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Challenges and opportunities in French bean (*Phaseolus vulgaris* L.) production and Market outlet in Togo: prospects and future perspectives

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Background: French bean (*Phaseolus vulgaris* L.) cultivation plays a growing role in vegetable farming systems in Togo by contributing to both household food security and income generation. However, limited information exists on production systems, constraints, and farmers' varietal preferences, particularly across contrasting agroecological zones.

Methods: This study was conducted in two major French bean-producing districts in Togo, Danyi and Assoli, to assess cropping practices, input use, production constraints, consumption patterns, and farmers' preferred bean traits. A purposive sampling approach was used to select farmers across villages. Data were collected from 166 farmers through structured interviews and focus group discussions. Content analysis was used to quantify the frequency of constraints and trait preferences via relative frequency (RF) and the score of relative importance (SRI). Thematic analysis was applied to identify and interpret patterns and underlying themes in the farmers' narratives. Descriptive statistics, chi-square tests (Excel), and Pearson's correlation were also used.

Results: Significant differences were observed between districts in terms of labor use, cropping practices, and input access. French bean production is primarily market oriented, with over 80% of the harvest sold. The informal seed system dominated, with 54% of the farmers using their own farm-saved seeds and 41% purchasing from local markets. The key production constraints included diseases (RF = 45.06; SRI = 183), insect pests (RF = 45.68; SRI = 158.5), and erratic rainfall (RF = 14.20; SRI = 49), along with limited access to quality seeds, labor shortages, and market challenges. The preferred traits of farmers are high pod yield, long pods, disease, insect and drought tolerant varieties, and staggered harvesting, reflecting both market demands and production and harvest of fleshy, tender and green French bean pods.

Conclusions: Improving French bean production in Togo requires a multifaceted strategy, including the development and dissemination of improved, market-preferred, and environment-specific French bean varieties. Strengthening local seed systems, enhancing extension services, farmer organization support, and promotion of fair and transparent market systems will improve French bean

production. All these initiatives are essential for boosting productivity, household income, and food security among smallholder farmers in Togo.

KEYWORDS

snap bean production, smallholder farmers, production constraints, market access, varietal preferences

1 Introduction

The number of people facing or at risk of acute food insecurity increased from 135 million to 345 million in 79 countries, including Togo, in 2023 (World Food Programme, 2023). In Togo, the country's development plan has placed agriculture at the heart of its strategy. This suggests that sustained investments are being made in the agricultural sector, targeting several value chains. From a scientific point of view, legumes are important crops that help mitigate food insecurity (Nassary et al., 2019; Ayilara et al., 2022; Knez et al., 2024), nutrition and alleviate the impact of climate change (Jensen et al., 2012; Considine et al., 2017; Stagnari et al., 2017; Rani et al., 2019; Peoples et al., 2019; Dutta et al., 2022). The most important legumes grown in Togo in terms of production and cultivated area are soybean, groundnut, and cowpea (Direction des Statistiques Agricoles de l'Information et de la Documentation, 2014). The first two are mostly used either as oil production crops or as by products/direct animal feed. In contrast, cowpea, common bean and snap bean (also known as French bean in Africa) are exclusively used for human consumption in Togo, making them a privileged source of protein and income for smallholder farmers. Unlike other major crop legumes, French bean (*Phaseolus vulgaris* L.) is neglected in Togo despite their agronomic and nutritional potential.

Phaseolus vulgaris is one of the world's most promising crops for global food security (Nadeem et al., 2021; Kumar et al., 2022; Lisciani et al., 2024). Agronomically, French bean is an important crop for soil improvement in agriculture (Kumawat et al., 2022; Santos et al., 2019). Like other grain legumes, French bean assimilates atmospheric nitrogen through symbiotic bacteria (Mahmud et al., 2020; Kawaka, 2022; Soumare et al., 2020; Wilker et al., 2019), thereby reducing the need for nitrogen fertilizer inputs (Rodriguez et al., 2020). Intercropping French beans with cereals has the potential to increase nitrogen use efficiency (Jensen et al., 2020) and to significantly and sustainably contribute to increasing yield stability while stimulating biodiversity (Jensen and Carlsson, 2020). Reducing the inputs of fossil-based nitrogen fertilizer will contribute to establishing a more sustainable and environmentally friendly cropping system in Togo. As is the case in most West African countries, grain legumes are mostly intercropped with

cereals, suggesting that farmers are aware of the multiple advantages associated with their use in an intercropping system (Gebu, 2015; Cuartero et al., 2022; Fernández et al., 2022). For improving nutrient management, *P. vulgaris* provides important benefits to soil health (Hayat et al., 2014; Geraldo et al., 2022).

