# A call for a systemic approach to the development of cowpea (*Vigna unguiculata*) in Senegal.

**Cathy CLERMONT-DAUPHIN[1,2*], Abdou L FALL[1,3], Omar B DIOP[1,3], Cheick T FAYE[1,4], Dan MOLCZADZKI[5], Ndeye F FAYE[6], Saïdou N SALL[4], Alpha O DIALLO[3].**

[1] LMI IESOL, ISRA-IRD Bel-Air, Dakar, Senegal

[2]Eco&Sols, Univ Montpellier, IRD, CIRAD, INRAE, Institut Agro, Montpellier; France

[3] Agronomy and Crop Protection (APC), Ecole Nationale Supérieure d'Agriculture, Thiès, Senegal

[4] Gaston Berger University, Saint-Louis, Senegal

[5] CIRAD, UPR AIDA, Dakar, Senegal

[6] ISRA-BAME, route des, BP 3120, Dakar, Senegal

***Correspondence:** cathy.clermont@ird.fr

**Abstract:**

Cowpea offers significant potential for sustainable West African agriculture. However to effectively promote a wider adoption on farms, it is crucial to understand the environmental, social, and economic factors that shape current farming systems. In Senegal, surveys reveal a stark contrast between the Sahelian Zone (SZ) and the Sudan-Sahelian Zone (SSZ). In the most water-constraint SZ, cowpea is a cash crop supported by public funding for synthetic inputs and improved varieties. Conversely, in the less water-constrained SSZ, cowpea is grown sparsely with millet, primarily for household and animal consumption, using minimal inputs. In both zones, farmers are more likely to cultivate cowpea on fields located further away from their homes. In SSZ, availability of high agricultural area and labor shortages also encourage its cultivation. SZ farmers value cowpea's positive effects on intercropped plants less than SSZ farmers. In both zones, farmers strategically cultivate a range of cowpea varieties to address diverse needs and strengthen their resilience against climate risks. The rapid expansion of cowpea in SZ has been accompanied by a loss of biodiversity and an increase in pest problems. In conclusion, effective cowpea development in Senegal necessitates a balanced approach: recommendations should be tailored to diverse farm strategies, valuing the preservation of agroecosystem biodiversity and ecological services as well as cowpea's commercial growth and income generation.

Keywords: **commercial chain, Socio-economic logic, Farmer perceptions, Bioaggressors, Varieties, Public policies, Sustainability, Sahel**

## 1. Introduction

Legume crops provide several benefits for low-input family farms in southern countries. Primarily, legumes supply protein-rich products that significantly contribute to both human and animal nutrition, as well as market income. Additionally, they offer ecological benefits by enhancing biodiversity in cereal agroecosystems, promoting bacterial fixation of atmospheric nitrogen, stimulating the development of mycorrhizae, and contributing to soil cover. These ecological benefits support the development of a more sustainable and resilient agriculture (Franke et al., 2018).

While cowpea is Senegal's second most important legume after groundnut, its cultivated area significantly lags behind. From 2015 to 2020, cowpea accounted for only 11% of cultivated areas, compared to 47%

for groundnuts (FAOStat, 2023). Despite its reputation for greater tolerance to drought and nutritional stress, and its potential for symbiotic nitrogen fixation which often surpasses groundnuts (Carvalho et al., 2019; Cassman et al, 1981; Bado et al., 2006; Hamidou et al., 2018), average grain yields of cowpea in Senegal did not exceed 0.3 T/ha/year before 2013 (Fig.1). The yield gap was substantial, since potential yields for most cowpea varieties range from 1.5 to 2.5 T/ha (ECOWAS et al., 2016). This gap stems partly from cowpea's perception as a crop for very poor farmers. Furthermore, cowpea's development has been hampered by unequal public support, favoring groundnuts, a situation often described as a 'technological lock-in' effect (Meynard et al., 2013). This prioritization has hindered the advancement of cowpea cultivation and related technologies in the country.

The year 2014 marked a significant shift in national agricultural policy regarding cowpea. The research approach evolved from a narrow focus on varietal breeding, to a broader perspective that includes all stakeholders in the cowpea sector: farmers, research institutes, input suppliers, extension services, and marketing channels. This evolution is exemplified by the creation of a National Inter-professional Framework (NIF), uniting diverse stakeholders to collaboratively address constraints across the cowpea value chain (IFAD, 2013). Since this policy shift, statistics reveal progress in Senegalese cowpea production, with increases in both cultivated land and yields (Fig. 1) (FAOStat, 2023). Furthermore, the improved, short-cycle varieties Melakh and Yacine (ECOWAS et al., 2016) have experienced increased adoption and impact since this period.

However, a sustainable agricultural policy for cowpea must also account for the diversity of farmers' perceptions, objectives, resources, and the crucial involvement of women among farmers (Meijer et al., 2014; Mbaye and Hamet, 2016; Koussihouede et al., 2020). In land-saturated regions, careful planning is crucial to prevent cowpea expansion from reducing species diversity and related ecosystem services (Ouyang et al., 2020). Moreover, it is crucial to develop strategies that mitigate the long-term risk of reduced millet yields arising from shared nematode vulnerability when cowpea frequency increases in millet rotations (Abade et al., 2016; Bagayoko et al., 2000; Mokrini et al., 2019; Mbengue et al., 2024).

The objectives of this study were to: 1) quantify cowpea cultivation areas across a network of farms and analyze their variation based on farm socio-economic characteristics and biophysical environment 2) highlight and compare farmers' perspectives on cowpea's advantages, constraints, and roles across two contrasting pedoclimatic zones 3) analyze the ecological aspects that need to be considered for the sustainable development of cowpea growing in Senegal.

