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Socio-Economic Constraints of Adopting New Cowpea Varieties in Three Agro-Ecological Zones in the Senegalese Peanut Basin

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Abstract: Socio-economic constraints like gender, education, age, and income significantly affect the adoption of improved agricultural technologies. The objective of this study was to determine socio-economic factors that affect the adoption of improved cowpea varieties in the Senegalese peanut basin. The study was conducted in three (Bambey, Kebemer, and Kaffrine) of six regions of the peanut basin based on regional importance of cowpea production and rainfall gradient. In each study region, ten villages were selected, and random sampling was used to select eight heads of agricultural households within each village. The questionnaires were administered to 240 randomly selected farmers across the three study regions, 7 communes, and 30 villages. Results showed most heads of households were middle-aged (52–54 years old), married (95–100%), illiterate (84%), and men (95–100%). Households were mostly agriculture dependent (87%), low literacy rates (26% least primary school), and large family sizes (average of 15 members). The median cowpea yields across the study area varied from 35–100 kg ha^{-1}, well below the ~300–400 kg ha^{-1} average yields reported for Senegal and Sub-Saharan Africa. The majority of farmers (67%) in the study regions did not use improved varieties, and the main reasons were low seed availability (78.8%) and limited access to technical knowledge and information (76.3%), but only 5.8% indicated seed price as a barrier to improved variety adoption. Major uses of cowpea in the study area were for marketing, livestock feed, and human consumption. In Kaffrine, fodder production was the major (85%) criterion for cowpea variety selection, whereas in the north (Bambey and Kebemer), taste, maturity date, and grain yield were major selection criteria. Factors that had positive effect on the likelihood of using improved cowpea varieties include; access to extension services, membership in farmers' organization, cowpea being the main crop of production, organic farming, market, and livestock-oriented production systems, access to farmland and credit, dependence on agriculture as the main source of household income, and education of head of household. We conclude that there is a critical need for training, access to improved seeds, awareness, and financial support to producers to increase the adoption of new improved cowpea varieties, yields, profitability, and nutritional security among smallholder farmers in the Senegalese peanut basin.

Keywords: characteristics of household; cowpea varieties; dryland; socio-economics; Senegal agriculture

1. Introduction

Agriculture production in Senegal is dominated by staple food crops including, pearl millet (*Pennisetum glaucum*; 38%), cowpea (*Vigna unguiculata*; 24%), maize (*Zea mays*; 20%), rice (*Oryza sativa*; 9%), and sorghum (*Sorghum bicolor*; 9%) which are mainly grown in the rainy season [1]. Groundnut or peanut (*Arachis hypogaea*) is important both in terms of volume of production and area harvested but is mainly market-oriented for local industries or export. Faced with growing food and nutritional needs of a population of more than 14 million, with projections to increase to 19 million in 2030 and 26 million by 2050 [2], increasing agricultural production to meet food demand is an important challenge.

Cowpea plays a significant role in food and feed, supplying a needed protein source [3], and generating income for Senegalese rural households. Cowpea is among the most cultivated grain legumes with important nutritional, economic, and cultural significance in semi-arid regions of west Africa [4]. In regions of low rainfall or delayed cropping season, farmers rely on cowpea because of the short production cycle and drought tolerance [5]. In normal growing seasons, the availability of cowpea green pods in early September provides food at a time of the year when granaries are almost empty. Cowpea marketing is an opportunity to generate income for smallholder producers. With food production lagging behind population growth and demand for livestock products booming due to rapid urbanization and climate change, cowpea cultivation is very valuable. Cowpea leaves and stems have high protein content and serve as nutritious fodder for cattle and other farm animals and its roots provide nitrogen to improve soil fertility.

Cowpea is a short duration crop well adapted to the erratic rainfall, extreme heat, and nutrient-deficient soils that prevail in semi-arid environments in west Africa. In Senegal, cowpea is grown in all agro-ecological zones, particularly in the north-central region of the peanut basin, which covers an average of 82% of the sown area and 80% of national production [6]. However, its role in rural households is affected by low productivity and the limited availability of fodder to support livestock, especially during the dry season. New cowpea varieties of dual-use offer both the ability to achieve greater grain yields for human consumption and high-quality fodder for animal production. Therefore, the adoption and scaling up of dual-use cowpea varieties has become very important with the aim of increasing rural incomes and supporting human food security and livestock production systems.

Since the 1980s, most research on the cowpea sector in Senegal has focused on the determinants of cowpea yield [7], adoption determinants of improved varieties, and market information systems [5]. Few studies have attempted to identify constraints to adoption in other semi-arid environments in West Africa [8,9] and in other parts of Africa [10,11]. Moreover, in the identification of new varieties' adoption determinants, the context of cropping system used in cowpea production is usually not considered. Notwithstanding the importance of socio-economic characteristics and access to information, cropping system including the choice of crop associations, the use of chemical and/or organic fertilizers, and the preference of farmers towards the production of fodder for animal feed or grain for marketing and income generation, improve the understanding of factors likely to influence adoption of new crop varieties. This study investigated the effect of socio-economic conditions and production choices of farmers on the adoption of new cowpea varieties to improve human food and animal fodder in Senegal. The specific objective was (i) to analyze the socio-economic characteristics of cowpea production systems and (ii) determine the profile of new cowpea varieties adopters in the Senegalese peanut basin through descriptive analysis and econometric analysis to see whether socio-economic conditions and production choices influence new cow variety adoption.

2. Materials and Methods

2.1. Study Area

The study was conducted in the peanut basin of Senegal, which covers the west and the center of the country, corresponding to the administrative regions of Louga, Kaolack, Fatick, Thies, Diourbel, and Kaffrine (Figure 1). It covers a third of the land area of Senegal, home to about half of the population, and is characterized by tropical ferruginous soils. Major agricultural crops grown are mainly dry cereals (i.e., millet and sorghum) and legumes (i.e., groundnut and cowpea). Three of the six regions of the peanut basin were chosen for the study based on annual rainfall amounts [Louga (arid), Diourbel (semi-arid) and Kaffrine (semi-humid)] and the acreage and importance of cowpea production. In each of the three regions, a study area was selected based on cowpea acreage produced. The selected study areas included Bambey in the Diourbel region, Kebemer in the Louga region, and Kaffrine in the Kaffrine region (Figure 1).

