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CHARACTERIZATION AND DETERMINANTS OF SMALLHOLDER PIGEON PEA FARMERS IN MACHAKOS COUNTY, KENYA.

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Abstract

Pigeon pea is a protein-rich legume grown in semi-arid areas. It ranks third among the pulses in Kenya and grows in different climates and soils. Characterizing pigeon pea farmers is important in formulating relevant policies for the farmers who differ from farmer to farmer. The study aimed at examining the characteristics of smallholder pigeon pea farmers. Using a cross-sectional survey of 310 pigeon pea farmers in Machakos, Principal Component Analysis and Cluster Analysis were used to characterize the pigeon pea farmers and to identify their determinants. Results showed that farmers could be grouped into three clusters described as low agricultural production, average agricultural production, and high agricultural production farmers. The clusters were mainly shaped by variations in main occupation, type of roads, distance to the market, land size, source of agricultural information, and group membership. The study recommends reforms in land ownership policies that would increase financial accessibility and the infrastructure required by smallholder pigeon pea farmers.
Keywords: *Pigeon pea farmers, characterization, principal component analysis, cluster analysis, determinants, variation.*
JEL Codes: *Q1, Q10, Q12*

1. Introduction

Pigeon pea is an important crop in Kenya, popularly referred to as "*Mbaazi*" in the local dialect. It grows in the semi-arid and sub-tropical areas of Kenya. Pigeon peas are reported to have originated in India and were introduced in Kenya as a perennial legume. Kenya is ranked third in pigeon pea production, cultivated on over 200,000 hectares of land (Esilaba *et al.*, 2021). It adapts to different climates and soils, but it is concentrated mainly in Machakos, Kitui, Makueni, Embu, Tharaka Nithi counties, and some parts of the coastal region. The current average production achieved by farmers is 544 kg ha1, which is below the potential yield of 1500–2000 kg ha1 (Esilaba *et al*., 2021).

Smallholder pigeon pea farmers in Kenya grow this crop primarily for consumption through mixed-crop farming. They are therefore classified by analyzing socioeconomic factors that help to map the existing farming characteristics and to aid in promoting agribusiness by making informed decisions based on the grouped farmers (Mohammadi *et al.*, 2020). It is achieved by organizing them in a way to aid in decision-making and the implementation of proper policy options that could enhance production efficiency. Smallholder farmer characterization is critical in determining farm typologies. According to Nyambo *et al.* (2019), characterizing farmers enables making informed decisions by identifying their demographics, work distribution, availability of labor, facilities, supply, and usage of farmer inputs. A smallholder farmer can be identified as a person who practices farming on a small piece of land to cultivate food for consumption and sometimes simple varieties of cash crops. Such farmers in various localities do mixed crop and livestock farming with an average acreage of land below two hectares (Lowder *et al*., 2016).

Every farmer is unique, and this helps to appreciate the variability of different producers. Therefore, farmers' different experiences and approaches to farming vary in production operations and are thus grouped to fit into different categories (Adzawla *et al.*, 2021). Existing studies have focused on the production aspects of pigeon peas, while the characterization of the producers has not been thoroughly done. There is a need to create knowledge on the socioeconomic factors of smallholder farmers that helps inform relevant and specific policies for efficiency and competitiveness in the sector. It helps to communicate the required information based on the different types of farmers. Understanding the current status of pigeon pea farmers will enable further development of the sector that benefits households in pigeon pea-growing areas. The present study aims to characterize pigeon pea farmers in Machakos County, Kenya, and analyze the factors influencing the variations in pigeon pea farmer typologies. The study complements the study by Matere *et al*. (2022), who examined the adoption of improved pigeons based on whether the family is headed by a male or female in decision-making. The study helped determine whether the head of a family would affect overall production and marketing decisions. This study will contribute to the pigeon pea value chain by characterizing farmers and the determinants of their variations to help inform the creation of appropriate policies.