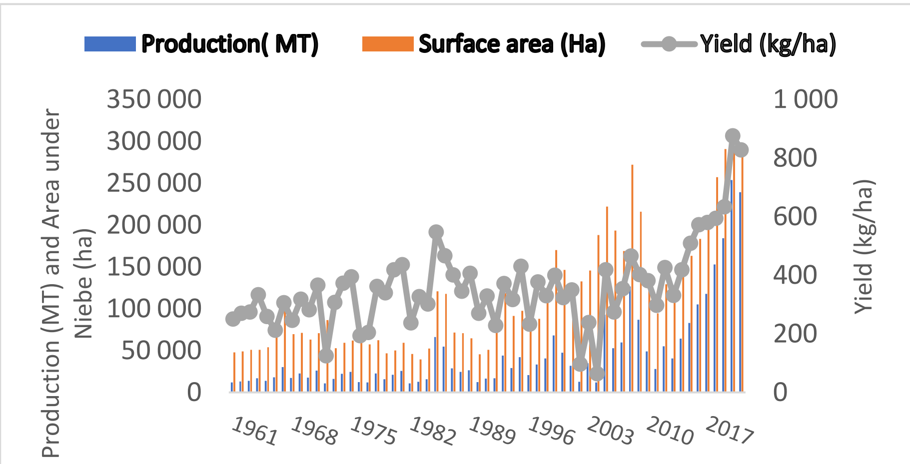


**Figure 1**: Cowpea production, area and yield in Senegal from 1961 to 2021 - data taken from FAOStat, 2023

## 2. Materials and methods

Two agro-ecological zones (AEZ) in Senegal's groundnut basin were examined:

- The Sahelian zone (SZ), with the lowest annual rainfall (250-500 mm). Represented by region of Louga, it accounts for almost half of Senegal's cowpea-growing area, producing around 160,000 tons from 168,756 ha in 2020. Public subsidies for certified seed multiplication and input access are well established.

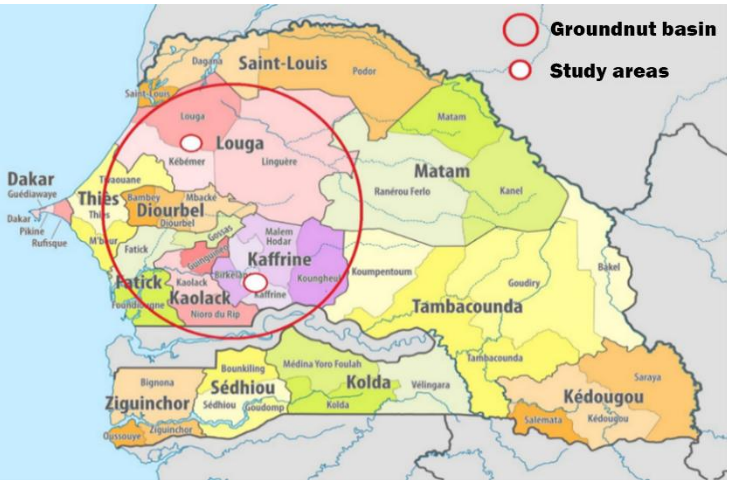


**Figure 2**: Location of study areas in Senegal

- The Sudano-Sahelian zone (SSZ), receiving higher rainfall (500-900 mm). Represented by the region of Kaffrine, cowpea is intercropped at low density with groundnuts or bissap (*Hibiscus sabdariffa L.*). Production was about 2,000 tons from 2,800 ha in 2020. Recourse to public subsidies is limited.

Various types of surveys were conducted. Interviews with representatives from the Agence Nationale de Conseil Agricole et Rural (ANCAR), the “Direction Régionale de Développement Rural” (DRDR), and farmers' cooperatives and associations in the two zones helped compile a closed questionnaire. This questionnaire was completed by 76 farms selected by informants as representative of small, medium, and large cowpea producers. The data collected allowed for quantifying the percentage of agricultural area devoted to each species or combination of species over the last five years. Based on this data, Shannon diversity indices (H') were estimated for the Louga and Kaffrine regions respectively:

$$\mathrm{H}' = -\sum_{\mathrm{i}=1}^{i=n} \mathrm{pi} * \ln \mathrm{pi}$$

where i = cultivated species i, pi = area occupied by species i over the total observation area.

The calculation includes the following conditions:

- Only species occupying more than 2% of the average cultivated area during the period 2018-2022 are considered.

- In Louga, the proportion of area under cowpea when intercropped with bissap is set at 80%, and in Kaffrine, the proportion of cowpea intercropped with groundnut is set at 20%. These percentages correspond to the density of cowpea plants in intercropping compared to their density in monocropping.

- The proportion of each species in the total observation area equals the sum of its monocropping area plus the proportion of area occupied by that species in intercropping.

A second series of surveys was conducted on a sub-sample of 30 farms strategically selected to represent the full range observed in the initial survey regarding the 'proportion of total area under cowpea'. The survey focused on the resources available on these farms and the technical management of cowpeas. At the conclusion of the survey, 13 socio-economic variables were selected as relevant indicators for farmers' decisions regarding cowpea area (Table 1 a and b). For example, the percentage of plots near the farmer's residence and the percentage of plots considered less fertile were analyzed to test the hypothesis that specific plot characteristics and their subsequent yield performance could influence the proportion of land allocated to cowpeas. The 'number of cattle' variable was used to test the hypothesis that the demand for haulm for cattle feed is a significant factor in the decision to cultivate cowpea at the farm level. The 'number of women/number of adults' variable was included to assess the role of female labor in this decision (Table 1a and b). These data were analyzed using generalized linear regression (GLZ) in STATISTICA software, with the percentage of area allocated to cowpea as the dependent variable and farm characteristics as the independent variables.

A third series of surveys explored the perceptions of both male and female farmers. This involved an initial stage of informal focus group interviews, conducted separately for each gender, with the aim to compile lists of the prior roles, and most common advantages and constraints associated with cowpea cultivation. In the second stage, individual interviews were conducted to rank the items on each list based on farmers' assessments. To achieve this, each respondent was given a batch of 50 seeds to allocate between items. The more important an item was considered, the more seeds it received. Finally, specific surveys were conducted to examine the advantages and constraints of the varieties they use.