Bean grains and pods provide nutrients such as carbohydrates, proteins, dietary fiber, minerals, and vitamins (Hayat et al., 2014; Popoola et al., 2023). Reports have suggested that bean grains contain a rich variety of polyphenolic compounds (Lin et al., 2008; Mullins and Arjmandi, 2021) with multiple health benefits, such as decreased risks of chronic degenerative diseases (Mendes et al., 2023). Studies have reported a positive health effect of consuming bean grains by children and their potential to enhance the nutritional and nutraceutical properties of gluten-free foods (Boy et al., 2017; Finkelstein et al., 2019; Imam et al., 2024).

In Togo, according to the Ministry of Health and the World Health Organization (Ministère de la Santé du Togo, 2012), more than 6% of children under 5 years old are acutely malnourished, with a high prevalence of micronutrient deficiencies. Moreover, at the whole population level, UNICEF reported that 15 to 64% of women face a high prevalence of micronutrient deficiencies (UNICEF, 2018). These deficiencies could be reduced by exploiting the immense potential of French bean to contribute to food and nutritional security.

Unfortunately, despite its enormous potential, there is no information on the status of French bean production in Togo. Multiple factors have often been reported by extension agents and may constrain the sustainable production of high-quality French bean, commercialization, and consumption. The study aims to provide information on the French bean production status in the country and to contribute to the designing of appropriate strategies for the sustainable exploitation of French bean potential for food security.

2 Materials and methods

2.1 Research sites

A survey was conducted in the two main French bean production areas of Togo: Assoli in the Kara region and Danyi in the Plateaux region (Figure 1). Danyi, located in the southwestern part of the Plateaux region at an elevation of 755 meters above sea level, covers 396.3 km² and has approximately 40,240 inhabitants (INSEED, 2022). The topography consists of mountains, hills,

Abbreviations: ITRA, Institut Togolais de Recherche Agronomique; MCDAT, Ministère de la Coopération du Développement et de l'Aménagement du Territoire; DSID, Direction des Statistiques Agricoles de l'Information et de la Documentation.

valleys, and plateau. The climate is Guinean, with two rainy seasons and two dry seasons, and the vegetation consists mainly of forests interspersed with grasslands and scattered shrubs (Ministère de la Coopération du Développement et de l'Aménagement du Territoire, 2009a).

Assoli, located in the southern Kara region, covers 993 km² and has 66,394 inhabitants (INSEED, 2022). It is bordered by Kozah to the north, Tchaoudjo to the south, Bassar to the west, and Benin to the east. The Kara region, is crossed by the renowned Monts Alédjo mountain range and is characterized by plains, mountains, and highlands (Ministère de la Coopération du Développement et de l'Aménagement du Territoire, 2009b). The climate is Sudanese Guinean, with one rainy season and one dry season.

2.2 Sampling procedures and data collection

The survey was conducted by researchers, a local extension agent, and a translator when necessary. Purposive sampling was used to determine the number of farmers per village. The extension agents provided a list of villages that guided the selection of the most representative community in each district and assisted in contacting farmers for interview and preparing focus group discussions. From each district, villages were selected based on the importance of French beans in the community via statistics from the extension agency. A survey was conducted in November 2022, involving 166 bean growers in nine (Peoples et al., 2019) villages selected from Danyi and Assoli districts (Table 1). While Ewe was the main spoken language in the Danyi prefecture; in Assoli, two main languages, Kotokoli and Kabyè, were used in the studied interaction. Each respondent constituted the experimental unit.

