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A Typology and Preferences for Pigeon Pea in Smallholder Mixed Farming Systems in Uganda

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Abstract: Pigeon pea (*Cajanus cajan*) remains an under-researched 'orphan crop' yet is important for food and nutrition security of smallholders. Furthermore, smallholders are heterogeneous, with varying perceptions and resource capacities. Against this backdrop, we clustered smallholders and assessed their preferences for pigeon pea. Data were gathered through a cross-sectional survey of 257 smallholders from northern Uganda, corroborated with key informant interviews. Using multivariate analysis, we generated six clusters that explained 63% of the total variance. Three farm types (LEX—low-resourced and experienced, LUN—low-resourced and inexperienced, and LED—low-resourced and educated) represented 15, 10, and 17% of the farms, respectively, and were resource-constrained with low farm size, low livestock units, low education level and low pigeon pea sales. Three other types (MEX—medium-resourced and experienced, HEX—high-resourced and experienced, HED—high-resourced and educated) represented 7, 6, and 7% of the samples and were highly-resourced given their above-average level of endowment. Pigeon pea was mainly produced for household consumption, especially by the low-resourced farm types. Across farm types, smallholders preferred pigeon pea because it fixed nitrogen (94%), is relatively easy to harvest (90%) and it provided more biomass (89%) compared to other crops. The developed typology allows for tailored pro-poor agricultural policies to address particular necessities of specific farm types. Understanding varied preferences can facilitate investments into improving pigeon pea traits, which are particularly desirable and appropriate for smallholders.

Keywords: pigeon pea; preference; endowment; smallholders; typology; Uganda

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1. Introduction

Over 80% of the people in sub-Saharan Africa (SSA) derive their livelihoods from smallholder agriculture [1]. Smallholders produce between 50 to 70% of global food, yet often remain food insecure [2]. Smallholders are heterogeneous, poor, and lack the necessary resources for agricultural intensification and transformation [3]. Soil degradation and climate change further put the low yields at risk [4]. Agriculture in SSA is characterized by seasonal cereal crops [5,6], sometimes intercropped with legumes [7]. Legumes are essential components of smallholder farming systems in many parts of SSA [8]. Most legumes, however, are often not on the radar of development discourses and policies and remain under-researched and underutilized 'orphan crops' [9].

Pigeon pea (*Cajanus cajan* [L.] Millspaugh) is a multi-purpose legume, cultivated on 6.97 million hectares globally, with a yield of 5.05 million tons [10]. Pigeon pea is mainly grown by smallholders in semi-arid regions in SSA, Asia, and Central America [11]. It is a semi-perennial legume, harvestable between 6 to 8 months. It can fix nitrogen between 40 to 250 kgha^{-1} and reduce soil erosion due to its taproot properties [12]. In Uganda, pigeon pea plays an important role for smallholder's food and nutrition security, especially in the resource-constrained semi-arid north of the country [13,14]. It is an inexpensive and reliable source of proteins, carbohydrates, minerals, and vitamins [15], and further provides fodder and residues that are used as feed, mulch, and fuel wood [8].

Previous government of Uganda programs and projects have provided blanket approaches towards the improvement of smallholder livelihoods and rural development [16]. Such approaches do not acknowledge and incorporate the stark heterogeneity among smallholders, their differing capacities, needs, and resources. As a result, such programs have remained largely ineffective and do not benefit smallholders equally, particularly the poorest [1,17]. Understanding diversity in farming systems is crucial to promoting agricultural livelihoods and to develop targeted policies and strategies for agricultural transformation [18]. Farm typology provides a framework for understanding the technical challenges in agricultural production, to develop a range of targeted solutions across different farm types [19]. There are many approaches to studying smallholder heterogeneity. Some studies suggest focusing on key elements that determine comparative advantages of different livelihoods considering, for example, the agricultural potential, market access, and population density [18]. Others in Ghana [20], Ethiopia [21], and South Africa [22] focused on linkages between smallholder diversity and technology adoption, livelihood strategies, and poverty dynamics.

In Uganda, Kansiime et al. [19] studied the diversity of smallholders in the West Nile Zone and identified three clusters based on resource use efficiency. Mulinde et al. [23] identified three and two clusters for coffee-producing smallholders in eastern and central Uganda, respectively. Further, Sebatta et al. [24] classified coffee- and banana-producing smallholders around Mount Elgon, eastern Uganda, and identified four clusters based on different crop intensification pathways. Bongers et al. [25] identified five clusters for coffee-producing smallholders in eastern and southern Uganda, based on differences in land size and the relative contribution of coffee, bananas, and off-farm labor to total household income. Dixon et al. [1] defined a farming system as a population of farm households, generally of mixed types and sizes, with similar configurations of resources, livelihoods, consumption, and opportunities.

Despite previous studies on smallholder heterogeneity, a scientific inquiry into the factors leading to diversity among marginalized farmers of northern Uganda is lacking. According to the World Bank [26], northern Uganda is the poorest part of the country, with 33% of the population living below the poverty line. Food insecurity is rampant, worsened by the conflict between 1986 and 2006 [27]. Shikuku et al. [28] reported that 59% of the households in northern Uganda consume only one meal per day. The dominant cereal crops are maize, rice, sorghum, and finger millet [27] and pigeon pea is the most important legume [14]. Smallholders keep some livestock (goats, sheep, cattle, and chicken) for additional income, food, manure, draught power, and for prestige [29].

This study therefore comprehends the heterogeneity of pigeon pea smallholders based on their socio-economic characteristics and resource endowments. Specifically, the study objectives were two-fold; (i) to characterize pigeon pea smallholders and describe smallholder types in northern Uganda and (ii) to assess pigeon pea smallholder's preferences with regard to production, marketing, and consumption attributes across the generated farm types.

2. Materials and Methods

2.1. Study Area

The study covered three districts (Lira, Pader, and Kitgum) in the mixed crop–livestock northern Uganda farming system (Figure 1). The case study districts were selected because they are pigeon pea bread-baskets in the country [30]. The region is characterized by rain-fed subsistence agriculture with a semi-arid climate [31]. It is more prone to climate change than other parts of the country [32]. Average rainfall is between 700 and 1200 mm, and the dominant soils are ferralsols, highly depleted in nutrients, as well as alisols and plinthosols [32,33]. In general, soil fertility is low, with a surface texture of sandy to coarse loamy; low Cation Exchange Capacity (CEC) and a high demand for P and K [34].