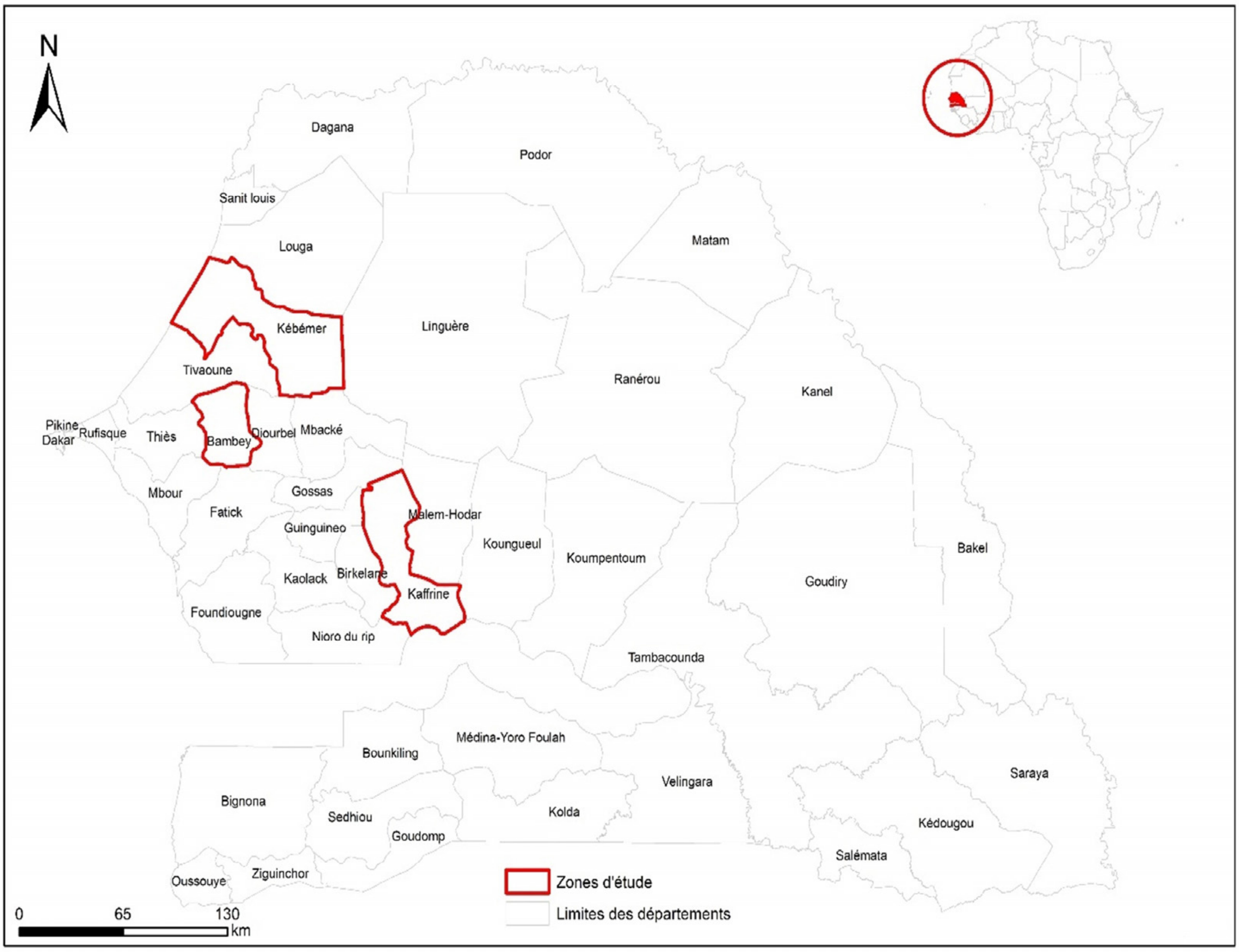

Figure 1. Map of location of Senegal in Africa and study regions (Kebemer, Bambey, and Kaffrine) and boundaries.

2.2. Sampling of Sites, Villages, and Targeted Population

We used a three-stage sampling procedure to select first, the communes, then the villages, and finally the agricultural households for the study. The objective of the selection was to balance the number of villages and communes chosen in each region, minimize the effects of sampling error or bias resulting from the proximity of the villages, and constitute a group of beneficiaries and control for the impact assessment study. Thus, 10 villages were randomly selected in each of the study regions at Bambey, Kebemer and Kaffrine. Climate type, average rainfall, and temperature, in each of the three study regions are indicated in Table 1. In each village, random sampling was conducted to select eight heads of agricultural households. In total, the questionnaire was administered to 240 selected farmers in three regions, seven communes, and 30 villages.

Table 1. Details of climate in study regions, average production, standard deviation (SD), minimum (Min), and maximum (Max) values reported by individual household by study area (in kilograms).

Study Region	Climate Type	Average Rainfall (mm)	Average Temp. (°C)	Average Prod.	SD	Min	Max
Bambey	sahelian	350	34.7	146.5	158.8	0	1000
Kebemer	sudano-sahelian	464.1	30	481.7	1140.6	0	9500
Kaffrine	sudano-sahelian	1000	29	124.9	138.6	0	800
Average	-	-	-	251.0	686.7	0	9500

2.3. Questionnaire

A baseline survey was conducted in the three study regions between April and May 2021. The questionnaire used for data collection consists of fourteen sections (see Supplementary Materials, with only relevant sections of questionnaire for this specific study). The first section had information on the identification of the household, and collected information on geographical, communal, and regional location. The next information collected was on the characteristics of the head of household including age, gender, marital status, type and level of education and experience. Characteristics of the household included information on composition, the cultural practice, sources of income and level of food security. The third section focused on farmland owned by the household, their location in relation to the family concession, method of acquisition, land tenure, farm size, cropping system practices and person responsible for decision-making. The fourth section collected information on cowpea production system by focusing on the methods used for each farming operation ranging from soil preparation, planting, harvesting and post-harvest operations. This section also covered aspects of labor mobilized in cowpea production as well as types of cowpea varieties and inputs used.

The fifth section requested information on contracts between producers and traders while the sixth section focused on the production tools used in the fields. Information on the quantity of crops produced and the distribution was the next subject covered in the seventh section before information on pest, diseases, storage methods and participation in demonstration field trials. Information on access to financial and extension services was collected in the next section before the approaches used for cowpea marketing were studied. Data was also collected on a role of livestock in the generation of household income.

2.4. Methodology for Data Analysis

To understand the constraints to new cowpea varieties adoption, we combined a descriptive statistical analysis with a Probit model to analyze the data collected from the survey. The descriptive analysis of the responses from the questionnaire was conducted on household characteristics, cowpea use and productivity, and use of improved varieties. The data collected were disaggregated and analyzed according to the agro-ecological zone and averaged when generalization was needed for the entire study. STATA software summarize commands were used to obtain average, standard deviation, minimum and maximum for quantitative data analysis by region. However, for qualitative data, the table command of STATA version 14 software generated proportions of modalities crossed with regions. Graphs and charts were developed using a sigma plot (Systat Software Inc., Palo Alto, CA, USA).

First, the characteristics of the head of household (CHH), including age, sex, marital status, and level of education, were analyzed for each of the three agro ecological zones. For a CHH with a continuous variable (i.e., age), average site CHH was calculated as the sum of the ages of the head of household from each individual respondent at the site divided by the total number of respondents (Equation (1)). Across regions, the average was calculated as the sum of the average CHH of each of the three regions divided by three.

$$Average\ age\ in\ a\ region\ (AAG) = \frac{\sum_{x=1}^{n} age\ of\ HH\ in\ respondant\ x}{n} \quad (1)$$

X = individual respondent, n = total number of respondents, and HH = head of household.

For CHH with discrete values (like gender, marital status, level of education), The percent CHH of each region was calculated as the total count of similar characteristic responses from individuals from a region divided by the total number of respondents multiplied by a hundred (Equation (2)). Across regions, percentages were calculated as the sum of the percent of each of the three regions divided by three.

$$CHH\ (gender,\ marital\ status,\ \ldots) = \frac{Number\ of\ responses\ with\ similar\ CHH}{n} \times 100 \quad (2)$$

Second, household characteristics were described by zone with a focus on household size, main source of income of the household and the highest level of education attained by a household member. Calculations of household characteristics were conducted similarly as described for the head of the household.