Two strategies were used for data collection: individual interviews and focus group discussions (FGDs). Farmers were individually interviewed via an open-ended questionnaire at their homes or in their fields, depending on their availability. When necessary, a translator was used, mainly in the Danyi district, where some farmers did not speak the local language fluently. The focus group discussion involved more women in Assoli, whereas in Danyi, the group was more balanced. Information was collected on socio-demographic variables agronomic practices, and constraints related to production and commercialization. The respondents were asked to describe their agronomic practices, the characteristics of the French bean landraces cultivated, major production constraints, variety preferences, and issues related to commercialization and French bean business. Focus group discussions led to long debates around constraints, as each participant was allowed to express their opinion.

2.3 Data analysis

QGIS version 3.6 was used to generate the map of the study area. Descriptive statistics were employed to characterize the cropping system via Epidata version 3.1 and STATA version 13. The chi-square test was conducted via Excel to highlight associations between variables, and Pearson's correlation coefficient

was calculated via R version 4.4.1 to explore relationships between continuous variables.

For the ranking of production constraints and preferred traits, a mixed qualitative approach combining content and thematic analysis was used. Content analysis was applied to quantify the frequency of production constraints and preferred traits through relative frequency (RF) and the score of relative importance (SRI). To account for the multiple constraints and preferences mentioned by farmers, a ranking system was developed in which the relative importance (RI) of the constraint mentioned were assigned progressively smaller weights based on the ranking by the respondent to reflect their relative importance in the production process.

To calculate the score of relative importance (SRI) for each constraint, the following formula was used:

$$SRI = \sum (W_j * F_j) / i$$

where: SRI = score for relative importance of the constraint; W_j = weight assigned to the j th constraint on the basis of its rank position; F_j = frequency of occurrence of the j th constraint; i = study area

The weighted ranking approach ensures that more frequently mentioned constraints, particularly those listed first, are considered more important. Thematic analysis was employed to identify and interpret recurring patterns and themes in farmers' narratives, providing deeper insights into their perceptions, practices, and priorities.

3 Results

3.1 Perception of bean importance

Cropping system in the study area is dominated by crops such as cabbage, melon, pepper, and French beans. There was a significant association between the study area and the perception of bean importance [χ^2 (2, $N = 166$) = 8.61, $p = 0.05$]. French bean was considered a major crop by 85.85% of the respondents and a minor crop by 13.21% of the respondents in Danyi. In Assoli, 68.33% of the farmers rated beans as a major crop, whereas 31.67% considered beans a minor crop (Supplementary Table S1).

These crops are cultivated both during the rainy season and the off-season. Cereals are also produced in the area but to a lesser extent than vegetables. Notably, in Danyi, most farmers are involved in the production of avocado, coffee, and pineapples.

In Danyi District, farmers grow French beans throughout the year, with nearly five crops per year, making Danyi the nationally recognized area of green bean production in Togo. In contrast, in Alédjo district, farmers cultivate French beans exclusively during the rainy season.

3.2 Bean cropping operations

The main types of cropping equipment mentioned by the farmers were hoes (83% of the farmers), machetes (72.89% of the