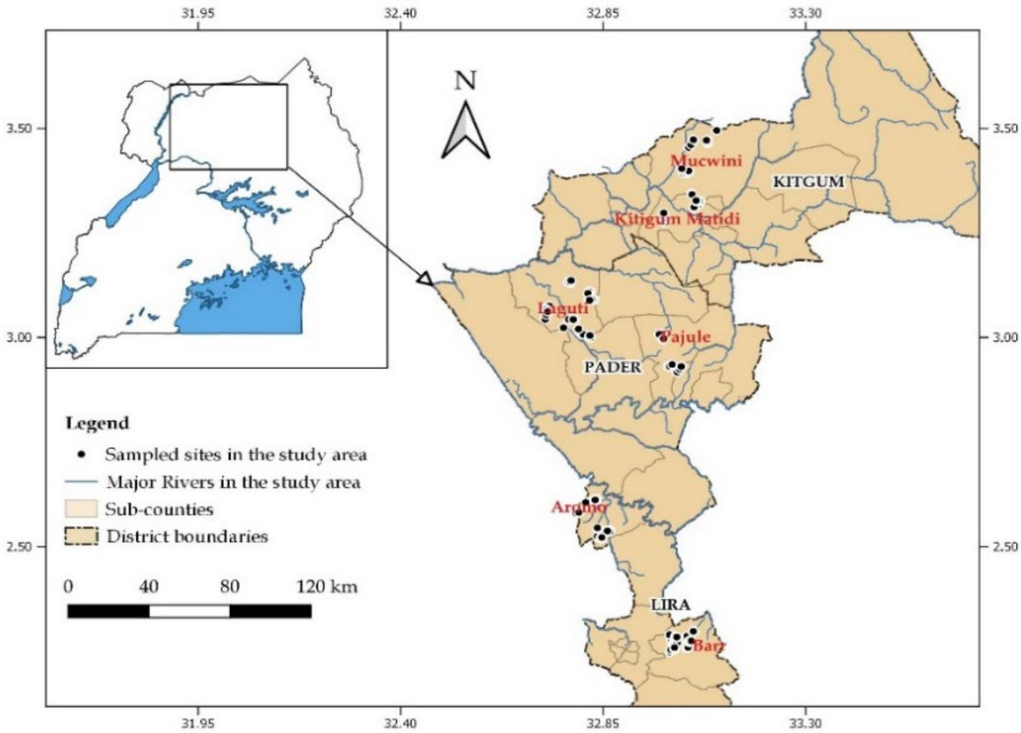

Figure 1. The study districts of Lira, Pader, and Kitgum districts in northern Uganda, black dots represent sampled households.

2.2. Sampling and Data Collection

A baseline study, including informal discussions with agricultural extension workers and researchers at the Zonal Agricultural Research and Development Institute (Ngetta-ZARDI) in Ngetta sub-county, Lira district, guided the selection of the study districts. Three districts were purposively selected following a multi-stage approach (from district to villages) and pigeon pea production statistics per district. In the second sampling stage, two sub-counties were selected per district, and in each sub-county, 3 villages (18 villages in total) were selected following a simple random sampling.

The study employed a quantitative approach that involved the use of a pre-tested semi-structured questionnaire to interview 257 pigeon pea smallholders using a Computer Assisted Personal Interview (CAPI) Kobo-collect toolbox [35]. The questionnaire included sections on household characteristics, pigeon pea production, marketing and consumption attributes, and farm endowments, as well as challenges and opportunities regarding pigeon pea production. The interviews were held in the *Langi* and *Acholi* languages and took between 30 to 40 min. All sampled smallholders had grown pigeon pea for at least two consecutive years.

Out of the 257 pigeon pea smallholders surveyed, 35% were from Pader, 34% from Lira, and 31% from Kitgum district. We targeted the household head or their spouse in case the head was absent at the time of the interviews. Key Informant Interviews (KIIs) with extension agents, Ngetta-ZARDI researchers, and village chairpersons were used to triangulate the survey data.

2.3. Data Analysis

2.3.1. Multivariate Statistical Analysis

We undertook three steps to build the typology: exploratory analysis, principal component analysis (PCA), and cluster analysis (CA). We used a Likert scale to assess smallholder perceptions.

Exploratory Analysis. We selected structural and functional variables for the construction of the typology. Variables were related to household characteristics, resource endowments, and pigeon pea production-related attributes (Table S1). Household characteristics included family size, farming experience, age, education, and years of experience of growing pigeon pea of the household heads or their spouse. Endowment variables included land used, the proportion of land dedicated to crop and livestock production, as well as the value of farm assets and livestock. Farming tools included hoes, pangas, axes, winnower, shovels, knapsack sprayers, and wheelbarrows.

To assess livestock ownership and its monetary value, we converted livestock into a uni-dimensional Tropical Livestock Unit (TLU) index of wealth in kilograms of live weight, following [30]. The index measures both wealth and manure available to the farm [25]. Each TLU unit was taken as an animal with a live weight of 250 kg [30]. Household income variables included both average monthly farm and off-farm income and the monetary value of farm assets. Pigeon pea-related attributes included acreage, yield, and the proportion of yield sold (in 2019). We used box-plots to visualize the data spread (accounting for outliers within variables) (Figure 2). During data cleaning and diagnostics one outlier farm was deleted, thus 256 smallholder farms remained for analysis.