## 3. Results

### 3.1. Areas allocated to cowpeas at farm level and consequences for biodiversity in agrosystems

Figures 3 and 4 illustrate substantial variability in the proportions of agricultural areas allocated to cowpea across different farms within the same region. In Louga (SZ), the allocation of cowpea monocrop area ranged from 0 to 15% on farms Nos 34, 40, 45, and 64, while it exceeded 70% on farms Nos 9, 14, 17, 24, 26, and 59. Conversely, in Kaffrine (SSZ), most farms allocated less than 10% of their area to cowpea monocrop. Exceptions included farms 11, 61, and 56, which allocated 20-30%, and farm 28, which allocated over 40%.

Assuming that the 75 farms surveyed represent the region's spatial diversity, these figures indicate that in Louga, cowpea (51% of the total area) and groundnuts (43%) dominate the cultivated area. Millet is scarcely present, contributing only 3% to the cultivated area. It appears that traditional rotations and legume intercropping with millet have been largely replaced by consecutive plantings of cowpea monocrop or cowpea as the predominant crop. Other crops such as sorghum, bissap, okra, sweet potato, cassava, and watermelon collectively account for less than 2% of the cultivated area.

In contrast, Kaffrine exhibits land use patterns more typical of the groundnut basin, with millet and groundnuts being the primary crops, each occupying approximately 44% of the cultivated area in rotation. The area under pure cowpea is minimal, less than 4%. Additional crops like maize, sorghum, watermelon, and bissap represent nearly 8% of the cultivated area. Kaffrine's Shannon index was calculated at 1.50, whereas Louga's index did not exceed 1.

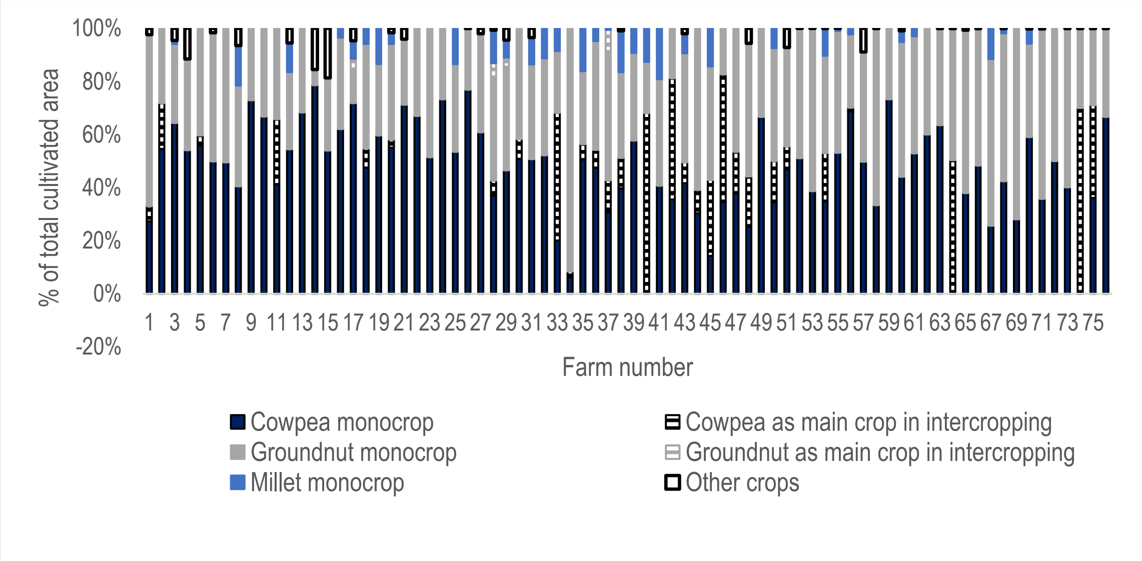


**Figure 3**: Average area cultivated by different species in the Louga region, in the Sahelian zone (SZ) over the period 2018-2022 on a sample of 76 farms covering a total average annual area of 386 ha.

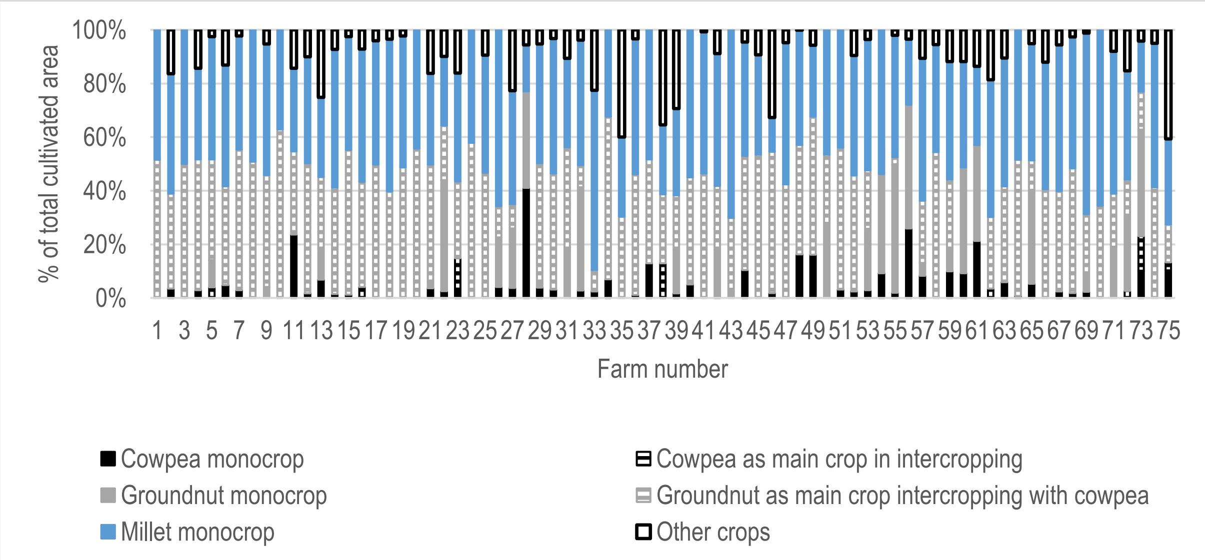


**Figure 4**: Average area cultivated by different species in the Kaffrine region, in the Sudano-Sahelian zone (SSZ) over the period 2018-2022 on a sample of 75 farms covering a total average annual area of 765 ha (NB: the 76th survey is missing).