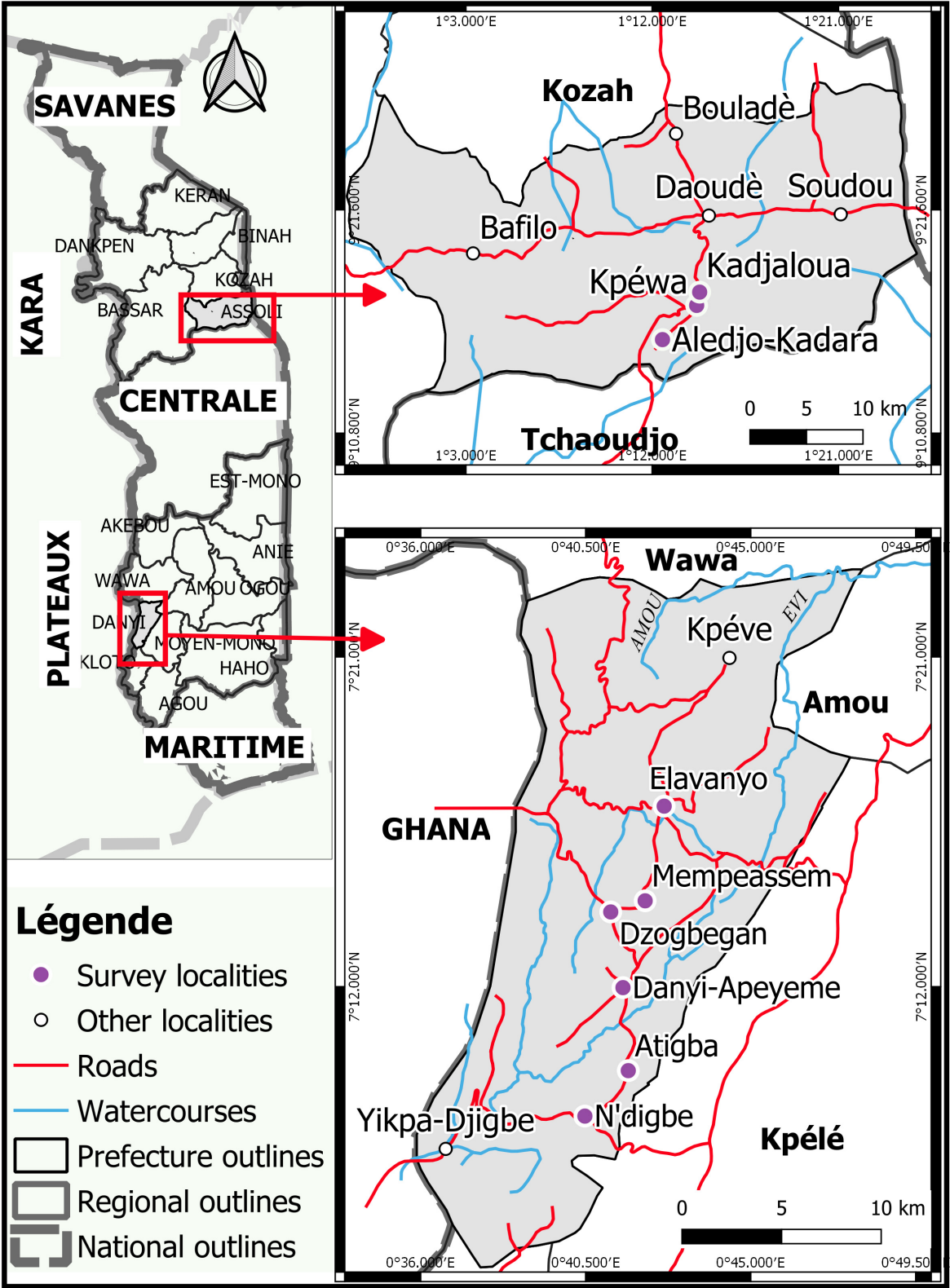


FIGURE 1
Map of the study area.

TABLE 1 Number of respondents and languages used in the two districts interaction and research sites.

Region	District	Village	Coordinates (°N, °E)	Language	Number of respondents
Kara	Assoli	KPEWA	9.2829° N 1.2358° E	Kotokoli & Kabyè	20
		KADJALOUA	9.29365° N 1.23823° E	Kotokoli & Kabyè	20
		ALEDJO-KADARA	7.2821° N 0.7106° E	Kotokoli & Kabyè	20
Plateaux	Danyi	ELAVANYO	9.2553° N 0.7106° E	Ewe	20
		MEMPEASSEM	7.2390° N 0.7020° E	Ewe	20
		DZOGBEGAN	7.2340° N 0.6863° E	Ewe	20
		APEYEME	7.1958° N 0.6919° E	Ewe	16
		ATIGBA	7.1608° N 0.6941° E	Ewe	15
		NIDIGBE	7.1409° N 0.6751° E	Ewe	15
		Total		166	

farmers), and digging hoes (72.29% of the farmers). In addition to this major equipment, pump engines were mentioned by 36.79% of the respondents in Danyi, whereas wood support was mentioned by 38.33% of the respondents in Assoli as important equipment for cropping beans. Other types of equipment mentioned in Danyi include atomizers for spraying insecticides, pipes, and watering cans; garden rakes, boots and gloves, basins, cords and scales (Supplementary Table S2).

