in social learning about a technology hence raising the likelihood to adopt the technologies.

Although researchers have reported the positive influence of the social groups on technology adoption, social group can however have negative impacts on technology adoption especially where free riding behaviors exist. Learning from experimentation from neighbor farmers, farmer may initiate negative adoption of the technology after they learn the risks and the disadvantages of the project through learning from the experimental sites or neighbors (Bandiera and Rasul, 2002). However, the characteristic of technology, the trialability or the level to which a potential adopter can try something out on a small scale first before adopting it fully is a major determinant of technology adoption (Mignouna et al., 2011; Doss, 2013).

A study of adoption agricultural technology studies in Western Kenya showed that the characteristic of a technology plays a vital role in adoption decision process by farmers. Mignouna et al., (2011) and Mamudu et al., (2012) argued that farmers who see the technology being consistent with their needs and compatible their environment are likely to adopt since they find it as a positive investment. The results indicated that perception of farmers towards fish farming facilitated its uptake. There is therefore a need for evaluation of farmers' perception to a new technology and its suitability to their circumstances.

Offering extension services to farmers improves farmer's ability to take a technology (Muzari et al., 2013). Acquirement of information about a new technology clarifies it and makes it more available to farmers. Availability of data reduces the ambiguity about a technology performance and can change personal assessment from merely skewed to purpose (Challa, 2013). Good information sharing programs and links with producers are essential aspects in knowledge distribution and acceptance. A new technology is as good as its mechanism of information transfer (Challa, 2013).

C. Challenges of Bamboo Farming

Bamboo has not been exploited to its full potentials in many areas where it grows. A number of studies have highlighted reasons as to why bamboo farming has not been popular within Africa (Lobovikov et al., 2005). According to KEFRI, 2008; Kigomo, 2007; and Ongugo et al., 2000 the major challenges of growing bamboo include; lack of awareness on bamboo farming, inadequate technology, and market chain systems for bamboo products. For bamboo farming to fully establish, it is critical that the constraints are identified and addressed for progress to be seen.

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III. METHODOLOGY

A. Description of the Study Area

The study was conducted in Ol'kalou Sub County and Ol'jororok Sub Counties which are in Nyandarua County-Kenya. Nyandarua is situated within the central region of Kenya and lies between latitude 0o 8' North and 0o 50' South, 35o13' East and 36o42' West. The county has an approximate area of 3245.2 km2 and borders Laikipia to the North, Nyeri to the East, Kiambu to the South, Muranga to the South East and Nakuru to the West.

B. Research Design

Open and closed ended questionnaires were administered to the targeted population and descriptive research design was adopted. Chi square correlation tests were carried out to determine whether there was any relationship between the agro-forestry systems and the rate of adoption, the social economic factors and the rate of adoption as well as the challenges and the rate adoption of bamboo for agroforestry

C. Target Population

The target population was 200 farmers which included 103 bamboo farmers from Ol'kalou and 97 bamboo farmers from Ol'jororok Sub-counties

Table 1 Target population

Sub county	Number of bamboo farmers
Ol'kalou	103
Ol'jororok	97
Total	200

(Source: Ministry of Agriculture Nyandarua County)

D. Sampling Techniques and Sample Size

The sample size for small scale farmers in the two sub counties was chosen using Krejcie and Morgan Table (1970), From the target population of 200 farmers a sample of 132 farmers was selected using random sampling technique to ensure the respondents were evenly distributed within the study area.

Table 2 Sample size calculations

Sub County	Target population	Sample size
Ol'kalou	103	103/200*132=**68**
Ol'jororok	97	97/200*132=**64**
Total	**200**	**132**

IV. RESULTS

Table 3 Response (%) of the zone where bamboo is planted

Bamboo planting zone	Sub-county	
	Ol'kalou	**Ol'jororok**
Cultivated area	23.8	11.5
Homestead farm	40	26.9
Farm boundary	11.3	15.4
Grazing area	7.5	15.4
Along the valley	17.5	30.8

Table 4 Selected household social economic characteristics in percentage (n=132)