2. Materials and Methods

2.1 Study Area and Sampling

The study was conducted in Machakos County, which is characterized by a high production of pigeon peas. The target population was smallholder farmers growing pigeon peas. Farmers were selected randomly in three sub-counties, Yatta, Mwala, and Masinga, using a multistage sampling procedure. Data was collected from smallholder pigeon peas individually and through organized focus group discussions. Extension and agricultural officers were also interviewed as key informants to offer more insights. Data was collected through a pretested questionnaire administering 310 farmers who were selected randomly.

The sample size was determined using the Cochran formula, which helps to calculate the ideal sample size given the level of precision, confidence level, and estimated proportion of the attributes found in the population (Mugenda, 2003).

$$\mathrm{n}=\frac{p\,(1-p)Z^2}{d^2}$$

Where,

Population size – n; Desired level of precision – d ;The proportion of the population growing pigeon peas – p; The abscissa of the curve cutting off the area at the tail at 1.96-at

95% Confidence Interval – z. The formula gave a total of 288 respondents and the total number of farmers was 310.

2.2 Analytical Model

The data was first analyzed creatively in order to compare farmer socioeconomic characteristics across sub-counties. A two-multivariate technique was used to characterize pigeon pea farmers, which consisted of principal component analysis (PCA) and cluster analysis (CA). The use of PCA was used to reduce information from the original variables to a smaller set of independent variables while retaining the original information. The resulting variables are referred to as components and were used as the inputs for CA, which is the second stage of identifying pigeon pea farmer typologies. According to Swathi and Pothugathi (2020), PCA decreases the dimensions that define the difference in the groups of correlated parameters based on separate sets of uncorrelated parameters. The use of PCA assumes normality in data independence, matrix factorability, and adequacy in data sampling. Data was subjected to the Kaiser-Meyer-Olkin (KMO) and Bartlett Test of Sphericity (BTS) to ensure that these assumptions were met. In the first stage of PCA, socio-economic variables were used to describe the attributes of pigeon pea farmers. The PCA condensed the interrelated variables to form a set of factors referred to as the principal components. The factors were then rotated using the varimax method, and the correlated variables were placed under each factor. According to the Kaiser criterion, factors with an eigenvalue above one were retained and explained. Field (2005) indicated that the Kaiser criterion is appropriate if the variables used are less than 30. In the second stage, inputs from the CA replaced the retained factors from the PCA. They are characterized based on the similarities and differences of the presented attributes. The number of clusters was then established. The technique was used because of its ability to select the clusters automatically and its ability to form clusters using both continuous and categorical variables. In addition to the cluster analysis, a one-way analysis of variance (ANOVA) test was used to identify differences between the clusters. Thus, the identified variables explained the largest differences between the clusters. The study tested the hypothesis that there were no statistical differences among smallholder pigeon pea farmers in Machakos County, Kenya.

3. Results and Discussion

3.1 Socio-economic Characteristics of Pigeon Pea Farmers in Machakos County

Table 1 presents findings on the socio-economic characteristics of pigeon pea farmers. The findings showed that 53.5% of the respondents were males and the rest were females (46.5%). This implies that farmers of both genders were all participants in smallholder pigeon pea farming. The results indicated that the majority of the household heads (50.3%) had attained primary school education while 36.1% had attained secondary school education. Nearly 10.3% had attained tertiary education and 1.3% had reached the university level. However, 1.9% of the respondents had no form of formal education. All the interviewed farmers grew pigeon peas, where 92.6% participated in pigeon pea marketing, while 7.4% did not sell but grew only for consumption. The larger number of farmers interviewed (96.1%) relied on farming as the primary source of income. Results showed that farmers participated in other sources of income such as private employment (1.6%), government employment (0.3%), and those owning their businesses (1.9%).