Plowing is conducted on ridges or flat plowing after sufficient rain or watering, and sowing is immediately carried out at a rate of three seeds per hill. Weeding is mostly performed twice during crop vegetation in both areas, but in Aledjo, 20 and 18% of the respondents carry out weeding once or three times, respectively (Supplementary Table S3). A significant difference was found between the two districts for weeding [$X^2 (2, N = 166) = 22.85, p < 0.001$]. Fertilizer is applied twice in Danyi at 15 and 30 days after sowing, whereas in Assoli few farmers apply fertilizer once, at 15–20 days after sowing.

Most of the respondents (82.93%) grow beans under monoculture cropping system. Those who intercrop beans with other crops are primarily maize producers. Harvest begins 45 days after sowing for early maturing varieties and can last 3 to 4 weeks, occurring at a frequency of one harvest every 3 or 4 days. Typically, a farmer can harvest five times during one cropping cycle. Average size of cultivated land per crop per householder is 1.54 ha, with nearly a third part of that land (0.5 ha) dedicated to French bean production (Table 2). The land dedicated to bean production per household is slightly greater in Danyi (0.55 ha) than in Aledjo (0.45 ha).

3.3 Labor use for French bean cropping

Three types of labor are used by bean producers in the study area (Figure 2): casual workers (73.78%), family member labor (22.56%), and mutual labor support (3.66%). A comparison of the two districts revealed that casual workers are used more frequently by bean producers in Danyi district (97.78%) than in Aledjo district (44.59%). The chi-square test indicated a significant association between the type of labor used in bean production and the land area [$X^2 (2, N = 166) = 59.78, p < 0.001$]. Overall, labor utilization revealed that casual workers serve as primary source of labor for all cropping operations (plowing, sowing, weeding, and harvesting) in the Danyi district, whereas family members are more involved in all cropping operations in Assoli (Table 3).

A gender disaggregation analysis revealed that men predominantly participated in some key cropping operations as follows: 83% in plowing, 34% in sowing, 66% in weeding, 82% in transport, 35% in postharvest processing, and 67% in selling (Figure 2). Women outnumbered men and youth in sowing (54%), harvesting (63%), and postharvest processing (55%). Young household members, mostly children, had minimal involvement in all farm activities, except for selling where they represented only 2%. There was no significant difference between Assoli and Danyi district, except for transport and selling. In Danyi, men were more involved in transport (85%) and selling (88%), whereas in Assoli, women had greater participation in these activities, 49% and 56%, respectively in Danyi and Assoli (Supplementary Table S4).

TABLE 2 Farmers' experience in growing beans and land size dedicated to bean production.

Variable	SD	Min	Max	Mean		
				Plateaux	Kara	Study area
Age	11.98	1	68	38.09	39.01	38.51
Number of years growing beans	9.88	1	46	10.95	11.34	11.11
Number of dependents	6.31	0	60	6.21	7.38	6.72
Land area owns by a farmer (ha)	4.75	0.1	50	4.24	1.37	2.95
Land area for agriculture (ha)	1.53	0.08	8	1.88	1.11	1.54
Land area dedicated to bean production	1.53	0.03	19	0.45	0.55	0.50

SD, standard deviation; Min, minimum ; Max, maximum.