The third sub-section of the results focused on cowpea production inputs, management practices, production and utilization. Adoption rates and reasons for a variety of adoptions, and family or farm locations were first analyzed to determine if differences in adoption can be explained by the climatic context. Then, the labor used by men, women and children in relation to farming operations including threshing, weeding, fertilization, soil preparation, and harvesting and transporting were analyzed. In addition, the types of diseases affecting cowpea production and post-harvest utilization are presented. Furthermore, prices and selling periods within the study regions were characterized as well as the different storage methods used in the different regions.

Finally, an econometrics analysis was performed using the Probit model in STATA to determine the effect of all gathered socio-economic information on new cowpea variety adoption by producers. The Probit model of the form (Equation (3)) was fitted:

$$Y_i^* = \theta_0 + \theta_1 X_{1i} + \theta_1 X_{2i} \ldots + \theta_K X_{Ki} + \varepsilon_i = X_i\,\theta + \varepsilon_i \quad (3)$$

where $\varepsilon_i \sim N(0,1)$. The vector $X_i = (X_{1i},\ X_{2i},\ \ldots\ ,\ X_{Ki})$ corresponds to the observable characteristics of the individual i and the vector $\theta = (\theta_{0,}\ \theta_1,\ \ldots\ \theta_K)$ represents the coefficients of each of these characteristics in order to qualify the variable, under the assumption that the above model is representative of reality. Theoretically, the binary variable Y_i, is such that $Y_i = 1$ where producer i adopts at least one new variety of cowpea, and when $Y_i = 0$, indicates the producer does not adopt a new variety of cowpea.

Empirically, the model used in this work is written as follows in Equation (4):

$$\begin{aligned}
&\textbf{\textit{Improved variety adoption}}\ (\boldsymbol{Y_i}) \\
&= \theta_0 + \textbf{\textit{Information access}}\ (\theta_1\ Village - field - distance + \theta_2\ Extension\ service\ access \\
&+\theta_3\ village - road - distance + \theta_4\ Information\ farmer - farmer \\
&+\theta_5\ Member\ of\ a\ producer\ groupi) + \textbf{\textit{Production system}}\ (\theta_6\ Cowpea\ monoculture \\
&+\theta_7\ Use\ of\ chemical\ fertilizer\ + \theta_8\ Use\ of\ organic\ fertilizer + \theta_9\ Market \\
&-oriented\ cowpea\ production + \theta_{10}\ Livestock - oriented\ cowpea\ production) \\
&+\textbf{\textit{Household characteristics}}\ (\theta_{11}\ Age\ of\ household\ head + \theta_{12}\ Height\ of\ household\ head \\
&+\theta_{13}\ Gender\ of\ household\ head + \theta_{14}\ Literacy\ of\ household\ head + \theta_{15}\ Area\ farmed \\
&+\theta_{16}\ Presence\ of\ diseases\ in\ plants + \theta_{17}\ Main\ source\ of\ income + \theta_{18}\ Access\ to\ credit) \\
&+\theta_{19}\ \textbf{\textit{study area}} + \varepsilon i
\end{aligned} \quad (4)$$

3. Results

3.1. Characteristics of Head of Household

The average age of the heads of household surveyed across the study region was 53 years old (Figure 2a). However, this varied among regions, with an average of 52 years at Bambey or Kaffrine and 54 years in Kebemer. The minimum age of the head of a household was 22 years old. This minimum age was registered in Kebemer while in Bambey and Kaffrine, the minimum age of the head of the household was 24 and 25 years old, respectively. The maximum age of 85 years old was recorded at Kaffrine, while the maximum age was 79 years in Bambey and 84 years old in Kebemer.

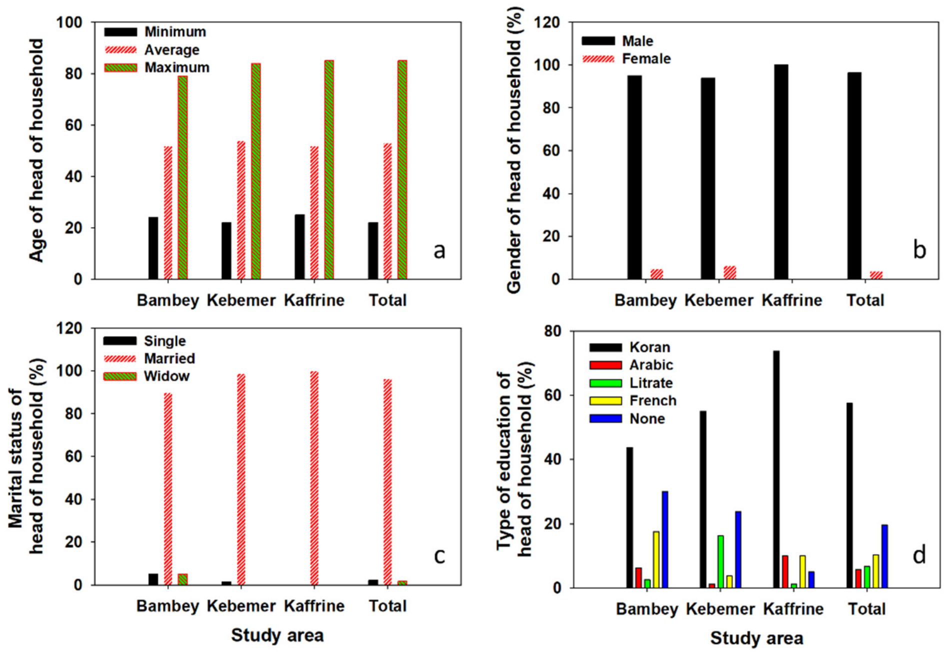

Figure 2. Characteristics of head of the household (**a**) age, (**b**) gender, (**c**) marital status, and (**d**) highest education level by study regions (Kebemer, Bambey, and Kaffrine) in Senegal.

Men were heads of households in 96% of the households surveyed (Figure 2b). This proportion was greater in Kaffrine, where men headed 100% of households surveyed. However, there were a few female-headed households in Bambey (5%) and Kebemer (6%). These observations were consistent with the configuration of households in rural areas where the heads of households were mainly men [12].

The majority (96%) of heads of household were married (Figure 2c). In Kaffrine, the households interviewed were all married. However, there were few singles in Bambey (5%) and Kebemer (1%). In addition, there were few widowed heads of household at Bambey (5%). These results were in agreement with the social reality of rural households because marriage promotes the formation of new households and a certain autonomy in use of land resources.

The percentage of heads of households enrolled in French schools was generally low (Figure 2d). Most heads of household had only received a Koranic education (58%). Kaffrine had the highest proportion of heads of household who received only a Koranic education (74%), followed by Kebemer with 55% of the heads of household and Bambey with 44%. Across regions, 10% of heads of household received French education with a higher proportion in Bambey (18%), followed by Kaffrine (10%) and Kebemer (4%). This finding agrees with Beye et al. (2018) who reported a French school rate of 10% among smallholder households in the Senegal River valley. Moreover, it was observed that only 6.6% of heads of households were literate. The Kebemer region had the highest proportion (16%) of heads of households who received formal education (Figure 2d). This was possibly because of government intervention programs implemented to reduce the school enrolment deficit in the region. The Arabic education level represented the lowest percentage in terms of education (5%). Arabic education of the head of the household was more at Kaffrine with 10% of heads of household, followed by Bambey (6%) and Kebemer (1%) (Figure 2d).