Socio-Economic Variable	Sub-County		
	Ol'kalou	**Ol'jororok**	**Mean (%)**
Gender of Household head			
Male	48.5	53.1	50.8
Female	51.5	46.9	49.2
Average age of household head(years)			
18-30	11.8	12.5	12.2
30-40	35.3	32.8	34.1
41-50	19.1	20.3	19.7
51-60	29.4	25	27.2
Above 61	4.4	9.4	6.9
Level of education			
Never attended school	7.4	9.4	8.4
Primary	13.2	17.2	15.2
Secondary	22.1	29.7	25.9
Tertiary	57.4	43.8	50.6
Occupation			
Farmer	19.1	25	22.1
Businessman/woman	22.1	29.7	25.9
Farming and business	35.3	32.8	34.1
Teacher	23.5	12.5	18
Household size			
1-3	45.6	37.5	41.55
4-6	36.8	35.9	36.35
7-9	13.2	17.2	15.2
10 and above	4.4	9.4	6.9
Monthly Income (Ksh)			
Less than 10,000	2.9	6.3	4.6
10,000-20,000	23.5	23.4	23.45
20,000-30,000	47.1	42.2	44.65
Above 30,000	26.5	28.1	27.3

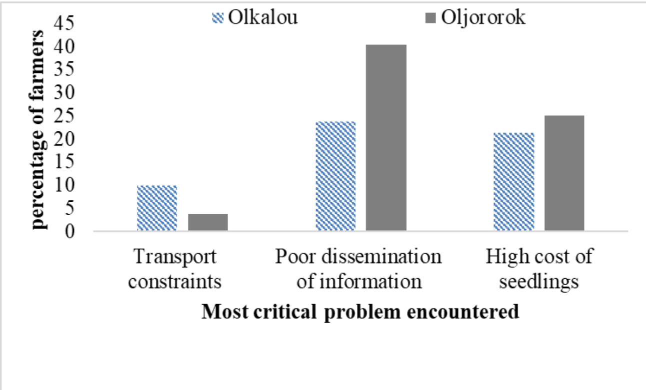

Figure 1 Response (%) on Critical problems encountered

Table 5 Chi-Square Test between agroforestry system and rate of adoption of bamboo for agroforestry

Sub County		Value	Df	Asymptotic Significance (2-sided)
Ol 'kalou	Pearson Chi-Square	14.173ª	4	.004
	Likelihood Ratio	11.548	4	.021
	N of Valid Cases	68		
Ol 'jororok	Pearson Chi-Square	25.243ᵇ	5	.000
	Likelihood Ratio	22.304	5	.000
	N of Valid Cases	64		

a. 6 cells (60.0%) have expected count less than 5. The minimum expected count is .10.

b. 8 cells (66.7%) have expected count less than 5. The minimum expected count is .16.

Table 6 Chi- Square Test between Land Size and Adoption of Bamboo for Agroforestry

Sub County		Value	Df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Olkalou	Pearson Chi-Square	1.433ª	1	.031		
	Continuity Correctionᵇ	.637	1	.425		
	Likelihood Ratio	1.476	1	.224		
	Fisher's Exact Test				.427	.214
	N of Valid Cases	68				
Oljororok	Pearson Chi-Square	4.633ᶜ	2	.009		
	Likelihood Ratio	5.558	2	.062		
	N of Valid Cases	64				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.50.

b. Computed only for a 2x2 table

c. 3 cells (50.0%) have expected count less than 5. The minimum expected count is .31.

Table 7 Training on bamboo farming and problems experienced during land preparation and planting Cross tabulation

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.764ª	1	.096		
Continuity Correction	2.153	1	.142		
Likelihood Ratio	2.817	1	.093		
Fisher's Exact Test				.119	.070
N of Valid Cases	132				

0 cells (0.0%) have expected count less than 5. The minimum expected count is 16.26.