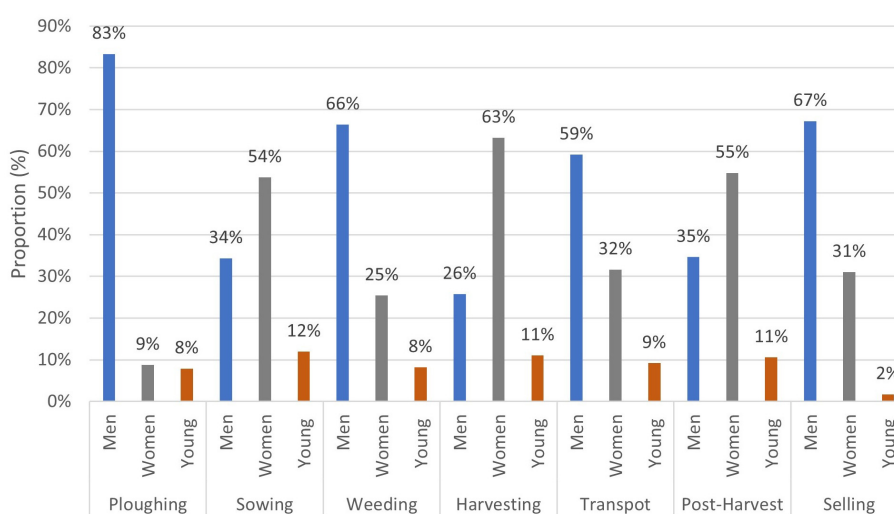


FIGURE 2
Gender-desegregated use of labor in the study area.

3.4 Cultivated accessions

Ten (10) ecotypes were reported by the respondents in the study area (Table 4). The ecotypes “Beure” and “Noire,” characterized by bush growth habits, are predominantly cultivated in Danyi (79.2%) and Assoli (67%) of the respondents. In Alledjo, the most popular ecotypes were “Koufoulmou” for 63.3% of the respondents, “Noire-grimpant” for 38.3%, and “Melange” for 30%, a climbing growth habit type. Various preferences are associated with these ecotypes, such as high yield, shining pods, staggering production, and disease resistance.

3.5 Seed sources and seed use

In the study areas, the respondents mostly save their own seeds (54% of the respondents) or purchase them from the local market (41%) (Figure 3). However, there was a significant difference between the two districts regarding the

seed source [χ^2 (2, $N = 166$) = 13.36; $p = 0.00125$]. Majority of the respondents in Danyi mentioned purchasing seeds from the market (53%) or saving their own seeds (44%), whereas the rest came from donations (2%). In Assoli, seeds are mostly from farmer own saved seeds (68%), whereas the rest come from purchases from local market (25%) or donations (7%).

3.6 Use of fertilizers and pesticides

The survey revealed that 59.51% of the respondents use chemical fertilizers, whereas 40.49% do not apply fertilizers (Supplementary Table S5). There was a significant difference between the two districts regarding the use of chemical fertilizers [χ^2 (1, $N = 166$) = 132.67; $p < 0.001$], as farmers in Danyi (98%) tend to use more fertilizers than those in Assoli (9.72%). The types of chemical fertilizers used in Danyi areas are NPK 15-15-15 (84.9% of respondents), urea 46% (23.6% of respondents) and, to a lesser extent, NPK 20-20-20, manure and organic liquid fertilizers (Supplementary Table S6). In Assoli, only NPK 15-15-15 (8.3% of

TABLE 3 Labor use in bean production operations.

Operation	Type of labor	Labor use (%)		
		Danyi	Alledjo	Study area
Plowing	Casual labor	94.51	52.70	75.76
	Family member labor	05.49	43.24	22.42
	Mutual labor support	00.00	04.05	01.82
Sowing	Casual labor	92.22	42.47	69.94
	Family member labor	07.78	54.79	28.83
	Mutual labor support	00.00	02.74	01.23
Weeding	Casual labor	93.33	41.67	70.37
	Family member labor	06.67	55.56	28.40
	Mutual labor support	00.00	02.78	01.23
Harvesting	Casual labor	89.01	45.21	69.51
	Family member labor	10.99	52.05	29.27
	Mutual labor support	00.00	02.74	01.22
Post-Harvest (drying, shelling, etc.)	Casual labor	57.30	36.99	48.15
	Family member labor	42.70	58.90	50.00
	Mutual labor support	00.00	04.11	01.85

TABLE 4 Characteristics of the cultivated ecotypes in the study area as described by farmers.