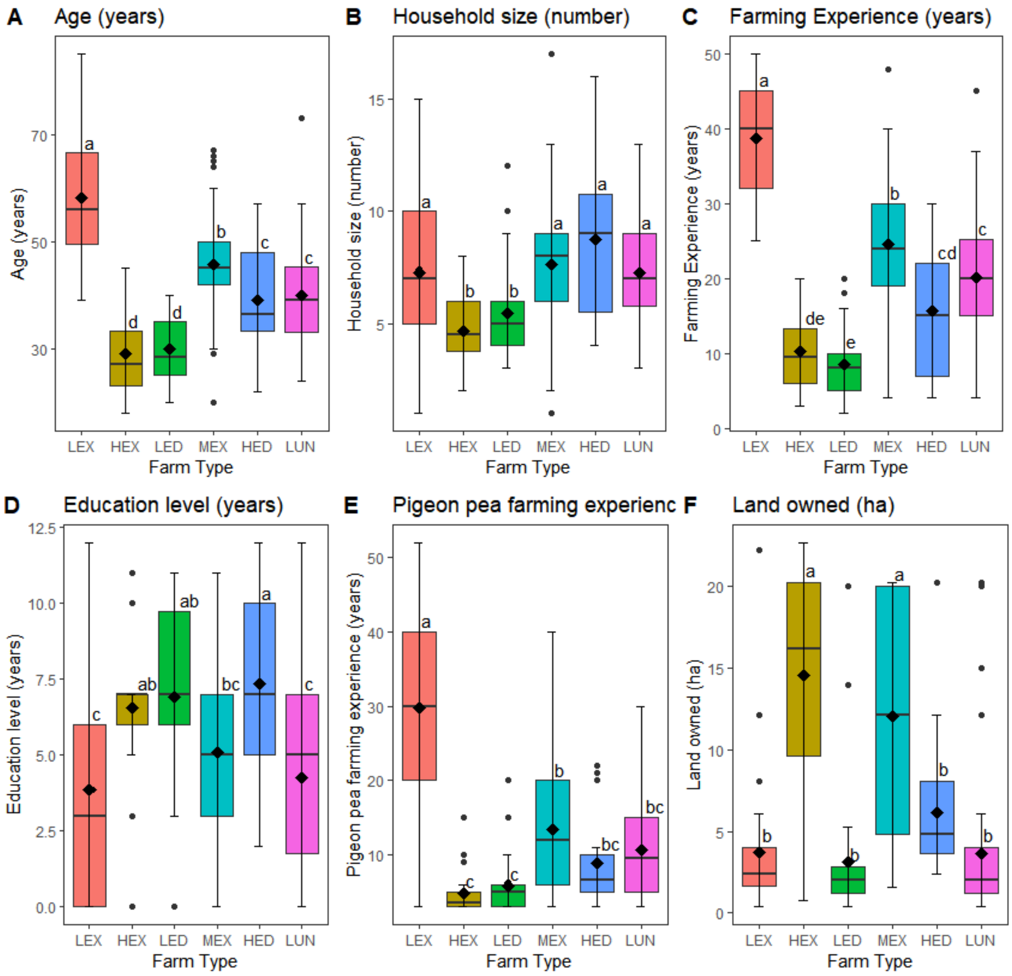

Figure 2. *Cont.*

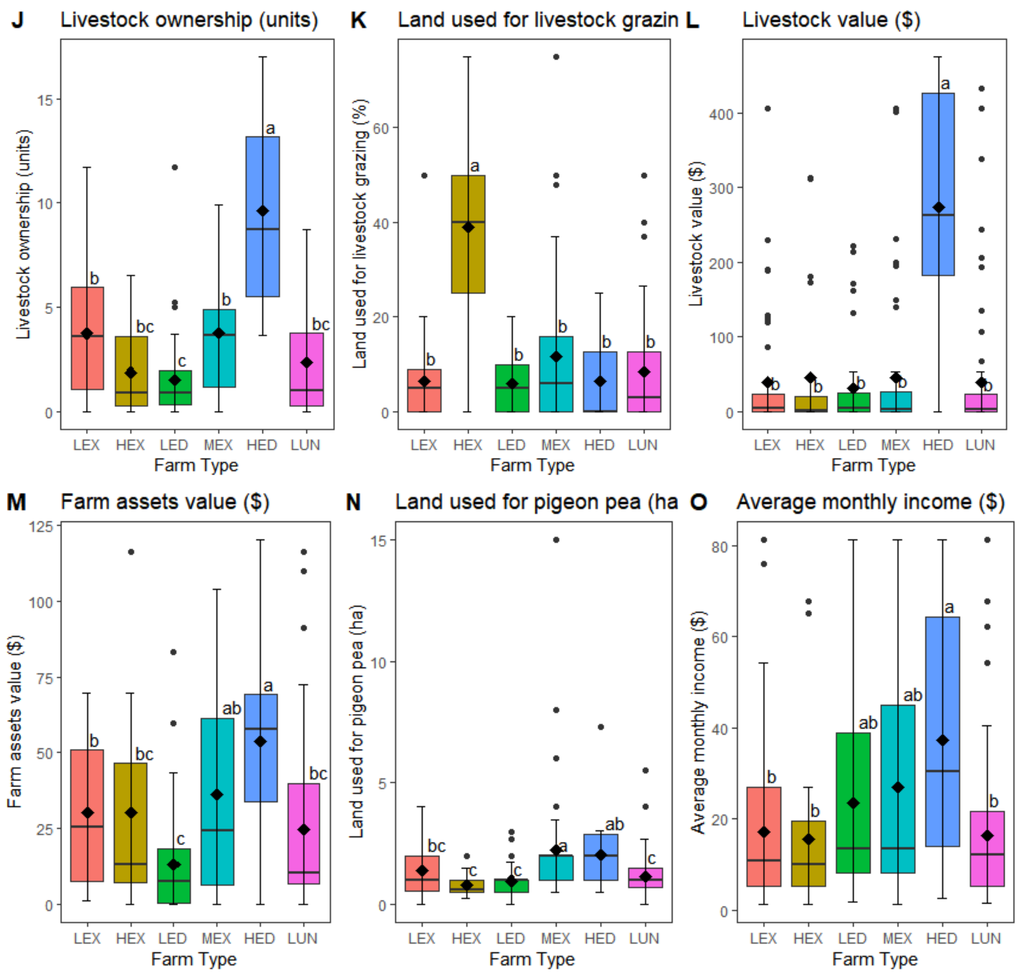

Figure 2. Farm features for the six farm types identified using hierarchical clustering analysis (n = 256). The black diamond dots represent the mean and outlier values (black circles). Farm types sizes were: LEX (low-resourced and experienced—47), HEX (high-resourced and experienced—24), LED (low-resourced and educated—42), MEX (medium-resourced and experienced—45), HED (high-resourced and educated—26), LUN (low-resourced and inexperienced—72), respectively. Error bars represent (estimated marginal) means +/− standard error. Means not sharing any letter are statistically significant by the Tukey test at a 5% level of significance.