Across the study area, about 26% of households had at least attained primary school education (Figure 3a). By study region, the percentage for primary education was 34% in Kebemer, 25% in Bambey, and in 20% in Kaffrine. After primary school, middle school level was the next high-level education reached by a member of the household with 26% of the households surveyed. A university level education represented a significant proportion of households, with an average of 18% across the three regions. Approximately 25% in Kebemer, 20% in Bambey and 10% in Kaffrine had university level education. The secondary school level represented the lowest proportion of households with an average of 10% across the three regions. This was mainly in Kaffrine (20%). However, there were households where no member had received a level of education in French. This proportion was 19% across the regions, but with a greater percentage in Kebemer (35%).

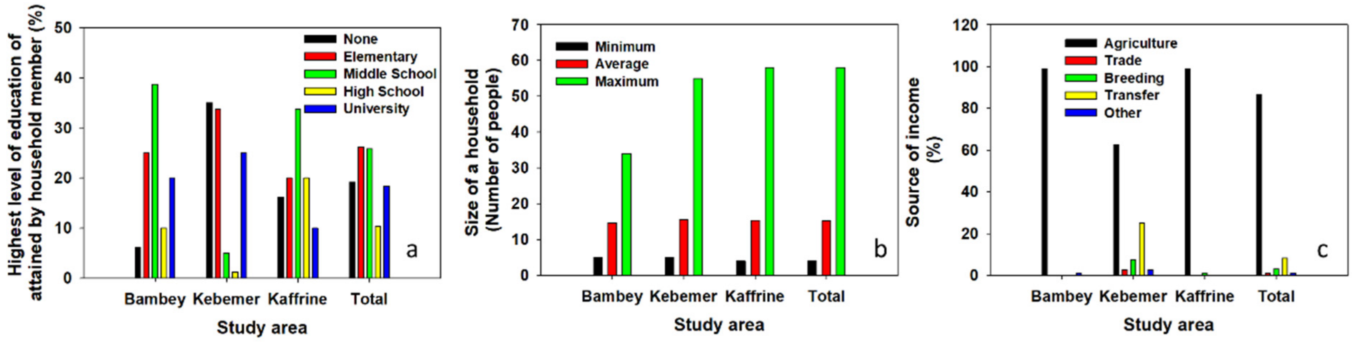

Figure 3. Characteristics of a household (**a**) highest level of education of the household, (**b**) size of household, and (**c**) income source by study regions (Kebemer, Bambey, and Kaffrine) in Senegal.

The average size of the households surveyed had 15 members (Figure 3b). The highest average household size was observed in Kebemer with 15.5 members, 15.4 in Kaffrine and 14.7 in Bambey. The minimum household size was four members was recorded in Kaffrine (Figure 3b). The maximum household size of 58 members was observed in Kaffrine, while the maximum was 55 members in Kebemer and 34 members in Bambey. It is worth noting that smallholder agricultural operations usually mobilize the entire available family and external labor, which is taken care of by the household. Therefore, it is possible households with large members may include external labor or farm help who may not be family members.

Agriculture was the main source of household income among 87% of households in the study regions (Figure 3c). This proportion was greater in Bambey and Kaffrine (99%). In these two regions, there was low diversification of incomes with only 1% of households in Kaffrine and in Bambey who had income from livestock and other commercial activities. However, there has been some income diversification in Kebemer where only 63% of households relied on agriculture as their main source of income but others receive remittances (25% of households), livestock (7.5% of households), trade (2.5% of households) and other activities (2.5% of households).

3.2. Cowpea Production, Input, Management, and Use

3.2.1. Cowpea Production

Cowpea production varied between minimum of 0 and maximum of 9500 kg per household across the three study regions (Table 1). Kebemer, had the greatest planted acreage of cowpea, with average production per household of 482 kg, while the average was 147 kg in Bambey and 125 kg in Kaffrine. The minimum production (which was zero) was the same in all the study areas. The maximum household production was 800, 1000, and 9500 kg at Kaffrine, Bambey, and Kebemer, respectively (Table 1).

In Bambey, 25% of the reported yield per hectare was less than or equal to 50 kg ha^{-1} and 75% of the grain yields were less than or equal to 200 kg ha^{-1}. The median yield was 100 kg ha^{-1}. This suggests that 50% of reported yields were less than or equal to 100 kg ha^{-1} and others above 100 kg ha^{-1}. At Kebemer, 50% of producers obtained grain yields ranging from 35 kg ha^{-1} to 200 kg ha^{-1}. The median reported yield at Kebemer was 77 kg ha^{-1}. At Kaffrine, half of the producers reported yields between 17.7 and 60 kg ha^{-1}. The median yield was 35 kg ha^{-1}. Cowpea position as an associated rather than a main crop could explain the relatively lower yields of cowpea in traditional cropping systems in the study region. Cowpea is often planted in relatively small areas of managed land as well as limited application of organic and chemical fertilizers. Indeed, Mbaye et al. [13] emphasized the place of cowpea as an associated crop because of its virtues in controlling crop pests, fighting diseases, improving cereal production for food security and conserving soil and water resources.

3.2.2. Inputs for Cowpea Production (Varieties and Labor)

The proportion of households using new dual-purpose cowpea varieties varied among regions (Figure 4a). The proportion of farmers adopting new dual-purpose cowpea varieties was greatest in Bambey with 48% of households surveyed, 32% in Kaffrine, and 20% in Kebemer. Indeed, access to improved varieties was generally explained by the presence of state or multi-national organizations sponsored research projects and programs in the region, this is particularly the case in Kaffrine. Similarly, in some regions, farmer proximity to agricultural research or extension centers can promote access to information on improved varieties. For example, the ease of access to information at Bambey can be explained by the presence of the Centre National de Recherches Agronomiques (CNRA) of Bambey which offers educational programs to scale up adoption of new agricultural technologies and innovations.

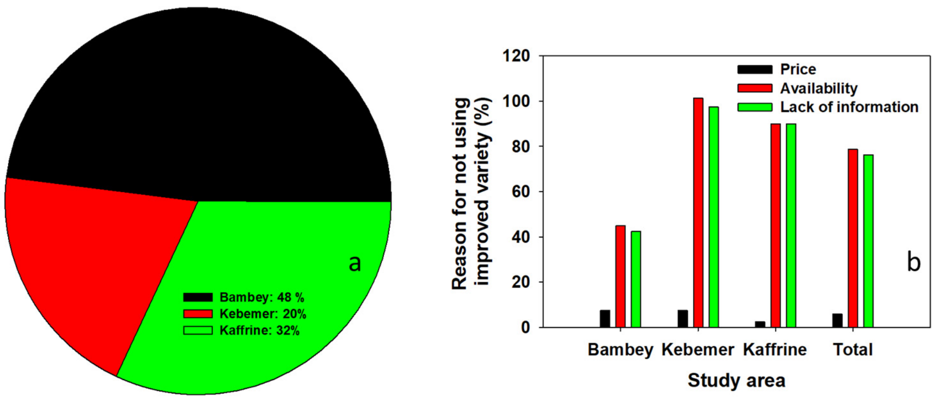

Figure 4. Cowpea (**a**) variety adoption and (**b**) reason for not adopting by study regions (Kebemer, Bambey, and Kaffrine) in Senegal.