Ecotype	Growth Habit	Pod characteristics	Seed color	Preferred characteristics	Cultivated area	
					Danyi	Assoli
Beure	Bush	Long pods	Butter yellow	High yield, Shining pods,	79.2%	–
Noire	Bush	Short pods	Black	staggered production (6 harvests per cycle), disease resistance	67%	–
Noire grim pant	Climbing	Short pods	Black	Adapted to local environment	–	38.3%
Beure grim pant	Climbing	Short pods	Butter yellow	Adapted to local environment	–	13.3%
Métisse	Bush	Long, large and hard pods	Spotted color	High yield, large pods	29.2%	–
Métisses grim pant	Climbing	Short, curved and large pods	Spotted color	Large pods	–	10%
Label	Bush	Short pods	White	High yield, and sweat pods	1.9%	–
Koufoulmou	Climbing	Long pods	White	Late maturing, high yielding	–	63.3%
Kisemo	Climbing	Short pods	Red	Nice pods	–	18.3%
Melange	Climbing	Long and short pods	Mixture	Staggering production	3.8%	30.0%

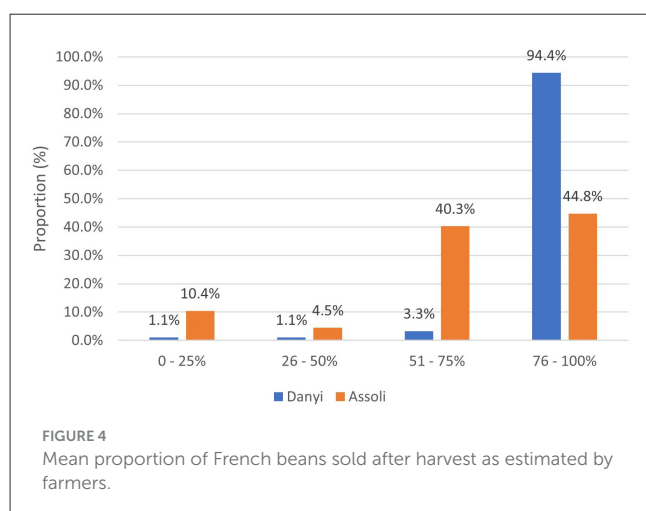
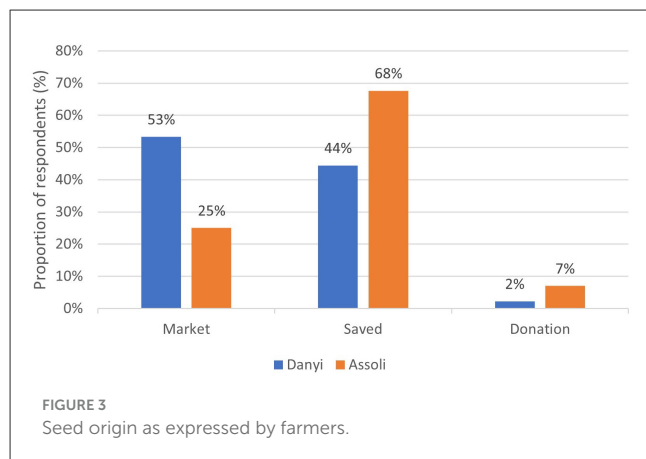
respondents) and urea 46% (3.3% of respondents) were mentioned as fertilizers used for French bean production.

Regarding the use of pesticides, the results revealed that, 69.62% of the respondents use pesticides (Supplementary Table S7). However, the comparison of the two districts revealed a significant difference [$\chi^2 (2, N = 166) = 93.64, p < 0.001$]. All the interviewed farmers (100%) in Danyi reported using pesticides, whereas only 28.36% of the interviewed farmers in Assoli used pesticides for pest control. The most frequently used pesticides in Danyi include insecticides (83% of farmers), fungicides (65% of farmers), and herbicides (6.6% of farmers). In Assoli, insecticides (21.67% of farmers) and acaricides (8.33%

of farmers) were the most frequently mentioned pesticides (Supplementary Table S8).