The dataset permitted the identification of primary patterns and variabilities. PCA was conducted on 16 variables using the orthogonal varimax approach [36]. Prior to using the PCA, we measured the suitability of the variables using the Kaiser–Meyer–Olkin (KMO) test of sampling adequacy [37]. Both the overall and individual variables' sampling adequacy was above the acceptable 0.5 threshold [38].

Principal Component Analysis. We used PCA to reduce the dimensionality of the data by applying the ade4 package in R version 4.1.0 [39]. A Bartlett's test was used to check if the observed correlation matrix diverged significantly from the identity matrix [40]. Bartlett's K-square was 63,225 (df = 16, $p < 0.001$), suggesting a rejection of the null hypothesis and implying, that the correlations between selected variables were significantly different from zero and large enough for the PCA. The decision rule for principal component (PC) selection followed an eigenvalue >1 and selected PCs with a cumulative variance >60% [41], thus we selected six PCs that explained 63% of the total variance (Table S3).

Cluster Analysis. We employed the new orthogonal data projection derived from the PCA (Figure S1). We constructed a dendrogram of an ascendant hierarchical classification, using Ward's criterion [42], to measure cluster dissimilarity and to minimize the total within-cluster variance. A dendrogram is a graphical representation of the hierarchy of farm types [43]. The selected farm types had a minimum of 24 and a maximum of 72 pigeon pea smallholder farms (Figure 3). All variables were subjected to one-way analysis of variance (ANOVA) to identify significant associations and/or differences between variables and farm types. This was followed by a Tukey's HSD (honest significant difference) for post hoc mean separation conducted in R, statistical differences ($p < 0.05$), presented by superscript letters (Figure 2).

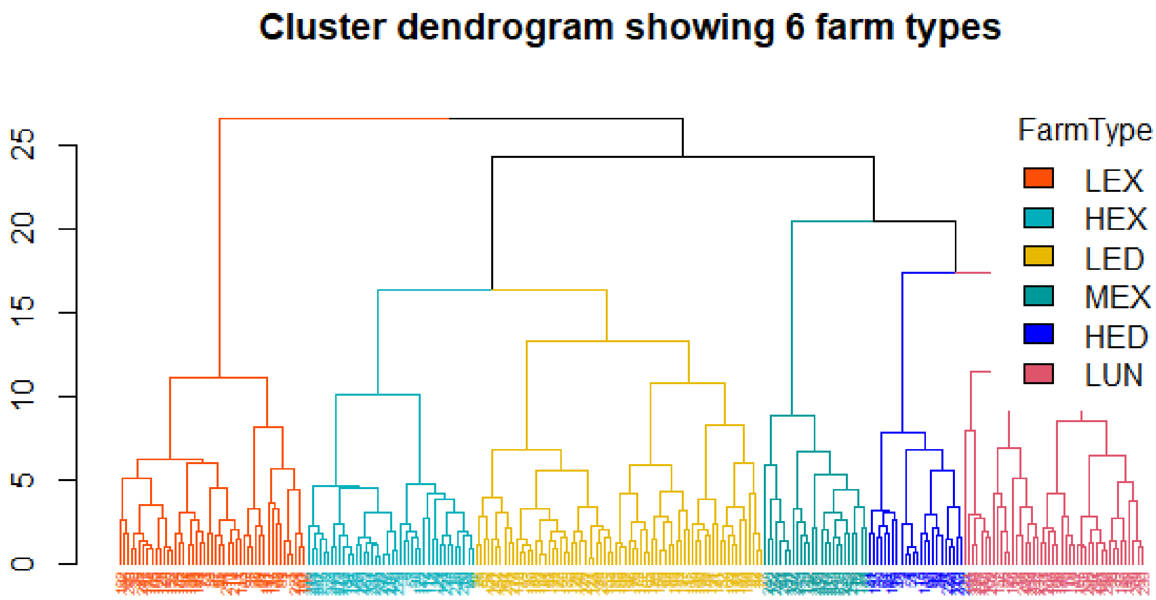

Figure 3. Representation of the six farm types constructed resulting from hierarchical clustering using the Ward's method. Farm types and their size were: LEX (low-resourced and experienced—47), HEX (high-resourced and experienced—24), LED (low-resourced and educated—42), MEX (medium-resourced and experienced—45), HED (high-resourced and educated—26), LUN (low-resourced and inexperienced—72), respectively.

2.3.2. Likert Scale Analysis

We assessed smallholder's preferences based on pigeon pea production, marketing and consumption attributes across the generated farm types. The attribute list (Figure 4) was developed from the literature and corroborated with interviews from agricultural extension officers. We used a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree), following [44]. Internal reliability estimates were obtained using Cronbach's α coefficient, with an overall value of 0.75, which is acceptable [45]. The alpha coefficients for each attribute were also above 0.5, which is acceptable. We visualized the preferences using diverging stacked bar charts with the Likert function in R software (R packages and resources by Jason Bryer. Available online: http://jason.bryer.org/likert) (Accessed on 5 January 2022) (Figure 4).