### 3.2. Socio-economic determinants of the area allocated to cowpeas

A generalized linear regression (GLZ) analysis was conducted using the percentage of area allocated to cowpea on each farm as the dependent variable. The predictor variables included various factors characterizing the farms' means of production and their specific socio-economic context (Tab.1 a and b). The analysis identified the major influencing factors by examining their P-values:

a) In Louga: the availability of tools, the proportion of area close to the farm, and the perception of soil fertility levels (Tab.1 a).

b) In Kaffrine: the age of the farm manager, the available agricultural area, the number of adults in the household, and the percentage of area within a 10-minute walk from the farm (Tab.1 b).

The coefficients from the statistical analysis indicated that, in Kaffrine, farmers who allocate substantial areas to cowpeas are typically older, have relatively large agricultural areas, and a significant portion of these areas is distant from their homes. These farmers tend to have limited labor and ancillary activities. Conversely, farmers in Louga who devote substantial areas to cowpeas share similarities with those in Kaffrine regarding distant plots and often less fertile land. However, unlike Kaffrine's farmers, Louga's farmers generally have fewer tools and smaller total cultivated areas compared to those who grow fewer cowpeas.

**Table 1** a and b: Results of generalized linear regression (GLZ) of % area allocated to cowpea as a function of farm characteristics in the Louga (SZ) and Kaffrine (SSZ) regions**.** Distribution: NORMAL, Linking function: LOG. *P< 0.05* indicates significant effect (in bold) and *P* values close to significance is underlined.

| a) Louga (SZ) | Coefficients | Standard error | Wald stat | Value of *P* (3) |
|---|---|---|---|---|
| Ord.Orig | -0.29 | 0.14 | 4.02 | **0.04** |
| Age of farm manager | -0.00 | 0.00 | 0.93 | 0.33 |
| Average cultivated area 2018-2022 | -0.00 | 0.00 | 1.22 | 0.27 |
| Number of adults | -0.01 | 0.04 | 0.09 | 0.76 |
| Number of consumption units (1) | 0.03 | 0.03 | 0.86 | 0.35 |
| Number of individuals who declared farming as their main activity | -0.01 | 0.01 | 0.17 | 0.68 |
| Number of women/number of adults | -0.07 | 0.13 | 0.27 | 0.60 |
| Surface less than 10 min from home | -0.40 | 0.12 | 11.01 | **0.00** |
| Surface with low fertility | 0.41 | 0.13 | 10.19 | **0.00** |
| Number of units Tropical cattle (2) | -0.00 | 0.01 | 0.03 | 0.85 |
| Number of carts | -0.09 | 0.06 | 2.37 | <u>0.12</u> |
| Number of seed drills | 0.03 | 0.06 | 0.28 | 0.60 |
| Number of Houe sine | -0.63 | 0.18 | 12.13 | **0.00** |
| Number of agricultural organisations with which one or more farm members are affiliated | -0.03 | 0.04 | 0.38 | 0.53 |
| Number of ladders | 0.07 | 0.01 | 58.00 | **0.00** |

| a) Kaffrine (SSZ) | Coefficients | Standard error | Wald stat | Value of *P* (3) |
|---|---|---|---|---|
| Ord.Orig | -2.89 | 0.54 | 29.07 | **0.00** |
| Age of farm manager | 0.02 | 0.00 | 13.10 | **0.00** |
| Average cultivated area 2018-2022 | 0.00 | 0.00 | 3.38 | <u>0.06</u> |
| Number of adults | -0.11 | 0.07 | 2.87 | <u>0.09</u> |
| Number of consumption units (1) | 0.11 | 0.07 | 2.17 | 0.14 |
| Number of individuals who declared farming as their main activity | -0.04 | 0.02 | 2.50 | <u>0.11</u> |
| Number of women/number of adults | 0.00 | 0.68 | 0.00 | 0.99 |
| Surface less than 10 min from home | -0.47 | 0.19 | 6.21 | **0.01** |
| Surface with low fertility | -0.33 | 0.27 | 1.51 | 0.22 |
| Number of units Tropical cattle (2) | -0.00 | 0.00 | 0.58 | 0.45 |
| Number of carts | -0.34 | 0.27 | 1.53 | 0.22 |
| Number of seed drills | -0.13 | 0.12 | 1.24 | 0.26 |
| Number of House sine | 0.29 | 0.11 | 6.08 | **0.01** |
| Number of agricultural organisations with which one or more farm members are affiliated | 0.04 | 0.11 | 0.12 | 0.73 |
| Number of ladders | 0.03 | 0.00 | 60.00 | **0.00** |

(1) the head of the household counts as 1, the other adults as 0.7 and the children as 0.5; (2) 1 adult bovine = 1 horse = 1 BTU; 1 sheep = 1 goat = 0.12 BTU. (3) P values in bold are those below 0.05, indicating a significant effect of the variable tested. P values closest to 0.05 have been underlined to draw the reader's attention.

### 3.3. Technical management

With numerous organizations supporting the cowpea sector, seed multiplication contracts, commissioned by the Senegalese State, are increasingly prevalent in Louga, requiring adherence to a set of specifications: fallow precedes the production of basic seeds, millet precedes the production of first-generation seeds (R1), and groundnut precedes the production of R2. Sowing density is set at 16 kg per hectare in cowpea monocrop, varieties must be distanced appropriately, plant spacing must be respected, sowing should occur after the return of rains (not before), weeding is necessary, and insecticide treatments must be applied. Certified seeds production is largely focused on two short-cycle varieties: Yacine and Melakh. The terms of these contracts include the provision of inputs, namely certified seeds and pesticides, on credit. In return, the farmer agrees to sell their entire dehulled and sorted harvest at a pre-determined price. This system is the main source of seeds for the national seed supply chain.