Table 1. Household Characteristics of Pigeon Pea Farmers

Characteristic	Category	Frequency	Percentage
	Male	165	53.5
Gender	Female	145	46.5
	Primary	156	50.3
	Secondary	112	36.1
	Tertiary	32	10.3
	University	4	1.3
Education level for HHH	No education	6	1.9
	Farming only	298	96.2
	Government employed	1	0.3
	Private employed	5	1.6
Source of income	Business person	6	1.9
	Katumani	23	7.4
	Kat 777	1	0.3
	Mbaazi 1	3	1
	Mbaazi 2	10	3.2
	Mbaazi 3	17	5.5
Variety used	Local races	256	82.6
	Friends	103	33.2
	Family members	51	16.5
	Government officials	91	29.4
	Farmer group	27	8.7
	TV/Radio	20	6.5
	Mobile phone	1	0.3
Source of information	Agrovet	17	5.5
	Farmers	310	100
	For consumption	23	7.4
Grows pigeon peas	For consumption and sell	287	92.6
	Direct consumer	29	9.4
	Rural retailer	167	53.9
	Rural and urban wholesalers	36	11.6
	Broker	55	17.7
Marketing channel	Did not sell	23	7.4
	No	109	35.2
Group membership	Yes	201	64.8
	Self-help group	98	48.76
	Farmer-based organization (FBO)	79	39.30
	SACCO	3	1.49
	Cooperative	7	3.48
Type of groups	Church group	14	6.97

Further, the majority of the respondents (82.6%) grew local varieties such as *Kionza and kalonzo* in the local dialect, followed by Katumani which is the second most common variety

planted by farmers (7.4%). Results showed other varieties grown (9%) such as M*baazi 1*, *Mbaazi 2*, and *Mbaazi 3*. A group in the Mwala sub-county from focused group discussions reported an ongoing efficacy trial using *Mbaazi 2* sponsored by the KSCAP project and was still waiting to get results on the crop performance to compare with the performance of the local varieties and Katumani seed from KALRO.

Results showed that friends were the main source of agricultural information (33.3%), followed by government officials at 29.4%, and family members at 16.5%. Other farmers got information from farmer groups (8.7%) which they were part of. However, some farmers and key informants (agricultural officers) reported the existence of different groups such as farmer-based organizations, SACCOS, and church groups, but none was for pigeon pea marketing. Almost all farmers owned a phone, but only one farmer who grew pigeon peas for sale used the phone to get information on agricultural production and less on pigeon pea marketing.

The majority of the farmers sold their pigeon peas to rural retailers (58%), followed by brokers (19.2%), rural and urban wholesalers (12.5%), and direct consumers (10.1%). Farmers reported that they sold their crops to rural retailers because they were more reliable and available at any time and others sold to brokers who came to their farm gate. The price of pigeon peas per kilo varied between seasons ranging from 30 to 70 Kenyan shillings. Farmers argued that the crop does well in the area because of low rainfall, however, they did not have the appropriate information on how they could venture more into commercialization. Farmers also reported that the crop is produced through mixed crop farming with maize, sorghum, and beans, and thus low production. They count specific lines, for example, three or four lines in a given piece of land. Thus, calculating the exact land size for growing pigeon peas was a challenge.

In regards to group membership, 201 farmers reported being in different groups such as self-help groups, farmer-based organizations, SACCOs, cooperatives, and church groups while 109 farmers were not in any group. Findings showed that farmers held groups for different purposes, and there was no specific group for pigeon pea marketing. Farmers in self-help and farmer-based organization groups reported borrowing money for production and other personal purposes such as paying school fees for their children. The other groups were for either church or welfare activities.

Table 2. The Socioeconomic Characteristics of Pigeon Pea Farmers

Variable	Mean	Std. Dev.	Min	Max
Gender	0.47	0.50	0	1
Age	48.24	14.89	18	93
Marital status	1.33	0.85	1	4
Number of Members	5.83	2.29	3	14
Education of household head	1.68	0.86	1	5
Occupation of Household head	1.24	0.67	1	4
Source of income	1.09	0.48	1	4
Type of road	1.60	0.49	1	2
Distance to the market	3.18	3.15	0.1	20
Land size	3.81	3.51	0.5	27
Variety used	5.46	1.38	1	6
Source of information	2.26	1.61	1	7
Group membership	2.63	1.43	0	1