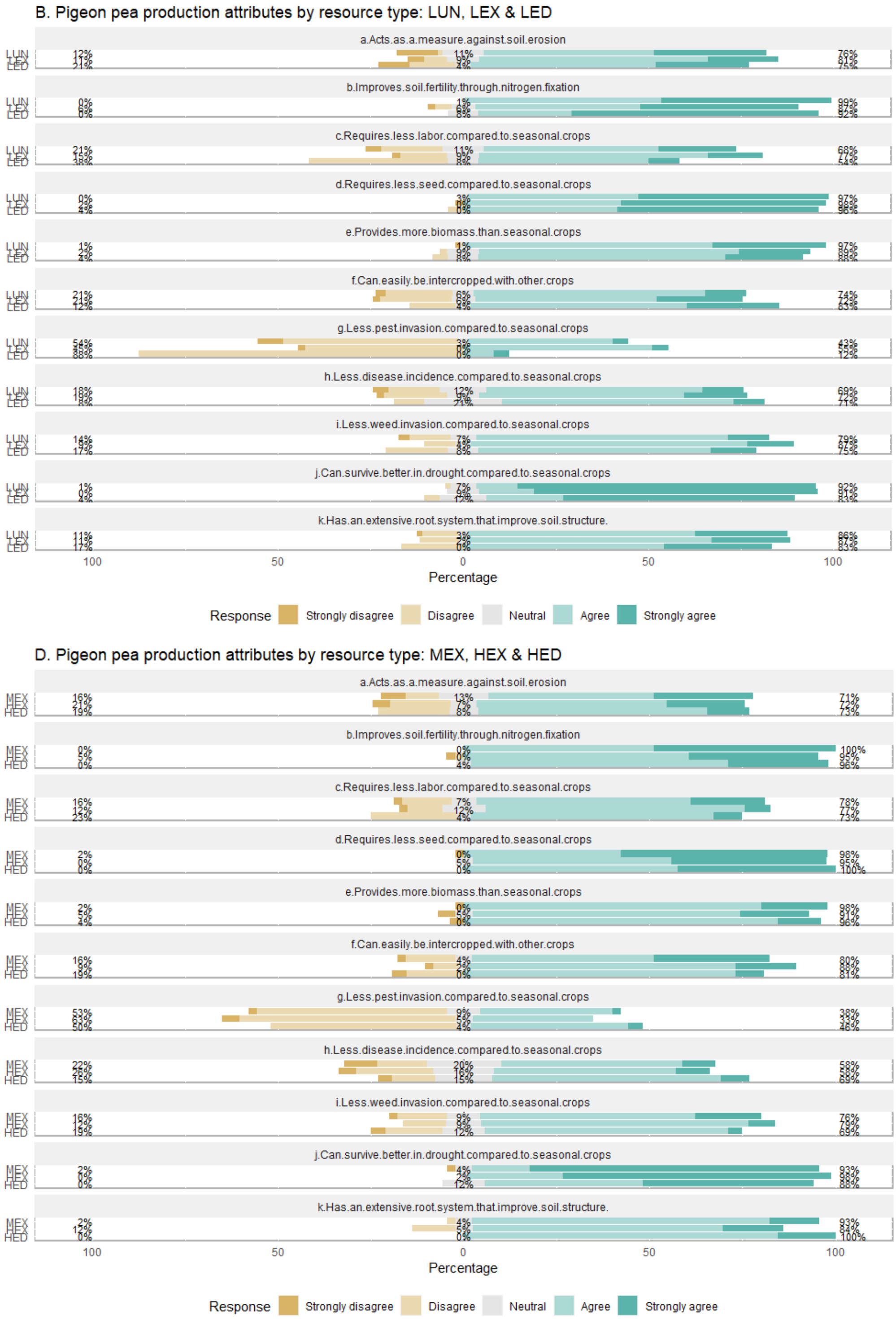

Figure 4. Perception of smallholders on pigeon pea, ($n = 256$). Likert type rate 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. The percentage on the left side indicate the share of respondents answering with 1 or 2 on the Likert scale. The percentage in the middle indicate the share of respondents answering with 3 (neutral). The percentages on the right side indicate the share of respondents answering with 4 or 5. (**B**) and (**D**) are production-related attributes across low, medium and high resourced farm types.

3. Results

3.1. Descriptive Results

The descriptive statistics are presented in Table 1. The average age of smallholders was 42 years, with an average farming experience of 21 years. Livestock ownership was on average 3.4 units with the highest value of 3.9 in the Kitgum district. On average, smallholders devoted 64% of their land to crop production, 11% to livestock production, and about 25% remained under fallow. Pigeon pea yield was on average 380 $kgha^{-1}$ (408 $kgha^{-1}$, 408 $kgha^{-1}$, and 341 $kgha^{-1}$ in Lira, Pader, and Kitgum districts, respectively).

Table 1. Descriptive statistics of selected variables in Lira, Pader, and Kitgum districts, northern Uganda.

Variable	Pooled Sample	Lira	Pader	Kitgum
	Mean (SD), *n* = 257	Mean (SD), *n* = 83	Mean (SD), *n* = 94	Mean (SD), *n* = 80
Age	41.6 (13.4)	40.8 (15.1)	42 (12.6)	41.7 (12.4)
Family size	6.9 (2.8)	6.1 (2.7)	7.4 (2.9)	7.3 (2.8)
Education level	5.3 (3.4)	5.6 (2.9)	4.5 (3.4)	5.9 (3.5)
Farming experience	21 (12.6)	20.9 (14.1)	22.4 (11.9)	19.7 (11.9)
Average monthly off-farm income	21.6 (21.17)	19.28 (19.97)	22.61 (22.02)	22.83 (21.44)
Land owned	2.55 (2.67)	2.99 (3.39)	2.51 (2.43)	2.02 (1.98)
Value of farm assets	29.22 (29.02)	26.23 (28.48)	31.69 (29.56)	29.42 (29.02)
Proportion of land: crop production	63.8 (20.9)	66.6 (20.9)	63.6 (18.7)	61 (23.1)
Proportion of land: livestock production	10.9 (15.2)	17 (18.9)	8.9 (12.4)	6.9 (11.9)
Livestock value	63.3 (117.65)	63.29 (107.77)	66.42 (118.43)	62.49 (127.54)
TLU	3.4 (3.6)	2.5 (2.4)	3.7 (3.9)	3.9 (3.9)
Pigeon pea acreage	0.57 (0.57)	0.38 (0.69)	0.65 (0.49)	0.69 (0.45)
Proportion of pigeon pea sold	28.8 (29)	19.9 (22.9)	21.8 (26.7)	46.5 (30.4)
Quantity of Pigeon pea produced per ha	380.3 (264.4)	385.8 (249.3)	407.7 (268.6)	341 (275.3)
Intercropped pigeon pea	0.78	0.53	0.93	0.87
Number of years for growing pigeon pea	13 (12.9)	14.8 (13.6)	13.8 (12)	10.6 (9.3)

Source: Survey data 2019. Means and standard deviation presented. SD is standard deviation. Note: Tropical Livestock Unit (TLU) conversion: cattle = 1; goats, sheep, and pigs = 0.1; donkeys = 0.5; oxen = 1.42; chickens, turkeys, ducks, and guinea fowl = 0.01; rabbits = 0.02 (Jahnke, 1982).