Louga village integrates more inputs and improved cowpea varieties into their cropping systems than Kaffrine. Mineral fertilization of cowpea plots is more common in Louga than in Kaffrine. Over the past five years, more than 50% of cowpea areas in Louga, regardless of certified seed production, have consistently used insecticides (Dimethoate, Neonicotinoids) on the crop, whereas only 30% have done so in Kaffrine. These products are typically applied up to three times during the growth cycle: initially at the start of flowering, then when pods appear, and finally two weeks after the second treatment.

The primary pests affecting cowpea include the hairy caterpillar (*Amsacta moloneyi*), black aphid (*Aphis craccivora*), and pod-sucking as well as pod-boring insects (including *Clavigralla tomentosicollis* and *Maruca vitrata* bugs). Numerous farmers have reported increasing damage from a new soil-borne pathogen responsible for root rot during the pod stage and wilting and mortality of cowpea plants. One farmer noted: "The plants start to turn yellow, then dry up completely in patches that spread. Termites then make galleries in the weakened plant." Another remarked: "It seems to me that it's a tiny black worm, which we call 'the guolana' here. It's more likely to be found when the soil is damp. There is currently no known treatment for this disease."

Several different cowpea varieties, usually local ones, are cultivated on each farm. Generally, local varieties are sown dry after shallow ploughing with an animal-drawn hoe (the “Sine hoe”). According to farmers, certified seeds of short-cycle varieties provided by public support do not perform well under dry sowing conditions, unlike local varieties. Even in Louga, only a minority of cowpea plots use certified seeds. Surveys indicate that only 25% of cowpea seeds used by farmers are certified, with the remainder sourced either from their previous stored harvests, without specific cleaning, grading, or certification for seed quality.  (25%) or from the local grain market (50%). It is common to find multiple varieties even within a single batch of seeds that appear to be the same color. For instance, the variety known locally as "white cowpea" exhibits this characteristic. Farmers' organizations reported that after 4 to 5 years of continuous sowing, certified seeds showed signs of degeneration, resulting in reduced yields, smaller and lighter seeds, lower germination rates, and increased susceptibility to pests. The Yacine variety reportedly begins to resemble the local Ndiagaaw variety over time. Average yields drop from 1,200 to below 400 kg per hectare. A farmer suggested that pod dehiscence, coupled with smaller seed size making them more vulnerable, could have caused the bird attacks in 2022.

## 4. Farmers' perceptions of the roles, advantages and constraints of cowpea cultivation.

Perceptions regarding the role of cowpea cultivation on farms varied across regions. In Louga, cowpea was primarily utilized for human consumption and income generation, whereas in Kaffrine, it was mainly used for both human and animal consumption, with a relatively weaker focus on generating income. This regional difference was noted among both men and women (Fig. 5 a, b).

Several advantages provided by cowpea cultivation were highlighted. The most anticipated advantage in both regions was early production due to the short growth cycle of cowpeas, which helps to bridge the hunger gap typically occurring before millet harvests. Men farmers in Louga were more aware of this benefit compared to women. Conversely, the yield-enhancing advantage of intercropping cowpea was more valued in Kaffrine. In Louga, women exhibited greater awareness than men regarding the yield-enhancing advantage of intercropping cowpea (Fig. 6 a, b).

Several constraints associated with cowpea cultivation were also identified. In Louga, both men and women cited susceptibility to pests as the primary constraint. In Kaffrine, seed quality was considered equally significant. Additionally, competition for labor between cowpea and other crops was reported more frequently in Kaffrine than in Louga (Fig. 7 a, b)

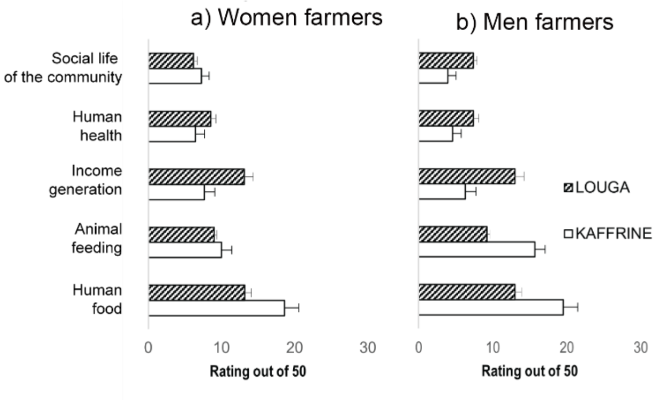


**Figure 5**: Perceptions of **roles of** cowpea cultivation in two regions in the Sahelian zone (Louga) and the Sudano-Sahelian zone (Kaffrine) in Senegal.

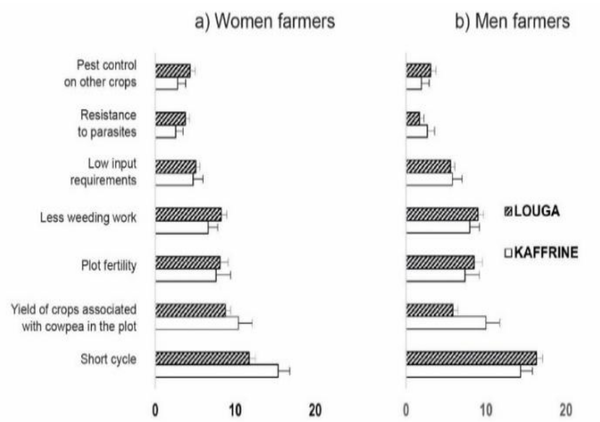


**Figure 6**: Perceptions of cowpea cultivation **advantages** in two regions in the Sahelian zone (Louga) and the Sudano-Sahelian zone (Kaffrine) in Senegal.