The adoption of improved varieties was constrained by the unavailability of seeds of new cowpea varieties (79%), lack of knowledge and information about cowpea varieties (76%), and to a lesser extent, high seed prices (6%) (Figure 4b). The constraints of availability and lack of knowledge of improved varieties decrease from Kebemer to Kaffrine and from Kaffrine to Bambey. Possibly, because of the presence of CNRA, farmers in Bambey have access to information on new cowpea varieties.

Surveyed households provided varied reasons that contributed to the choice of cowpea varieties. Observation of preferences showed that households rely mainly on five major criteria in selecting cowpea varieties. This included high grain yield, fodder production, taste, early maturity, and producer visual preferences of seed color (Table 2). There are other lesser selection criteria such as the price of seeds (29% of farmers surveyed), low market demand because of the price (26%), and availability of seeds (19%). The criteria for choosing varieties are different across regions. For example, at Bambey, the choice of cowpea varieties was mainly explained by the preferences of farmers and the production of fodder. In addition, households use cowpea varieties because of their early maturity (60% of households) and taste (58.75% of households) at Bambey. In Kebemer, the reasons for the use of cowpea varieties are diverse but dominated by taste (50% of households), grain yield (44% of households) and fodder production (12.5%). At Kaffrine, cowpea variety selection was mostly determined by its early maturation (96% of households), fodder production (85%), affordable seed price (74% of households), and to a lesser extent its taste (63.75% of households). Aside from human consumption, cowpea was also used for fodder for livestock at Kaffrine and Bambey (Table 2). The southern region of the peanut basin which include Kaffrine is an area of reception for transhumant herders. Indeed, little forage availability from pasturelands in breeding areas (such as Kebemer) leads to the seasonal movement of herders towards the peanut basin, particularly in the dry season. The presence of herders and their animals create a market for cowpea fodder, which explained farmer selection and preference of cowpea varieties with greater fodder yields in the Kaffrine region.

Table 2. Reasons for new cowpea variety adoption by study regions in Senegal. In bold are the greatest reason for new variety adoption in each region and average across regions.

Reason for New Cowpea Variety Adoption	Study Region			Average
	Bambey	Kebemer	Kaffrine	
Affordable seed prices	3.75	10.00	73.75	29.17
Producer preferences	**83.8**	33.75	41.25	52.92
Weed tolerant	12.5	12.50	12.50	12.5
Drought tolerant	6.25	5.00	12.50	7.92
Early ripening/drought escape	60.0	5.00	**96.25**	**53.75**
High efficiency	55.0	**43.75**	88.75	74.58
Seed availability	11.25	15.00	30.00	18.75
High price problem in the market (high demand)	23.75	38.75	26.25	26.25
Suitable for conservation	12.50	22.50	41.25	25.42
Good performance under low soil fertility	5.00	2.50	7.5	5.00
Taste	58.75	50.0	63.75	57.5
Fodder	80	12.5	85	62.08

All family members (men, women, and children) participated in cowpea cultivation operations (Figure 5). Labor participation is greatest at fertilizer application (mostly applied to the cereal intercrop) with an average of 1.4 men, 2.8 women and 1.3 children. Cowpea is often used in intercropping with cereals because of their nitrogen-fixing attributes as a legume. When cowpea is fertilized, it is often organic manure; chemical fertilizer is mostly reserved for cereal intercrop. The workforce is also heavily mobilized for threshing, winnowing, and sorting operations, which required a maximum number of 8 men, 7 women and 7 children. However, few individuals are used in weeding operations which is mostly done by the female workforce (0.9 women on average). The results also showed that children are utilized more in soil preparation and planting operations (Figure 5d). On the other hand, adult men and women do harvesting operations because this activity requires a relatively intense labor force (Figure 5e).

3.2.3. Cowpea Management

The major diseases and pests encountered in cowpea fields in the study regions were termites (33%), rodents (29%), Striga, bacterial and fungal (24%), stem borers (15%), grasshoppers (7%) and birds (0.42%) (Table 3). Analysis by region showed that rodents (54%), termites (30%), Striga, bacterial and fungal (23%) are the main problems affecting cowpea farming in the Bambey region. Birds do not pose a major threat to cowpea in Bambey and Kebemer. Birds were only identified as a threat to cowpea in the Kaffrine region. The main diseases and pests found in the Kebemer region are Striga, bacterial and fungal (36%), stem borers (25%) and termites (20%). Again, in Kaffrine, the most recurrent threats to cowpea production were caused by termites (48%), rodents (31%), grasshoppers (15%), Striga, bacterial and fungal (13%), and stem borers (11%).

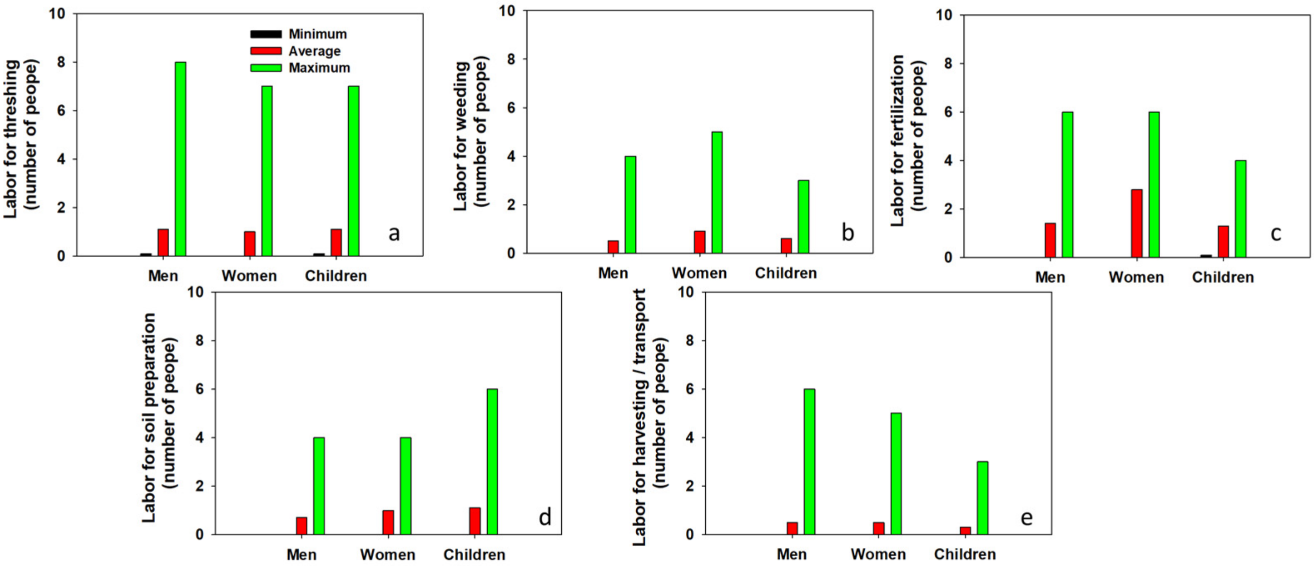

Figure 5. Family labor used at (**a**) threshing, (**b**) weeding, (**c**) fertilization, (**d**) soil preparation, and (**e**) harvesting and transporting cowpea in Senegal.

Table 3. Types of pests or diseases that affects production of cowpea and part of the plant they affect.