Table 2 shows the socioeconomic characteristics of the households interviewed during the study in Machakos County. The findings showed that the mean age was 48 years old. Households had a minimum of 3 members, and the one with the highest number of household

members had 14. Every household head had at least attained a primary school education. The results showed that all the households had an acreage of 0.1 acres, with a mean average of 3.8 acres for all the households. This implies that all farmers participated in farming. Households had different sources of income, with farming as the main source. Other sources included self-owned businesses and employment from both the public and private sectors. The roads were either gravel or tarmac in nature. The distance covered by the nearest household to the market was 0.1 km, while the longest was 20 km. Farmers reported different types and varieties of pigeon peas they grew, and the local variety was commonly used. There were different sources of information, and most of the farmers had at least two sources of information. Farmers had joined various types of groups, and the majority of them were members of at least one group.

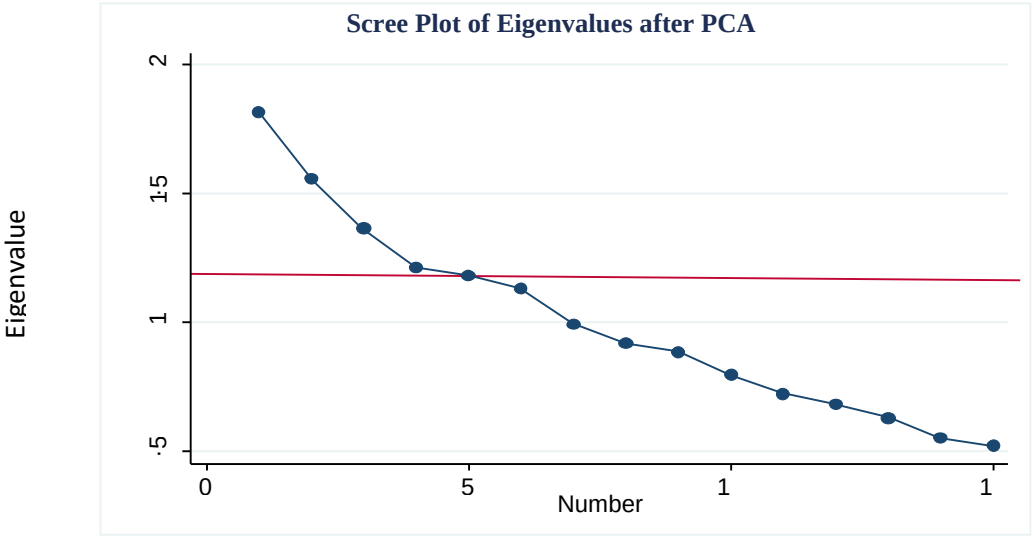
3.3 Principal Component Analysis Results

The Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity (BTS) for the Principal Component Analysis were done and the results obtained are shown in Table 3.

Table 3: Kaiser-Meyer-Oklin and Bartlett's Test of PCs

Kaiser-Meyer-Oklin Measure of Sampling Adequacy	0.540
Bartlett Test of Sphericity Chi-square	264.974
Degrees of Freedom	105
P- value	0.000

The KMO value was 0.540, indicating the efficiency of the items obtained for each factor. Bartlett's test was 274.62 with a p-value of 0.000, showing the appropriateness of data for PCA. The use of elbow criteria helped to explain the PCA results thus determining the number of clusters in a data set (Ledesma *et* al., 2015). Therefore, the tests met the KMO criteria and thus supported the appropriateness of applying PCA. In PCA, the Kaiser rule provides that only the Eigenvalues greater than 1 are retained (Pugno & Verme, 2012). In this study, the Eigenvalues that were greater than 1 and with substantial differences of 1.2, were obtained. Table 4 shows the eigenvalues and components explained.



Source: Author's Data Computation

Figure 1. Scree Plot for the Eigenvalues

Figure 1 presents results from the scree plot showing the first four factors that account for 39.73% of the total variance. The four components were selected for the analysis because they represent a substantial variation from each other retained for the study.