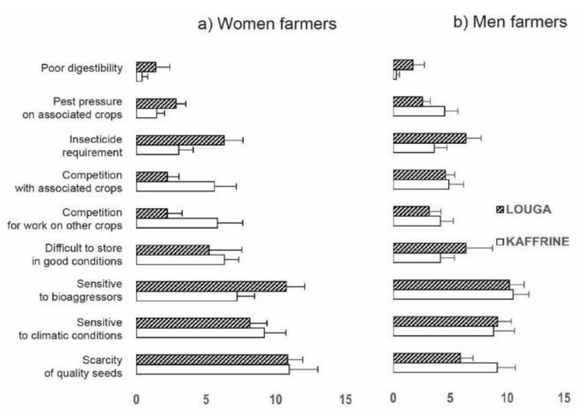


**Figure 7**: Perceptions of cowpea cultivation **constraints** in two regions in the Sahelian zone (Louga) and the Sudano-Sahelian zone (Kaffrine) in Senegal

**Table 2**: Perceptions of male and female farmers in Kaffrine (SSZ) of the advantages and constraints of some of the most widely used varieties

| Varieties | Assets | Constraints |
|---|---|---|
|  **Ndiassive**<br>*(local, creeping variety, 90 days*)* | ▪ Good forage yield<br>▪ Improves soil fertility<br>▪ High nutritional value of forage<br>▪ Treats diseases and parasites (teigna, worms)<br>▪ More resistant to *Aphis cracivora* black aphids than other varieties<br>▪ Capacity for regeneration after cutting stems in September to produce seeds in December | ▪ Can only produce seeds from December onwards<br>▪ Its fodder is bitter when green, so it is not eaten by animals when green.<br>▪ Incompatible with peanuts<br>▪ Cannot be stored for longer than 6 months. As winter approaches (monsoon period), the quality begins to deteriorate and can lead to constipation in animals that do not ruminate (horses and donkeys, etc.). |
|  **Baye ngagne**<br>*(local, creeping variety, 90 days)* | ▪ Good seed and fodder yields (3 to 4 harvests)<br>▪ Large seeds, easy to harvest and shell<br>▪ Excellent fodder for draught horses<br>▪ Controls *Mitrocarpus villosus* on peanuts<br>▪ Fodder easily consumed by animals in green or dry state<br>▪ Elastic" variety<br>▪ Good taste<br>▪ Leaves can be prepared as a sauce for couscous<br>▪ Does not need much water at flowering time<br>▪ Earlier start to flowering if sown early.<br>▪ Swells more than small-seeded varieties when cooked<br>▪ One of the earliest long-cycle varieties<br>▪ Good cultural precedent | ▪ Difficult to maintain when combined with groundnuts<br>▪ Sensitive to insects<br>▪ Sensitive to caterpillars in the event of a break in rainfall<br>▪ Loses its leaves as soon as the rain starts to fall<br>▪ Sensitive to dew (mould growth affecting hay quality)<br>▪ Heavy rainfall causes flowers to fall sharply<br>▪ Susceptible to rotting if harvested late<br>▪ Requires sufficiently moist soil to germinate (difficult to sow dry) |
|  **Cowpea *fouta***<br>*(local variety, semi-rampant, 90 days)* | ▪ Good forage yield<br>▪ Better nutritional value than *baye ngagne* and *ndiassive*<br>▪ Does not lose its leaves early | ▪ Sensitive to thrips and some lepidopterans<br>▪ Sensitive to heavy rain, which causes flowers to drop<br>▪ Starts flowering late (70 JAS)<br>▪ Requires rich soils for good forage yields |
|  **Large-seeded white cowpea** (Niébé blanc à grosse graine)**<br>*(local variety, semi-rampant, 85 days)* | ▪ Early<br>▪ Good seed yield<br>▪ Easy to harvest<br>▪ Average forage yield<br>▪ Ripe pods will not rot if harvested late | Early leaf loss<br>▪ Sensitive to stem borers<br>▪ Very sensitive to pod borers<br>▪ Farinière |
|  **Volète**<br>*(local variety, erect, 35 days)* | ▪ Early<br>▪ Good seed yield<br>▪ Less attacked by pod borers than other varieties<br>▪ Less attacked by bruchids | ▪ Difficult to harvest<br>▪ Little forage |
|  **Ndiaga aw**<br>(*local variety, semi-rampant, 90 days)* | ▪ Early<br>▪ Average forage yield | ▪ Difficult to harvest<br>▪ Sensitive to pests<br>▪ grain cracking or discolouration during post-harvest drying |
|  **Yacine**<br>*(improved var, erect, 35 days)* | ▪ Good performance<br>▪ Early harvest<br>▪ More attractive price because it's much appreciated by restaurateurs | ▪ Does not tolerate late sowing<br>▪ Sensitive to pests<br>▪ Susceptible to rot if harvested late<br>▪ Pod dehiscence at maturity<br>▪ grain cracking or discolouration during post-harvest drying |

* This local name could include a mixture of several varieties, including the Mélakh variety.

### 4.1. Diversity of varieties and farmers' perceptions of their strengths and weaknesses

More than twenty cowpea names were mentioned during the surveys carried out on the 76 farms in Louga, and about ten in Kaffrine. Farmers reported cultivating multiple cowpea varieties on the same farm to capitalize on the unique advantages each variety offered. (Tab. 2) and to ensure a minimum yield under various climatic conditions. According to the farmers, susceptibility to insect attacks varies among the different cowpea varieties. For instance, the local variety 'Ndiassive' is reputed to be more resistant to the black aphid *Aphis cracivora* compared to other varieties. Conversely, 'Baye Ngane' is particularly vulnerable to hairy caterpillar attacks and is not suitable for intercropping with groundnuts. However, this variety has the advantage of being dual-purpose for both animal feed and human consumption, and it allows for harvesting pods three to four times during its cycle.