	Grasshoppers	Termites	Rodents	Birds	Rod Drillers	Striga, Bacterial and Fungal	None
Bambey (*n* = 80)	3.75	30.00	53.75	0	7.50	22.50	15.00
Kebemer (*n* = 80)	1.25	20.00	1.25	0	25.00	36.25	0.00
Kaffrine (*n* = 80)	15.00	47.50	31.25	1.25	11.25	12.50	8.75
Total (*n* = 240)	6.67	32.50	28.75	0.42	14.58	23.75	7.92
Part of plant affected							
Leaf	13.98	55.91	13.98	1.08	12.90	43.01	-
Seed	7.46	24.63	49.25	0.00	15.67	17.16	-
Stem	6.82	45.45	18.18	2.27	40.91	38.64	-

Leaves of cowpea suffer the most attacks from termites (56%), Striga, bacterial and fungal (43%), grasshoppers (14%) as well as attacks by rodents, stem borers (13%), and birds (1%). Seeds suffer the most attacks from rodents (49%), termites (25%), Striga, bacterial and fungus (17%), and from grasshoppers (7%). The major finding is that seeds do not suffer attacks from birds. Finally, stems suffer the most recurrent attacks from termites (45%), stem borers (41%), Striga, bacterial and fungal (39%), rodents (18%), grasshoppers (6.82%), and birds (2.27%).

Farmers in the study regions used several methods to control diseases and pests. These methods included chemicals (27.1%), cultural methods (5.9%), biopesticides (5.6%), and biological controls (1.4%). Among these methods, chemical controls are the most used to control diseases and pests (48%), termites (45%), grasshoppers (36%), rodents (19%), Striga, bacterial and fungal (12%), and stem borers (9%). Individuals who have not developed control strategies for diseases and pests represent 60% of the producers surveyed.

3.2.4. Cowpea Use

Cowpea has several functions in the regions studied, including marketing, consumption and use as fodder for livestock feed (Figure 6). While most of the cowpea produced was intended for marketing (119 kg on average), a large part is used for livestock feed (82 kg) and home consumption (62 kg). However, other uses included seed reserve and storage for food. Cowpea uses by households differed among regions. Farmers in Kebemer marketed most of their cowpea, while the amount of cowpea intended for animal feed is greater in Bambey (156 kg year^{-1}). At Kaffrine, cowpea is mainly used for household consumption.

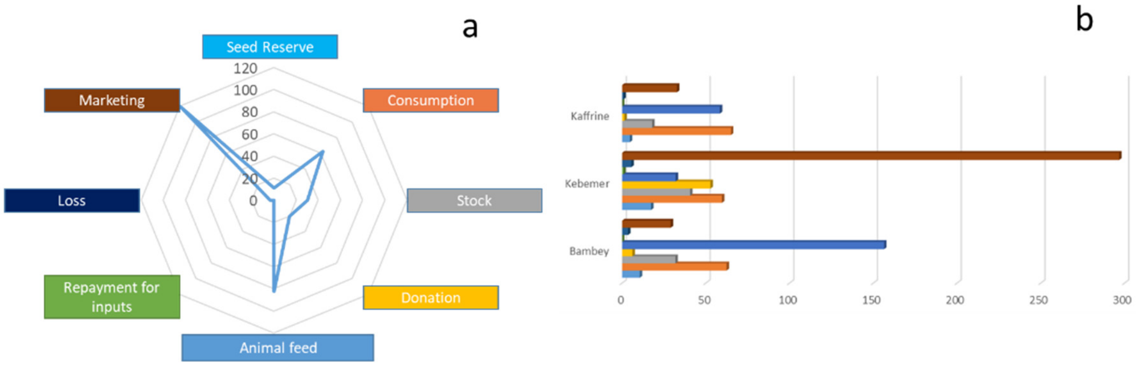

Figure 6. Uses of cowpea produced (**a**) across the study regions and (**b**) by three study areas (Kebemer, Bambey, and Kaffrine) in Senegal. Background color for cowpea use in (**a**) are legend for bars in (**b**).

Households mainly use cowpea fodder for feeding cattle (81% of households) and sheep (74%). Only 30% of households use cowpea fodder for goat feeding (Figure 7). This relatively smaller proportion is explained by the fact that goats are more mobile and can find their own food within their environment. The results also showed that cowpea fodder intended for cattle feed is more common in Kaffrine and Kebemer (Figure 7). The proportion of households using cowpea fodder for feeding sheep is more common in Kaffrine (79%) and Bambey (76%). Using cowpea fodder for feeding goats was more common in in Kebemer (43%) and Bambey (11%).

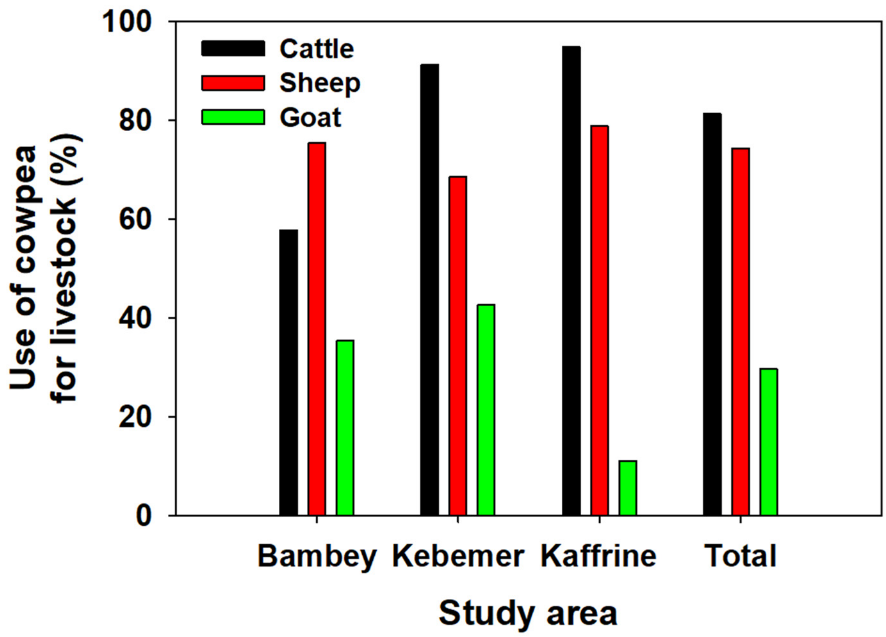

Figure 7. Use of cowpea for livestock by study regions (Kebemer, Bambey, and Kaffrine) in Senegal.

3.3. Sales Price and Period

Out of a total of 240 households surveyed, half (50%) made sales from their cowpea production. Farmers in Kebemer are more market-oriented compared to Bambey or Kaffrine. Out of 119 farmers who have carried out cowpea sales, 96% of them were in Kebemer followed by Bambey (31%), and only 21% in Kaffrine.

The average selling price of a kilogram of cowpea grain was estimated at \$0.58 with a large variation around the mean of up to \$0.17 kg^{-1} (Table 4). Kaffrine, which recorded the lowest proportion of sales had the highest grain price of \$0.74 kg^{-1}. This is explained by the fact that cowpea has become rare in the region and its price was increased based on the quantity offered and the quantity demanded. The average cowpea grain price at Bambey was \$0.67, and Kebemer with the highest cowpea acreage among the study regions had the lowest grain prices, averaging \$0.51 kg^{-1}.

Table 4. Average selling price in US dollars per kilogram of cowpea grain by study area.