V. DISCUSSION

A. To Investigate the Agroforestry Systems in the Selected Sub Counties of Nyandarua County

Results from table 3 on agroforestry systems practiced with bamboo revealed that bamboo was mostly planted along the homestead farm (Mean= 33%) followed by along the valley (Mean=24%). Bamboo planting on grazing area was the least (Mean =11%) According to Ogungo (2012) in Kenya bamboo grows on hilly areas and along valleys which could be attributed to massive growing of bamboo along valleys on the study areas. The bamboo grown on grazing areas was the least maybe because bamboo is good fodder crop thus discouraging planting on grazing areas because the bamboo grown by farmers was commercial. Bamboo is a good fodder crop, good in energy production and a source of food in Kenya (Karanja *et al.*, 2015) and farmers may have shunned away from planting the crop within grazing areas because on grazing areas it would have been eaten by grazers and hence not reach the goal of the farmers.

B. To establish the factors influencing the adoption of bamboo for agroforestry in the selected Sub Counties of Nyandarua County

From table 5, it was evident that agroforestry systems significantly affected the rate of adoption of bamboo for agroforestry (P value =0.004 and 0.000) for Olkalou and Oljororok sub counties respectively. The results were in conjunction with Nath *et al.*, 2009 who found out that agroforestry systems favor different crops compared other crops. Nath *et al.*, 2009 argued that the results might have behaved so due to allelopathic effects of some agroforestry trees compared to others.

Results (Table 4) also revealed that more male headed households had adopted bamboo farming (mean=50.8%) compared to women (mean=49.2%). The results are in agreement with findings by Yeshabel *et al.*, (2011) who established that land related investments were more adopted by men than women due to land ownership related issues. More Farmers aged between 30 and 40 Yeshabel *et al.,* (2011) had adopted bamboo farming (34.1%) in comparison to other age brackets. It was also evident that farmers earning a monthly income above ksh. 20,000 had adopted bamboo farming more compared to the ones who had little income (44.65% and 27.3%). The results are in agreement with Loesvinsohn *et al*., (2013) who established that income per house hold influenced the rate of adoption of new agricultural technologies. The results could have been attributed to the high cost of acquiring seedlings and land preparation for bamboo growing.

According to Nath *et al.,* 2009 it was established that farmers land size influences the type of agroforestry system practiced by the farmers. This was in agreement with the results of this study (table 6), which found out that land size directly influenced the rate of adoption of bamboo for agroforestry as well as the type of agroforestry system.

C. To Examine the Problems Faced by Farmers Cultivating Bamboo in Selected Sub Counties of Nyandarua

It was established that (figure 1) the most critical problems encountered by bamboo farmers included poor dissemination of information, high cost of seedlings and transport of bamboo seedlings. The results (Table 7) established that the problems encountered by farmers were not related to training received by the farmers concerning bamboo farming ($p < 0.096$). The results were not in agreement with Mignouna *et al.,* 2011and Doss, 2013 who established that the problems encountered by agricultural farmers were directly influenced by the training undertaken by the farmers concerning the farming techniques. The results here in could have been so may be because the problems encountered were not related to the trainings undertaken by the farmers.

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Recommendations

Ministry of Agriculture should encourage bamboo for agroforestry with leguminous crops and root tubers such beans and potatoes.

Extension officers for Ministry of Agriculture and Non-Governmental Organizations should continue providing information on agroforestry practices available for bamboo as well as regular trainings on the entire value chain from bamboo planting to harvesting and marketing

Investors willing to venture in bamboo industry can provide subsidies to farmers provide seedlings to farmers willing to venture in bamboo growing which will reduce costs of land preparation. The incentives will reduce the effect of farmers being affected by the costs incurred during bamboo growing thus increasing bamboo production

To increase the supply of bamboo seedlings more training on propagation of bamboo seedling through the government should be done to the local communities

The Ministry of Education should introduce farming, its value chain and value addition in education curriculum. The trainings will reduce the predominance of non-Governmental institutions and thus reduce monotony thereby reducing the prices of seedlings and bamboo products to an affordable amount hence more farmers and more investors into bamboo business.

Research institutions such as Kenya Forestry Research Institute and Kenya Agricultural and Livestock Research Institute should undertake more researches to establish the best crops for intercropping with bamboo for maximum production.

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