The short-cycle varieties developed by researchers, such as 'Yacine' and 'Melakh', are highly valued for green consumption and for reducing the hunger gap. These varieties perform well in the local market. The large red grains of the Yacine variety are preferred for making 'ndambé', a cowpea stew popular in small street food restaurants. Nonetheless, Yacine is prone to pod dehiscence if harvesting is delayed. The local long-cycle variety 'Fouta' produces a substantial biomass, making it particularly desirable for livestock farmers. Among the long-cycle varieties, some show better drought adaptation than others, such as 'Ndiassive'.

## 5. Discussion

These results highlight the socio-economic and ecological risks associated with a value chain approach that prioritizes market penetration of a single species without considering its interrelationships with other species. The area dedicated to cowpea cultivation in Louga (SZ) has significantly expanded, driven by increased public and private investment across its value chain. However, this expansion has coincided with a decline in crop diversity in the region, potentially hindering natural pest regulation. Farmers have reported a rise in insect infestations in recent years. The newly observed syndrome affecting cowpea crops may be linked to infestation by a root-lesion nematode of the genus Pratylenchus, a known cowpea parasite (Mbengue et al., 2024). Future research is needed to definitively identify the causal pathogen.

Several farmers in Louga have observed a decline in the effectiveness of chemical pesticides promoted for cowpea intensification. This reduced efficacy is likely due to several interconnected factors: increasing insect resistance to pesticides over time, limited resources at the Plant Production Department (DPV) hindering communal-scale plant protection services, and delayed interventions. These initial results raise questions about the sustainability of the chemical control strategy for cowpea intensification in the study context. In Kaffrine (SSZ), where cowpea cultivation is less prevalent and integrated into intercropping and rotation systems with other crops, pest pressure remained low. These results align with literature highlighting the critical role of biodiversity in the natural regulation of pests (Peñalver-Cruz et al., 2019; HE et al., 2019; Yang et al., 2023).

Our findings suggest that cowpea cultivation strategies differ between Louga (SZ) and Kaffrine (SSZ). In SZ, intensive cowpea cultivation is driven by the search for quick income on marginal land, with little interest in cowpea's ecological services. In SSZ, cowpea is regarded more as an additional crop providing emergency food, livestock fodder, and ecological services. Cowpea is integrated into diversified production systems where millet and groundnut remain dominant crops, receiving priority for farm labor and fertile land resources. Cowpea managements involving high levels of chemical inputs would not align with the objectives of farmers in SSZ. One of the key processes underpinning the ecosystem services expected from legumes, namely symbiotic nitrogen fixation, could also be significantly inhibited by nitrogen fertilization and pesticide treatments (Ahemad and Khan 2011; Lamichhane et al., 2020; Reinprecht et al., 2020).

The current certified seed production system, which focuses on short-cycle varieties, meets the needs of intensive systems but overlooks the requirements of intercropping and forage systems. It ignores that farmers value the use of diverse local varieties to improve the farm resilience and ability to meet multiple objectives (Toure et al., 2022). These local cowpea varieties, although not well documented scientifically, are well known by farmers. Our surveys have enabled us to compile a vernacular catalogue revealing varietal characteristics often overlooked by official catalogues. This vernacular catalogue was particularly appreciated by farmers in other regions of Senegal interested in introducing cowpea into their systems, such as the Casamance region in southern Senegal. It could also guide breeders in developing improved varieties that better address the diverse needs of farmers.

## 6. Conclusion

Our study emphasized the critical influence of socio-economic and environmental factors on Senegalese farmers' cowpea cultivation strategies. It stressed the need for a systemic approach to enhance production, one that considers the diverse socio-economic situations of farms, their varying biophysical environments, and the imperative of long-term sustainability. While national policies supporting high-input systems in the Sahelian zone have increased cowpea production, they might also inadvertently led to reduced cultivated species diversity and weakened natural pest control mechanisms. In the Sudano-Sahelian zone, cowpea support policies should simultaneously aim to maintain the biodiversity of cultivated crops, optimize the nutritional and agronomic benefits of cowpea, as well as its ecological services within cereal-based agroecosystems.

### Ethics

The authors declare that the experiments were carried out in compliance with the applicable national regulations.

### Declaration on the availability of data and models

The data supporting the results presented in this article are available on request from the author of the article.

### Declaration on Generative Artificial Intelligence and Artificial Intelligence Assisted Technologies in the Drafting Process.

The authors have used artificial intelligence-assisted technologies to translate from French to English.

### Author ORCIDs

SNS: https://orcid.org/0000-0002-4854-3958
CCD: https://orcid.org/0000-0001-6500-9194

### Authors' contributions

Conceptualisation: C.C.D. Methodology: All co-authors. Investigation: A.L.F; O.B.D; C.T.F; and D.M. Data analysis: C.C.D; A.L.F; O.B.D; C.T.F and D.M. Original version: C.C.D. Revision and editing: C.C.D; A.L.F; O.B.D; C.T.F; D.M; N.F.F. Acquisition of funds: C.C.D.

### Declaration of interest

The authors declare that they do not work for, advise, own shares in, or receive funds from any organisation that could benefit from this article, and declare no affiliation other than those listed at the beginning of the article.

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**References:**

Abade CLP., Pedrosa EMR., (...) Guimaraes LMP., 2016. Spatial variation of plant-parasitic nematodes in areas under cowpea cultivation after eradication of guava orchard. Nematropica 46, 172-187.

Ahemad M., Khan M.S., 2011. Insecticide-tolerant and plant-growth-promoting Rhizobium improves the growth of lentil (Lens esculentus) in insecticide-stressed soils. Pest Management. Science, 67: 423-429. https://doi.org/10.1002/ps.2080

Bado BV, Bationo A & Cescas MP., 2006. Assessment of cowpea and groundnut contributions to soil fertility and succeeding sorghum yields in the Guinean savannah zone of Burkina Faso (West Africa). Biology and Fertility of Soils 43, 171-176. doi.org/10.1007/s00374-006-0076-7.