Study Region	Obs	Mean	SD	Min	Max
				$ kg^{-1}	
Bambey (N = 25)	25	0.67	0.28	0.33	1.47
Kebemer (N = 77)	77	0.51	0.08	0.33	0.82
Kaffrine (N = 17)	17	0.74	0.10	0.65	0.98

About 38% of households claimed they sold cowpea shortly after harvest while 28% of farmers sold their cowpea in the second quarter after harvest (Table 5). The latter was greater in the region of Kebemer where 23% of the producers surveyed said they marketed their cowpea in the first quarter after harvest. About 19% of producers marketed their cowpea just before next year's sowing, especially in Kaffrine and 15% of producers during the first quarter after harvest. In the Bambey region, most of the households surveyed conducted cowpea sales shortly after crop harvest (68%), but in Kebemer, sales are made over all periods but mostly in the second quarter (35%) after harvest.

Table 5. Cowpea sales period and Storage techniques by study area in % from respondents.

Study Region	Sales Period			
	Shortly after Harvest	**First Quarter after Harvest**	**Second Quarter after Harvest**	**Just before Next Year's Sowing**
Bambey (n = 25)	68.0	0.0	4.0	28.0
Kebemer (n = 77)	33.8	23.4	35.1	7.8
Kaffrine (n = 17)	11.8	0.0	29.4	58.8
Total (n = 119)	37.8	15.1	27.7	19.3
	Storage technique			
	Metal silos	Bags	Metal drums	Cans
Bambey (n = 80)	0.0	5.2	11.7	87.0
Kebemer (n = 80)	1.3	15.0	61.1	47.5
Kaffrine (n = 80)	0.0	1.9	0.0	98.2
Total (n = 240)	0.5	8.1	27.5	74.9

3.4. Cowpea Storage Methods

Cowpea occupies second place in the dietary habits of Senegalese households. About 88% of the households surveyed store part of their cowpea produced compared with 12% who did not store cowpea from their farming operations. In the Kebemer region, all households surveyed stored part of their cowpea produced. This is explained by the fact that cowpea occupies a strategic place after groundnuts and millet in the region. In Bambey, almost 96% of households stored a portion of cowpea produced compared to 68% in Kaffrine. It is worth highlighting the breakthrough of cowpea in the region of Kaffrine located in the heart of the groundnut basin, which currently records a high rate of integration of cowpea in the farming system.

The canister method is the most widely used cowpea storage technique (Table 5). Mostly used by 98% of cowpea farmers in the Kaffrine region, 87% by farmers in Bambey and 48% in the Kebémer region. The use of metal drums was the next popular method (27%), and was generally used by 61% of farmers in the Kebemer region. This region has the largest acreage of cowpea production in Senegal. Storage in bags (8%) and metal silos (0.5%) are also storage techniques used in some regions.

3.5. Estimated Impact of Socio-Economic Conditions on Variety Adoption

The result of the econometrics analysis indicated that access to extension services and membership in producer organizations significantly affected variety adoption compared with other information accessing opportunities (Table 6). The production system practiced also had a significant influence on variety adoption by farmers. Those farmers that solely grow cowpea, organic farmers, and market oriented production and livestock farmers tend to use new varieties. Household characteristics such as area of farmland, access to credit, dependence on agriculture as the main source of household income and the literacy of the head of household had a positive effect on the likelihood of using improved cowpea varieties. However, household size appeared to be a constraint to the adoption of new cowpea varieties because the increase in household size tended to decrease the likelihood for the household to use new and improved varieties. Lastly, agro-ecological zone or study location affected the adoption of cowpea varieties. For example, farmers in Kebemer are more likely to use the improved cowpea varieties compared to those in Bambey and Kaffrine.

Table 6. Variables used in probit model and resulting coefficient from econometrics analysis in STATA to identify their importance in determining cowpea adoption by individual farmers. ***, ***, * indicate significance at *P* less than 0.001, 0.01, or 0.05 level.

Probit Regression						Number of observations	240
						LR chi^2 (2)	98.79
						Prob > chi^2	0.0000
						Pseudo R^2	0.3111
Description	unit	Mean	SD	Min	Max	Coefficient	SE
Information Access							
distance to market	Miles	7.939	5.645	0	25	0.00601	−0.0064
distance to extension services	Miles	0.667	0.472	0	1	1.382 ***	−0.327
distance to main road	Miles	4.23	4.111	0	16	−0.0227	−0.0366
farmer-to-farmer information	[1 = yes]	0.287	0.454	0	1	0.00338	−0.0278
Membership of farm cooperative	[1 = yes]	0.412	0.493	0	1	−0.596 **	−0.304
Cultural System							
monoculture cowpea	[1 = yes]	0.563	0.497	0	1	0.796 ***	−0.211
chemical fertilizer user	[1 = yes]	0.412	0.493	0	1	0.401	−0.285
organic fertilizer user	[1 = yes]	0.542	0.499	0	1	0.142 *	−0.0741
market oriented	[1 = yes]	0.483	0.501	0	1	0.135 **	−0.0631
livestock oriented	[1 = yes]	0.912	0.283	0	1	1.225 ***	−0.192
Household Characteristics							
Age of household head	years	52.846	13.365	22	85	−0.000398	−0.0059
Household size	person	13.875	5.705	4	28	−0.0515 ***	−0.0158
gender of the head of household	[1 = man]	0.963	0.19	0	1	0.984 **	−0.399
alphabetization	[1 = yes]	0.804	0.398	0	1	0.645 ***	−0.138
Cultivated area	hectare	2.651	2.091	0	8.5	0.0767 ***	−0.0079
diseases presence	[1 = yes]	0.921	0.271	0	1	−0.526	−0.386
agriculture as main source of income	[1 = yes]	0.867	0.341	0	1	0.893 **	−0.366
Credit access	[1 = yes]	0.033	0.18	0	1	1.004 ***	−0.179
Study Arae **(ref: Bambey)**							
Kebemer						0.581 ***	−0.146
Kaffrein						−0.384	−0.299
Constant						−4.290 ***	−0.901

4. Discussion

From the results of our study, we can define the average head of the household in our three study regions as middle aged (52–54 years old), married (95–100%), and -illiterate (84%) and male

(95–100%). These results are consistent with the last Senegalese census where the average age was estimated at 55 years old, the overwhelming majority of whom are married and illiterate in the rural area [12]. There was only little variation across our study regions that do not fit this description of the head of the household. Auman et al. [14] compared male versus female household headship and concluded that compared with male household heads, female heads of households were significantly less educated, owned land and cultivated smaller land parcels, were less efficient in agricultural production and disposed of a significant portion of the produce in the local market. The reasons were that most female heads of household in agriculture were divorced, marginalized, and reside in places where there was a male labor migration. The latter occupies an increasingly important place in the income of rural households in the groundnut basin of Senegal [15]. Other researchers also agree with the conclusion that there is a significant difference in male and female heads of household [16,17]. When based on gender and marital status, most heads of household in our study regions being male and married might project a stable environment compared with the alternative discussed in the literature. However, literacy levels reported for most of the heads of the household in our study were low. Despite a married male-dominated head of household in the study region, the low literacy rate could decrease the tendency of adopting efficient agriculture practices to improve crop yields.