3.2. Typology

We generated six farm types; LEX (low-resourced and experienced), HEX (high-resourced and experienced), LED (low-resourced and educated), MEX (medium-resourced and experienced), HED (high-resourced and educated), LUN (low-resourced and inexperienced), respectively (Table 2). Mean and standard deviation were used to describe and compare farm types (Table S3 and Figure 2). The farm types represented 47, 24, 42, 45, 26, and 72 smallholders respectively. The correlations between farm types and the variables are presented in Table S2.

3.3. Smallholder Perception

Ninety-two percent (92%) of LUN smallholders preferred pigeon pea because it is more drought resistant than other crops grown against 91% LEX and 84% LED smallholders (Figure 4). Regarding ease of harvest, 96% MEX preferred pigeon pea because it is easy to harvest, compared to 98% HEX and 96% HED smallholders, compared to other legumes and cereals. Sixty-four percent (64%) of LEX smallholders perceived that growing pigeon pea provided many benefits, such as grain, fodder, and residues for mulching and fuel wood, compared with 47% LUN and 58% LED. A male smallholder from the Pader district reported:

> *"Pigeon pea has several benefits; best food crop, sticks used for cooking and the grain provides a small income for household necessities like soap, paraffin and school necessities for our children." (Male respondent, Pader district, 30/11/2019).*

Table 2. Description of farm types of pigeon-pea smallholders in northern Uganda obtained from hierarchical cluster analysis.

Resource Category	Farm Type	Description
Low	LUN Low-resourced and inexperienced, (n = 24, 6%)	Smallholders were young, about 38 years on average, with low levels of education and only about 3 years of schooling. They had small family sizes, about 7 persons per household. They owned about 1 ha of land on average, of which they dedicated 73% to crop production, about 11% to livestock, and 16% unused. The average monthly income is about USD 10.98 and the monetary value of farm assets, about USD 15.2 on average. Smallholders in this cluster further owned limited livestock, on average 1 TLU per household, with an average of USD 10.7 livestock monetary value. They produced 327 kgha^{-1} and allocated about 0.38 ha to pigeon pea production. They had about 17 years of farming experience.
Low	LED Low-resourced and educated, youngest, (n = 42, 10%)	Smallholders here were the youngest, 30 years on average, and more educated with 8 years on average. However, they had the lowest farming experience of 9 years, and had grown pigeon pea for an average of 5 years. They owned about 1.6 ha, of which they dedicated 74% to crop production, 10% to livestock, and 16% under fallow (Table S3). They owned 2.2 livestock units on average and produced about 364 kgha^{-1} of pigeon pea, with 40% sold. Their family size was about 5 persons per household with a monthly income of about USD 26.56 and low livestock value; USD 35.35
Low	LEX Low-resourced and experienced, older smallholders; (n = 72, 17%)	They were the oldest with an average age of 58 years and 44.5 years of farming experience on average. However, they were resource-constrained, with least livestock (2.5 TLUs), low value of livestock (USD 23.77), and a low proportion of pigeon pea sold in 2019 (13%). They owned on average 2.9 ha of land, with 55% of this land dedicated to crop production, 12% for livestock production and the remaining 33% unused or under fallow. Family size was about 5 persons per household and an average of 4 years of education per respondent.
Medium	MEX, Medium-resourced and experienced, (n = 45, 7%)	Smallholders in this farm type were 48 years on average and had 29 years of farming experience. They had larger family sizes, about 8 persons with an average of 4 years of schooling. They owned about 1.3 ha, of which they allocated over 70% to crop production, 6% to livestock and 23% left under fallow. They owned about 4 units of livestock. Pigeon pea production was about 402 kgha^{-1} for the 2019 harvest, of which 25% was sold. They had a high monetary value for farm assets (USD 34.6) and livestock value (USD 37.98).
High	HEX, High-resourced and experienced, (n = 47,15%)	Smallholders in this farm type were 39 years old on average and relatively well educated with 6 years of school. They owned 6.4 ha on average and 44% of this land was allocated to crop production, 21% allocated to livestock, and 35% left unfarmed. Farming experience was low with an average of 19 years and about 10 years for growing pigeon pea. They produced about 375 kgha^{-1} of pigeon pea and sold 27% of it. They owned 3.3 livestock units on average with a high livestock value (USD 77) per household. Their family size was about 7 persons per household.
High	HED High-resourced and educated, (n = 26, 7%)	Smallholders in this farm type were 43 years old on average with 7 years of schooling. They owned on average 2.4 ha of land with 49% of it allocated to crop production, 8% for livestock production, and 43% unused. They harvested 478 kgha^{-1} in 2019, and sold 50%. They owned about 10 livestock units, with the highest level of livestock value (USD 324). They had the highest average monthly income (USD 32.77) and the largest family size with about 10 persons per household. Smallholders had on average 18 years of farming experience, which is low compared to farm types LEX and HED.

Across low-resourced farm types, 94% of smallholders perceived that pigeon pea fixed nitrogen, and that it provided more biomass (89%) compared to other crops. Smallholders reported that they weed pigeon pea only once or twice a year compared to thrice or more for cereals and/or other legumes. Women took up most of the work and responsibility for pigeon pea, including plowing, sowing, weeding and harvesting, as reiterated by a male smallholder from Kitgum District:

"Pigeon pea and other legumes are mostly grown by women because it requires less labor and effort for all the farm activities. The sale of surplus grain enables them to buy oxen, afford household necessities, pay school fees and have additional income to support other enterprises." (Male respondent, 7/12/2019, Kitgum District).