Table 4. Principal Components Factor Loading

Factor and Item Description	Factor Loadings	% Variance Explained
Factor 1: Infrastructure factor		***12.05%***
Type of road	0.4936	
Distance to market	0.3070	
Land size	0.3025	
Factor 2: Demographic factor		***10.48%***
Age	0.5264	
Gender	0.5427	
No. of household members	0.4782	
Marital status	0.4117	
Factor 3: Economic factors		***8.82%***
Education of household	0.3461	
Occupation of household	0.4553	
Source of income	0.3254	
Factor 4: External factors		***8.16%***
Buyer services	0.4432	
Group membership	0.4175	
Total Variance explained		39.51%

Table 4 gives the results of the selected and retained components. The first retained component was named the infrastructure factor. It accounts for 12.05% of the total variance made of four items, namely type of road (0.4936), distance to the market (0.3070), and land size (0.3025). The second component retained was named the socio-demographic factor, with four items accounting for 10.48%. The items contained in the element include age at 0.5264, number of household members at 0.4782, gender at 0.5427, and marital status at 0.4117. The third factor was named education and income factors, with three items accounting for 8.82%. The items were the education of the household at 0.3461, occupation of the household head at 0.4553, and source of income at 0.3254. The last component was named the external factor, with two items accounting for 8.16%. The items include the buyer services at 0.4432 and the group membership at 0.4175. Therefore, the factor loading makes it clear that infrastructure, socio-demographics, education, income factors, and external factors of group membership and buyer services were essential factors in characterizing pigeon pea farmers.

3.4 Cluster Analysis Results

The four components retained in the PCA were used as inputs for the cluster analysis to characterize the pigeon pea farmers. The farmers were grouped in three clusters as shown by the dendrogram in Figure 2.

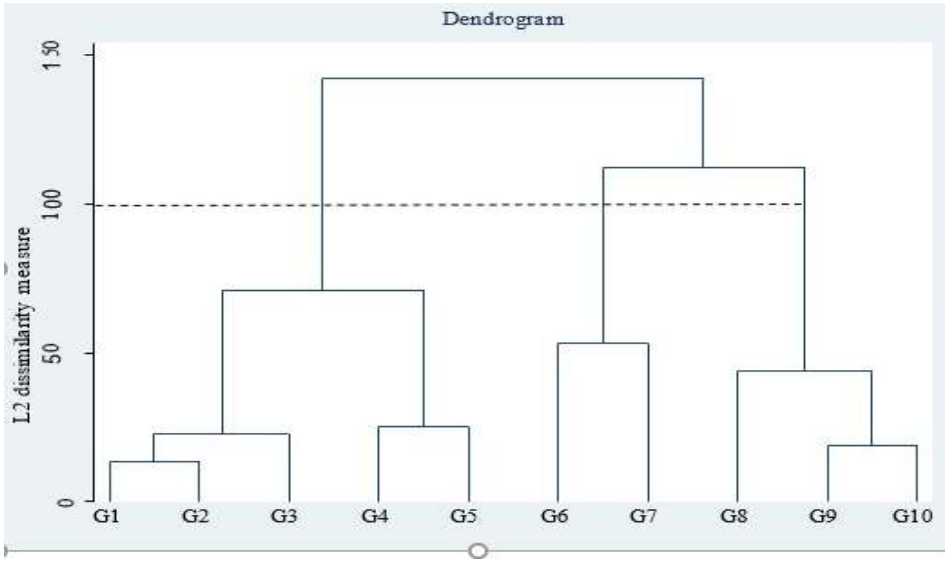


Figure 2. Cluster Dendrogram

Table 5 presents the results of cluster analysis (CA). The results showed that the pigeon pea farmers were not homogenous because of their different socioeconomic characteristics. The ANOVA analysis showed three distinct clusters of pigeon pea farmers based on various characteristics as shown in table 5.