The characteristic of the entire household in our study regions could also be summarized as highly agriculture dependent (87%) household, with low literacy (26% least primary school), and big family size with an average of 15 members. Purwantini et al. [18] concluded that the level of education of the households, the number of people in the household, and cropping intensity affect household agricultural income significantly. When households are highly educated, there is an increased diversification of income sources, a general increase in household income, and an improvement in household livelihood [19,20]. Household size determines per capita income of the household and that in turn determines access to financial credit and government subsidies when necessary [21].

The median cowpea yields significantly varied across the study regions from 35–100 kg ha^{-1}. These yields are well below the average cowpea yield of 300–400 kg ha^{-1} reported for Senegal and sub-Saharan Africa [22,23]. Only a few respondent farmers in our study reported cowpea yields above 200 kg ha^{-1}. This situation is explained mainly by the secondary nature of traditional cowpea varieties in most agricultural production systems in Senegal, since it is essentially used as an associated legume crop to fix nitrogen and thus boost the yields of cereals such as millet and sorghum. This low cowpea yield in West Africa is explained by Baoua et al. [24] in a study in Niger and listed factors such as poor agronomic management practices (e.g., inadequate weed control, seeding rates, fertilizer application), pressure from crop pests, aphids and caterpillars, diseases and weeds that cause significant yield losses. Participatory farmer field school (FFS) approach could be one channel for communication and dissemination of improved technologies to improve cowpea yields. Similarly, Omomowo and Babalola [25] described drought, salinity, excessive demand among farmers for synthetic chemicals, the impacts of climate change, declining soil nutrients, microbial infestations, and pest issues as challenges of cowpea production. The authors suggested the deployment of bio inoculants, applying climate-smart agricultural (CSA) practices, agricultural conservation techniques, and multi-omics smart technology in the spheres of genomics, transcriptomics, proteomics, and metabolomics, for improving cowpea yields and productivity. However, these climate smart technologies suggested might be appealing to researchers and educated farmers but considering household education and awareness at the farm level in our study regions, there is more work to be done at a more basic level. Among those basic things are short-term trainings regarding best crop management practices, demonstration of different varieties, creating extension systems for delivery information on available technologies, and marketing opportunities (timing of sales of grain and fodder) for cowpea grain and fodder.

A major reason why reported yields were very low was that majority of farmers in the study regions did not use improved varieties. In addition, the main reasons for not using improved varieties were the limited availability of seeds and little awareness of improved varieties and agronomic management practices. Institutions that study cowpea within the region and extension services should be supported to increase the availability of improved varieties and use by farmers. Studies conducted elsewhere reported seed cost as a major barrier to adopting and using improved crop varieties [26]. However, our findings showed seed costs are not the major barrier for cowpea use in our study region as only 6% of the respondents indicated seed price as a problem.

The three major use of cowpea in the study region were for marketing, livestock feed, and human consumption. The dual- use of cowpea grain for human and fodder for animal consumption should increase government interest in this crop, which provides quality fodder for livestock during the lean season, which coincides with the beginning of fieldwork and the low availability of fodder from other crops (such as peanut or millet stover). To increase the production of cowpea, the use and demand need to increase and be a driver. This seems to be the case with the multiplication of cowpea fodder programs, which could replace peanut fodder, whose prices are increasing at a very steady pace. As a highly drought-tolerant crop with low water requirement and greater heat tolerance, cowpea has the potential for food security in Africa and around the world. Besides cowpea grain, its pods and leaves are also nutritious and edible [27]. It is a leguminous crop, that should also be promoted for N fixation as part of a crop rotation or as a cover crop to maintain soil fertility [28]. However, with most of the crop residues being removed, very little residual N is likely to return to the soil. More research is needed to compare the value of the residue for crop production as compared to being used for livestock feed. Promotion on the various uses of cowpea in and outside the study region, creates a demand for the crop, motivates farmers to increase production, and creates a fertile environment, more markets, and profit.

The effect of socio-economic status of producers extends beyond the choice of cowpea varieties. Once cowpeas are planted, management of the crop and after harvest, choice of proper storage also require knowledge and economic potential. In our study region, 60% of producers have not developed control strategies for diseases and pests. The popular cowpea storage is using cans. Due to the large number and diversity of cowpea diseases and pests, an integrated set of management at different stages of cowpea growth was recommended [29,30]. Dissemination of chemical free hermetic bags for cowpea storage has also improved cowpea storage in most parts of Africa, but due to several alternative hermetic bags, testing and making the best storage available to producers may be essential [31]. To increase productivity and to reduce post-harvest losses in storage, training, awareness, and financial support may be required.

The adoption of improved varieties was explained by three sets of variables including access to information, production system, and the characteristics of the household. These groups of variables are defined by the literature and the context of the study. While some research had focused particularly on household and producer characteristics or market practices to estimate the probability of adopting a new crop variety [32–34], to our knowledge, no study considered these three groups to estimate the adoption of new cowpea varieties in the West-African Sahelian region. Access to information regarding the usage of new varieties is an important factor that affects adoption [35]. The importance of information capability through multidimensional sources to improve producers' production and marketing decisions have been reported in recent studies [36,37]. Our descriptive analyses showed producers could access information on improved varieties through five channels: markets, extension services, urban centers, their peasant neighbors, and producer organizations. In the current study, extension services and producers' organizations were important factors affecting the use of improved cowpea varieties. Compared to producers using cowpea as an associated crop, farmers dedicated to sole cowpea production are more likely to use improved varieties. In addition, farmers using organic fertilizer are more likely to use the improved cowpea varieties possibly to take advantage of biological N fixation. Market-oriented producers and those who use cowpea fodder for livestock are also likely to adopt improved varieties with greater fodder production.

5. Conclusions

The specific objective of the current study was to analyze the socio-economic characteristics of cowpea production systems, gather baseline information on adoption of improved dual-use cowpea varieties in the Senegalese peanut basin, and study correlation between socio-economic characteristics and variety adoption. Results of the study showed most heads of the household in our three study regions as a middle aged (52–54 years old), married (95–100%), illiterate (84%), and mostly men (95–100%). The characteristic of the entire household in our study region could also be summarized as highly agriculture dependent (87%), with low literacy (26% least primary school), and big family size with an average of 15 members. The median cowpea yields significantly varied across the study region and varied from 35–100 kg ha^{-1}, which was well below the average yield reported for sub-Saharan Africa. The Majority of farmers do not use improved varieties, and the main reasons for not using improved varieties were lack of seed availability and little awareness of improved varieties. The three major uses of cowpea in the study region were for marketing, livestock feed, and human consumption. The effect of socio-economic status of producers extends beyond the choice of cowpea varieties to cowpea production, management, and storage. Access to extension services, membership in producers' organization, sole cowpea production, organic farming, market, and livestock oriented production systems, access to large acreage of farmland, access to credit, dependence on agriculture as the main source of household income, and literacy of the head of household seem to have a positive effect on the likelihood of using the improved varieties. We concluded the need for training, access to improved seed, awareness, and financial support to producers to increase the adoption of new and improved cowpea varieties to increase yields, profitability, and nutritional security among smallholder farmers. The results presented in this paper are based on baseline survey data in the three regions of Senegal and it is a unique (novel) contribution connecting technology adoption with socio-economics of the region. Results have to be taken with the context of the regional and other limitations and further research on the impact of recommended interventions (training, access to improved varieties, awareness, and financial support) in technology adoption is crucial.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su142114550/s1, Table S1: Questionnaire.

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