A female smallholder from Lira District said:

"Men take the (pigeon pea) harvests to local markets because they are able to move around and also the household heads. However, for harvesting; women are mostly involved because men have a lot of other work during the harvest season." (Female respondent, Lira District, 25/11/2019).

Further, smallholders attributed higher crop yields when they intercrop with pigeon pea. A female smallholder from the Lira district stated that:

"Pigeon pea plots are intercropped with cereals for example millet and sorghum, and other legumes, and pigeon pea is also sometimes rotated on an annual basis depending on our needs and labor availability." (Female respondent, Lira District, 21/11/2019).

The majority of the female smallholders (65%) (Figure S3) mentioned that pigeon pea is highly infested by pests compared to 55% of the men. The latter participated in the spraying of pigeon pea with insecticides (most often cypermethrin), while women rather engaged with the physical labor of, for example, hand-picking pests. Smallholders in the Lira and Pader districts mostly planted the medium-term pigeon pea variety *Apio Elina*, harvestable at 6 months (plant in March and harvested in August/September). In the Kitgum district, smallholders mostly plant the long-term local variety *Agogi,* harvestable at 8 months (plant in April and harvesting around December/January). Depending on the household need for fresh peas, sometimes after harvest they were piled for later threshing. Smallholders also stocked threshed pigeon pea to wait for better prices, some eaten along the way, and a proportion was kept for next season planting.

4. Discussion

Using multivariate analysis, we generated six farm types of pigeon pea growing smallholder in northern Uganda. The Tukey HSD test showed significant differences ($p < 0.05$) for majority of the variables across farm types (Figure 2), indicating the differences between the low, medium, and high-resourced farm types. In addition, we found varying preferences for pigeon pea attributes regarding production, marketing, and consumption attributes across farm types and gender and districts (Figures S2 and S3).

4.1. Resource Endowment, Household Characteristics and Heterogeneity

Our findings strongly mirror the aging trend of smallholders in northern Uganda, possibly due to previous conflict that led to the abduction and migration of many adults and youths during and after 1986 to 2006 [46]. We found the average age of smallholders was above 30 years across farm types and districts. LED and MEX had the oldest smallholders compared to HED and HEX, and age was statistically significant ($p < 0.05$) across farm types. Many youths (between 15 and 30 years) do not continue with agriculture but migrate for urban-related opportunities, as noted in southern Africa by [22]. Rietveld et al. [47] reported differences between male and female youths in central Uganda in terms of rural–urban migration, with male youths migrating majorly for work and female youths for both work and marriage. In northern Uganda, many male youths are more commonly engaged in small businesses in nearby small towns, often in very precarious and part-time arrangements. On the other hand, older farmers are normally more experienced, as also evidenced from our findings. Youths are considered more risk-averse than older farmers due to limited experience and are less likely to adopt new crop types, as reported in Albania [48]. The migration of youths also affects household labor endowment which reduces the level of farm operations since it is the old people left on farms.

Overall, the education level of sampled smallholders was low, an average of 5 years, and statistically different ($p < 0.05$) between the low and high-resourced farm types. This indicates the lowest literacy rates in northern Uganda compared to other regions of the country [31]. This can be explained by the lack of schooling infrastructure and high poverty rates. From the results, better educated farmers were likely to be high-resourced (HEX and HED), implying that they owned more resources compared to the low-resourced counterparts (LUN, LED and LEX). This confirms findings by Occelli et al. [49] who illustrated that formal education combined with local knowledge has a multiplier effect for agricultural development among smallholders in Ethiopia. In the same vein, Granzhdani [48] also reported higher rates of agricultural technology adoption by well-educated smallholders compared to less educated ones. Additionally, education further influences access to formal employment and thus high household income. Low average monthly income among the low-resourced is explained by the remoteness of the sampled villages and households, which limits market accessibility. For insistence, Chikowo et al. [50] found a positive association between crop quantities sold and household income in rural SSA. Yet a continuous cash income is important and a major determinant for food self-sufficiency in rural SSA [51]. Apart from farming, smallholders reported to generate additional income from selling of local brew '*Ajon/Malwa*', as well as charcoal and firewood. Female smallholders also engaged in tailoring and the road-side selling of fruits and vegetables for an additional income. The overall significance suggests the provision of targeted literacy programs to encourage both formal employment and agricultural technology adoption.

Such marginal average incomes are further reduced by the low prices from crop and livestock product sales. For example, smallholders reported low sale prices for pigeon pea, about USD 0.28 kg^{-1}, which is the same for all the other crops sold. It is generally documented that majority of smallholders in SSA sell to middlemen at the farm-gate [51], which accounts for the low prices. This trend has an effect on farm returns and the reasons why poverty prevails within smallholder households. Strategies to improve farmer's access to markets through reduced transaction costs and timely market information can improve farm-gate prices and ultimate farm efficiency [19].

Further, our results show that all smallholders owned some livestock, which was significantly different ($p < 0.05$) across farm types. This implies the high-resourced farms kept high-value livestock, such as cattle and oxen, compared to low-resourced types with mostly poultry and small ruminants: goats and sheep. Livestock acts as a contingency in case of crop failure or as a 'life-saving' income source mostly sold when there was a quick requisite for money. However, there has been a decline in livestock numbers in northern Uganda due to cattle rustling and the civil war, according to [52]. Similarly, Rockmore [46] showed that livestock-keeping in northern Uganda was more risky during the conflict than farming and many smallholders consequently resorted to small-scale farming as a livelihood option. Such evidence is mirrored in the low livestock units recorded in this study, and much of the land is dedicated to crop production rather than animal grazing, especially for low-resourced farm types. HED owned more livestock units and monetary value, compared to other farm types; however, HEX allocated more land to livestock grazing.