Bagayoko M., Buerkert A., Lung G., Bationo A. & Römheld V., 2000. Cereal/legume rotation effects on cereal growth in Sudano-Sahelian West Africa: soil mineral nitrogen, mycorrhizae and nematodes. Plant and Soil 218 (1), 103-116. doi.org/10.1023/A:

Carvalho M., Castro, I., Moutinho-Pereira J., Correia C., Egea-Cortines M., Matos M., Rosa E., Carnide, V., & Lino-Neto T., 2019. Evaluating stress responses in cowpea under drought stress. Journal of Plant Physiology 241, 153001. https://doi.org/10.1016/j.jplph.2019.153001.

Cassman K.G., Whitney A.S. and Fox R.L.,1981. Phosphorus Requirements of Soybean and Cowpea as Affected by Mode of N Nutrition[1]. Agronomy Journal 73, 17-22. https://doi.org/10.2134/agronj1981.00021962007300010005x.

ECDAEA-UEMOA-CILSS, 2016. Regional Catalogue of Plant Species and Varieties, 1-109.

DAPSA, 2023. Rapport de l'Enquête Agricole Annuelle (EAA) 2022-2023. SENEGAL: DAPSA - Direction de l'analyse de la prévision et des statistiques agricoles.

FAO STAT, 2023. https://www.fao.org/faostat/fr/#data/QCL (23/06/2023).

FIDA, 2013. Projet d'Appui aux Filières Agricoles Supervision mission from 21 October to 01 November 2013, Republic of Senegal, 19 p.

Franke A.C., van den Brand G.J., Vanlauwe B. & Giller K.E., 2018. Sustainable intensification through rotations with grain legumes in Sub-Saharan Africa: A review. Agriculture Ecosystems & Environment 261, 172-185, doi.org/10.1016/j.agee.2017.09.029.

Hamidou F., Harou A., Achirou B. F., Halilou O., & Bakasso Y., 2018. Nitrogen Fixation by Groundnut and Cowpea for Productivity Improvement in Drought Conditions in the Sahel. Tropicultura (TSI) 36 (1).

He HM, LIU LN, Munir S, Bashir N.H, Wang Y, Yang J, LI Cy, 2019. Crop diversity and pest management in sustainable agriculture. Journal of Integrative Agriculture 18 (9), 1945-1952, ISSN 2095-3119. https://doi.org/10.1016/S2095-3119(19)62689-4.

ISRA, 1998. Annual Report 1997. ISRA, Dakar Senegal. 91 p.

Kouakou CK., 2004. Diversité génétique des variétés traditionnelles de niébé au Sénégal". DEA de Biologie Végétale dissertation, UCAD, http://bibnum.ucad.sn/viewer.php?c=mmoires&d=mems%5f2847.

Koussihouede H., Clermont-Dauphin C., Aholoukpe H., Barthès B., Chapuis-Lardy L., Jassogne L., Amadji G., 2020. Diversity and socio-economic aspects of oil palm agroforestry systems on the Allada plateau, southern Benin Agroforestry Systems. https://doi.org/10.1007/s10457-019-00360-0.

Lamichhane JR., You M.P., Laudinot V., Barbetti MJ., and Aubertot JN., 2020. Revisiting sustainability of fungicide seed treatments for field crops. Plant Disease 104 (3), 610-623.

Mbaye C.T., Hamet IT., 2016. In-depth gender-sensitive analysis of the cowpea value chain in Senegal". Senegal: ICCO cooperation.

Mbengue M., Tall L., Diakhate S., Founoune H., Diedhiou P. M., Diedhiou I., Trap J., Cournac L., & Clermont-Dauphin C., 2024. Intercropping Millet with Cowpea Reduces Pratylenchus Abundance and Improves Land Use Efficiency in a Low Input Sub-Saharan Cropping System. Journal of Soil Science and Plant Nutrition *24* (1), 1448-1459. https://doi.org/10.1007/s42729-024-01648-6.

Meijer SS, Catacutan D, Ajayi OC, Sileshi GW, Nieuwenhuis M., 2015. The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. International Journal of Agriculture Sustainability 13, 40-54. https://doi.org/10.1080/14735903.2014.912493.

Meynard J.M., Messéan A., Charlier A., Charrier F., Fares M., Le Bail M., Magrini M.B., Savini I. 2013. Barriers and levers to crop diversification: a study at farm and commodity chain level. Oilseeds and fats, Crops and Lipids 20 (4), 10 p.

Mokrini F., Viaene N., Waeyenberge L, (...) Moens M., 2019. Root lesion nematodes in cereal fields: importance, distribution, identification, and management strategies. Journal of Plant Diseases and Protection 126, 1-11. https:// doi. org/ 10. 1007/ s41348- 018- 0195-z.

Ouyang F., Su W., Zhang Y., Liu X., Su J., Zhang Q., Men X., Ju Q., Ge F., 2020. Ecological control service of the predatory natural enemy and its maintaining mechanism in rotation-intercropping ecosystem via wheat-maize-cotton, Agriculture, Ecosystems & Environment 301,107024, ISSN 0167-8809, https://doi.org/10.1016/j.agee.2020.107024.

Peñalver-Cruz A., Alvarez-Baca J.K., Alfaro-Tapia A. *et al.* 2019. Manipulation of Agricultural Habitats to Improve Conservation Biological Control in South America. Neotropical Entomology 48, 875-898. https://doi.org/10.1007/s13744-019-00725-1.

Reinprecht Y., Schram L., Marsolais F., Smith TH., Hill B., and Pauls KP., 2020. Effects of Nitrogen Application on Nitrogen Fixation in Common Bean Production. Front. Plant Sci. 11:1172. doi: 10.3389/fpls.2020.01172doi: 10.3389/fpls.2020.01172

Touré K., Mbaye T., Diatta P., Foncéka D., Faye I. & Mills B., 2022. Use of improved varieties in the groundnut basin of Senegal. Research note, 1-8.

Yang X., Delgado-Baquerizo M., Niu Y., Christie P., Chen J., Hu, H. and Chen Y., 2023. Optimizing cropping systems to close the gap between economic profitability and environmental health. New Phytologist 240, 2498-2512. https://doi.org/10.1111/nph.19310.