Table 5. Characteristics of the Clusters Based on the Means

Socio-economic Characteristics	**Cluster 1**	**Cluster 2**	**Cluster 3**	**F value**	**Prob > F**
Age	38.4	56.3	47.8	47.0	**0.000**
Gender	0.0	1.0	1.0	8.36	0.073
No. of HH members	4.0	7.0	5.0	50.9	**0.000**
Marital status	1.0	1.0	1.0	5.31	0.125
Education of HH head	2.0	1.0	1.0	5.08	**0.007**
Main occupation of HHH	4.0	2.5	1.0	12.78	**0.030**
Source of income	4.0	2.1	1.0	0.19	0.324
Type of road	1.0	2.0	2.0	51.08	**0.000**
Distance to the market	2.3	3.0	4.0	20.69	**0.000**
Land size	2.5	4.1	5.0	4.86	**0.000**
Variety used	5.6	5.3	6.0	1.52	0.223
Source of information	1.0	2.0	2.9	3.08	**0.048**
Mode of transport	2.4	3.0	2.3	4.90	0.783
Buyer services	0.1	0.4	0.3	129.81	0.414
Group membership	0.0	0.7	1.0	38.12	**0.000**
Cluster frequency	*81*	*117*	*89*		
Cluster distribution	*28.22%*	*40.77%*	*31.01%*		

3.4.1. Typologies of the Pigeon Pea Farmers

Pigeon pea farmers fit clusters 1, 2, and 3 according to the clusters identified in Figure 2. Type 1 represents low agricultural production with 110 households, accounting for 28.22% of the study sample. Farmers in this cluster had the lowest average age of 38 years compared to other groups. The household depends on small, family-owned businesses as its main source of income, implying that farming is not the main activity. According to the findings, the majority of household heads are married, have at least a secondary school education, and each family has a minimum of four members. Households in this cluster are located closer to the market at a mean distance of 2.3 kilometers. Because of their proximity to the market, roads near these homes are paved. They have relatively less land, with a total of 2.5 acres, and thus low production based on the acreage. This class showed a low turnout of farmers involved in various groups because most of them are involved in individual activities.

Type 2 represents farmers with average agricultural production. The cluster has 117 farmers, representing 40.77% of the total sample. The heads of households in this group had at least attained a primary school education. Farmers in this cluster had relatively greater access to land compared to farmers in cluster 1, with an average of 4.1 acres. The households are located further away from the market, with an average distance of 3.0 km, and are involved in farming for their livelihoods. Most farmers are relatively involved in different groups and thus engage in various activities.

Type 3 represents farmers associated with high agricultural production. The class has 89 households, representing 31.01% of the total study sample. Many farmers in this cluster are married, with an average of five household members. Farmers depend heavily on farming as their main occupation and source of livelihood. They are located away from the market, covering an average distance of 4 km. Farmers have high access to land, with at least 5 acres of land per household. Therefore, they are engaged in different agricultural activities and thus have high production. Farmers in this cluster are members of groups for different purposes.

3.4.2. Factors Influencing Variations in Characterization of Pigeon Pea Farmers

Tables 4 and 5 provide results from principal component analysis and cluster analysis, with distinctive factors determining the pigeon pea farmer typologies, respectively. These factors include age, number of household members, education of the household head, the main occupation, type of roads, distance to the market, land size, a source of agricultural information, and group membership.

The age of household heads varied considerably among farmers ($P < 0.0191$). Farmers in cluster 2 had the highest number of years, showing more experience in growing pigeon peas, followed by cluster 3 and then cluster 1. This is an indication that experience was a determining factor in making decisions based on growing and commercializing pigeon peas. The study is in line with the study by Abdulai *et al.* (2018) who investigated the characterization of cocoa production, income diversification, and shade tree management along a climate gradient in Ghana. He reported that the age of the head of the household head was significant in making decisions on income generation with cocoa and non-farm activities.