Land owned was differed significantly ($p < 0.05$) across the low- and high-resourced farm types. Our findings show that low-resourced farm types allocated more land to crop production compared to animal grazing. Kansiime et al. [53] found in Kenya that low-resourced smallholders allocated substantially more acreage to crop production than high-resourced ones. Similarly, smallholders allocated about 0.57 ha to pigeon pea farming, with an average productivity of 380 $kgha^{-1}$. Productivity is low and below the potential yield of hybrid pigeon pea varieties of up to 3000 $kgha^{-1}$, as reported in Tanzania and Mozambique [54]. The observed low pigeon pea productivity can further be attributed to low and often below recommended rates of fertilizer use in many farm households in Uganda [31] in addition to poor market linkages and poverty [55]. Fallowing was used as a strategy by smallholders to replenish soil fertility and similar findings in Ethiopia reported that 22% of farmers left their land under fallow [56]. Improvement in fertility management especially across the low-resourced farm types can increase crop productivity and realize higher returns.

4.2. Smallholders' Preferred Attributes of Pigeon Pea

Smallholders' preferences are important to meet their socio-economic and agro-ecological conditions. We disaggregated preferences across farm types, districts, and gender of the farmers (Figures 4 and S2. The most important production-related attributes were drought-tolerance (89%), high biomass (91%), and pigeon pea's ability to improve soil quality through nitrogen fixation (93%) across the low-resourced farm types. Similar results were reported in Kenya and the Democratic Republic of Congo (DRC), where farmers preferred pigeon pea due to its nitrogen fixing capability and thus high soil fertility improvement potential [57]. Likewise, Snapp and Silim [58] illustrated that smallholders in Kenya and Malawi prefer pigeon pea varieties that were high-yielding and had a good inter-cropping ability. Given the semi-arid nature of northern Uganda and the increasing effects of climate change [29], 44%, smallholders rank pigeon pea as one of the crops that can survive during the hot seasons compared to other legumes and cereals. Future research should focus on breeding pigeon pea varieties that are more drought-tolerant on the one hand and high yielding on the other.

Most smallholders preferred pigeon pea because it is a low-labor crop, for example, weeding once or twice before harvest compared to other cereals and legumes grown. Similarly, [58] showed that smallholders in Kenya and Malawi mentioned the low-labor requirement of pigeon pea as a major attribute. Much of the farm labor (sowing, weeding, and harvesting) for pigeon pea is provided by women. Similar findings from Ethiopia showed that labor provided by women smallholders was directed towards food crops, while men focused their labor on cash crops [59]. Our findings, however, show that the majority of the smallholders disagreed on the pest and disease attribute across farm types (62% of the low-resourced and 55% for the high-resourced). High pest incidence remains a challenge affecting not only pigeon pea production but also other crops in general. Farmers mentioned infestation by aphids, borer, leaf miner, and caterpillars, locally known as *Acwii, Ongude, Ocoko,* and *Oruru*, as well as fungal diseases (such as *Fusarium* wilt) especially at flowering stage. The breeding of pest- and disease-resistant varieties can improve the productivity of pigeon pea.

Over 80% of the low-resourced smallholders preferred the green peas (fresh) for domestic consumption because they cooked faster and tasted better compared to dry peas and/or other legumes. Similar results in Benin [60] illustrated that smallholders ranked short cooking time as the most important attribute for pigeon pea. The green peas are mostly used to produce a thick soup, termed '*Dek Ngor'* that accompanied staple foods, such as millet, sorghum bread (*kwon Kal*), and mashed sweet potatoes or cassava (*layata*). The *Dek Ngor* soup is usually consumed at least once in two days (either lunch or dinner) depending on the season and the availability of pigeon peas, and believed to be nutritious for all age groups. Anitha et al. [61] reported a positive impact by consuming pigeon pea soup on wasting, stunting, and underweight and a high acceptability of such a diet in children in Myanmar. Hence, there is a high potential for pigeon pea to contribute to (more) food and nutrition security in northern Uganda, especially for the resource-constrained smallholders.

5. Conclusions

In this study, we generated six distinct farm types of pigeon pea-growing households in northern Uganda using multivariate statistical approaches and assessed smallholder preferences for pigeon pea across farm types, gender, and study districts. We argue that farm households are heterogeneous and 'one-size-fit-all' approaches to agriculture development are inappropriate. The variability in farm types generated was largely explained by differences in resource endowment at a household level: farm size and livestock units owned and land allocation to either crop or livestock farming. About 54% of smallholders were low-resourced with smaller land sizes, TLUs, and low average incomes compared to their medium- and high-resourced counterparts. Smallholders highly preferred pigeon pea because it is more nutritious, improved soil quality through nitrogen fixation, and required minimum labor compared to other legumes and cereals. However, there are still the challenges of the high incidence of pests and diseases that further affect its productivity. Thus, breeding research should aim at the dissemination of pest and drought-resistant varieties that are easy to intercrop as major traits to increase pigeon pea production. Such breeding activities should not solely focus on highest yields (which are most often only achieved on agricultural research stations) but also address important pigeon pea attributes expressed by smallholders.

We also recommend targeted training and literacy programs in northern Uganda to improve agricultural technology uptake across farm types, since education level is low. This can also encourage youth participation in agriculture, the establishment and training of youth-groups, and the provision of 'start-up' micro-credit should be improved. Future policies and programs should target the particular necessities of different farmer types, especially the low-resourced ones who are more illiterate, face low crop productivity, and face market access challenges compared to the high-resourced farmers. Such efforts should include access to improved germplasm of orphan crops, such as pigeon pea, and better market linkages.

Policies should further target women who are largely involved in the cultivation, processing, and to some extent the marketing of orphan crops, such as pigeon pea.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/agriculture12081186/s1, Table S1. Description of variables used to cluster smallholders in Northern Uganda, Figure S1. PCA and CA outputs (PC1-PC2), correlation circles and scatter plot along the first two principal components, Table S2: Selected principal components, loadings, Eigenvalues and variance from PCA, Table S3. Variable mean that characterize the partitioning of the six different farmer types, Figure S2. (A,C): Smallholders' perceptions of pigeon pea (the sample size was 257). Figure S3. (A–D): Smallholders' perceptions of pigeon pea (the sample size was 257).

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