Farmers' characteristics were significantly influenced by the type of roads ($p < 0.000$). Some were closer to the market, and others were further away from the market. According to Jenkins *et al*. (2020), transport plays an essential role in farm-to-market transport. Farmers closer to the road can easily access different services such as health services, extension services, and better markets for their products. Farmers in this study showed a significant impact on the type of road leading to the market. Furthermore, farmers closer to tarmac roads tend to access markets even if they are far away, compared to farmers in areas where the roads are not in good condition.

Distance to the market varies significantly ($P < 0.0004$) among the pigeon pea farmers in Machakos County. Farmers in cluster 1 were closer to the market and thus had more options for selling their pigeon peas compared to clusters 2 and 3. They can sell to brokers at farm gates, to rural retailers, or to rural and urban wholesalers. Astatike & Gazuma (2019) argued that households far away from the market are likely to have high production because of large acreage but reduced marketing opportunities compared to those closer to the market because they can participate in different off-farm activities. Farmers close to the market can access information and services from buyers and agricultural officers.

Access to land was a significant factor in defining pigeon pea farmers. The results showed that land size significantly determined pigeon pea farmer characteristics ($p < 0.000$). Farmers with more land intensified their production, and therefore more was available for marketing. Cluster three had more access to land compared to clusters 1 and 2. Land plays a vital role in agricultural production and marketing. Having considerable land implies more production and thus more pigeon peas for sale. This results in more income and, therefore, better living standards for the farmers. Farmers with greater access to land can use it as collateral for other services, such as access to financial assistance. This is in agreement with the study by Muriungi *et al.* (2022) who studied the characterization and determinants of baobab processing in Kenya. He argued that land is important in characterizing farmers and can be us as a collateral when seeking financial assistance.

The source of agricultural information varied differently across the clusters ($P > 0.000$). Farmers require information from the time the crop is planted until the final product is sold to the consumer. Farmers in the three clusters accessed information from different sources. Farmers who can access information are better informed about current trends in prices, the best seeds, and other relevant information compared to those without. Farmers in cluster 1 have the highest access to information compared to clusters 2 and 3. This helps them make informed decisions on marketing. This is in agreement with the study by Muthini (2015) who investigated on the assessment of mango farmers' choice of marketing channels in Makueni, Kenya. He found out that farmers who had access to agricultural information were better off in making the proper decision on the choice of mango marketing channels.

Group membership for farmers varied significantly ($P < 0.000$). Farmers in cluster 3 are part of different groups compared to those in clusters 1 and 3. Farmer groups are important for farmers as they can get different benefits, such as market information, training from agricultural officers, and price changes. Farmers in groups can easily be trained by different agencies to support their production and marketing. According to Adeyonu *et al.* (2019), training farmers promotes group marketing and bargaining for better prices for their products. Those who market in groups have increased bargaining power and better marketing terms. Due to the current challenges faced by farmers in production and marketing, government agencies and donor agencies have been interested in transforming agriculture through farmer groups, which are the best channels to reach more farmers (Abdul-Rahaman & Abdulai, 2018). Therefore, group membership by farmers is significant for all farmers.

4. Conclusion and Recommendation

The study investigated the characterization and determinants of smallholder pigeon pea farmers using a sample of 310 farmers. Principal component analysis, and cluster analysis techniques were used to analyze the results. Findings indicated that half of the farmers interviewed had attained primary school education. While all the farmers reported growing pigeon peas, some grew them for consumption only, the rest grew for both consumption and for selling. The study concluded that most farmers were in different groups but no group existed for pigeon pea marketing. Farmers were grouped into three clusters of low agricultural production farmers, average agricultural production farmers, and high agricultural production

farmers. Factors that led to variations among pigeon pea farmers were age, number of household members, education of the household head, main occupation, type of roads, distance to the market, land size, source of agricultural information, and group membership. Based on the conclusion of the study, the study suggested the following recommendations: First, there should be training where farmers would be given information on production, extension services, marketing information, and price dynamics. Farmers should also be informed about the benefits of joining a group, which can help them increase their bargaining power and lower their costs. Land policies should also be improved and reformed to streamline ownership so farmers can widen their production capacities and can use the land as collateral for accessing credit.

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