3.7 French bean consumption

Farmers were asked to estimate the shared proportion of their French bean harvest between consumption and sale during the last two harvests. The results revealed that 94.4% of the farmers in Danyi sold more than 75% of their harvest (Figure 4). In Assoli, 40.3 and 44.8% of the farmers sold 51–75% and 76–100% of their harvest respectively. Nearly 10% of the farmers in Assoli sold fewer



than 25% of their products, whereas only 1% of the respondents sold fewer than 25%. Farmers in Assoli had a greater consumption proportion than did the farmers in Danyi.

3.8 French bean commercialization

The respondents said that they sell their products per kilogram in Danyi and per round plastic basin (bowl) in Assoli to the local market resellers. In Danyi, the most important reseller mentioned was COVELET (63% of the respondents), which is a vegetable woman reseller cooperative. Resellers from Ghana were mentioned by 33.4% of the respondents in Danyi (Figure 5). In Alledjo, resellers mainly came from Bolla (72.9% of the respondents). Overall, four (Knez et al., 2024) French bean distribution channels were identified (Figure 6). The first two channels consist of farmers selling directly to traders from Ghana or Lome; and in the second and third channels, farmers sell to local resellers who sell the products to traders from either Lome or Ghana. The mean price of fresh French bean during the last two cropping seasons varied from 100 to 150 FCFA (0.17–0.25 USD) per kilogram. The minimum price in the rainy season (75 FCFA = 0.13 USD) was lower than the minimum price in the dry season (300 FCFA = 0.50 USD).

3.9 French bean production and trade constraints

The results indicated that diseases (RF = 45.06, SRI = 183), insects (RF = 45.68, SRI = 158.5) and erratic rainfall (RF = 14.20, SRI = 49) were the most important constraints mentioned by bean producers in the study area (Table 5). There was a difference in the perception of constraints between the two districts in the study. Diseases, insects, and erratic rainfall were the most important constraints in Danyi, whereas insects appeared to be the most significant constraints affecting farmer production in Assoli. Other two important constraints in terms of ranking were mentioned in Assoli including plant support (RF = 14.86, SRI = 30) and a lack labor (RF = 8.11, SRI = 15).

The three most important constraints related to French bean trading mentioned by farmers were poor sales in the rainy season (57% of the respondents in Danyi and 38% in Assoli), low prices (52% of the respondents in Danyi and 46% in Assoli) and issues related to transport (16% of the respondents in Assoli and 7% in Danyi). Other constraints mentioned by the respondents are pricing strategies, credit risk and weighing fraud (Figure 7).

3.10 Farmers preferred French bean product characteristics

Based on cultivated accessions, constraints in French bean production and marketability, farmers enumerated various preferences (Table 6). For Danyi district, the three most preferred characteristics are high pod yield (RF = 62.07%; Sc = 173.25), disease resistance (RF = 46.55, Sc = 73.2), and long pods (RF = 36.21%; Sc = 82.5). Other preferred characteristics include insect resistance (RF = 20.69%; Sc = 37.5), drought resistance (RF = 10.34%; Sc = 21.75), and staggered harvest (RF = 8.62%; Sc = 15). In Assoli, high pod yield (RF = 53.88%; SRI = 33), high market value (RF = 38.46%; Sc = 27) and insect resistance (RF = 38.46%; Sc = 22) were observed. With the same relative frequency, market value and long pods appeared to be more important than insect resistance and drought resistance.

In terms of seed color, butter yellow color was the most preferred color (RF = 62.50%; SRI = 225) in Danyi, whereas the white color (RF = 53.85%; SRI = 86) and red violet color (RF = 61.54%; SRI = 37.5) were the most mentioned colors in Assoli (Figure 8). The other colors mentioned by farmers were the spotted seed color in Danyi and the black seed color in both areas.

3.11 Relationships between factors

Various correlation was observed for key parameters (Table 7). Farming experience was positively correlated with age ($r = 0.56$, $p < 0.0001$) and negatively correlated with education level ($r = -0.21$, $p = 0.0195$). The mean bean land cultivated area and access to extension services were weakly positively correlated ($r = 0.19$, $p = 0.0192$). Access to extension services was positively correlated with access to financial services ($r = 0.17$, $p = 0.0286$) and membership in farmer organization ($r = 0.31$, $p = 0.0001$).

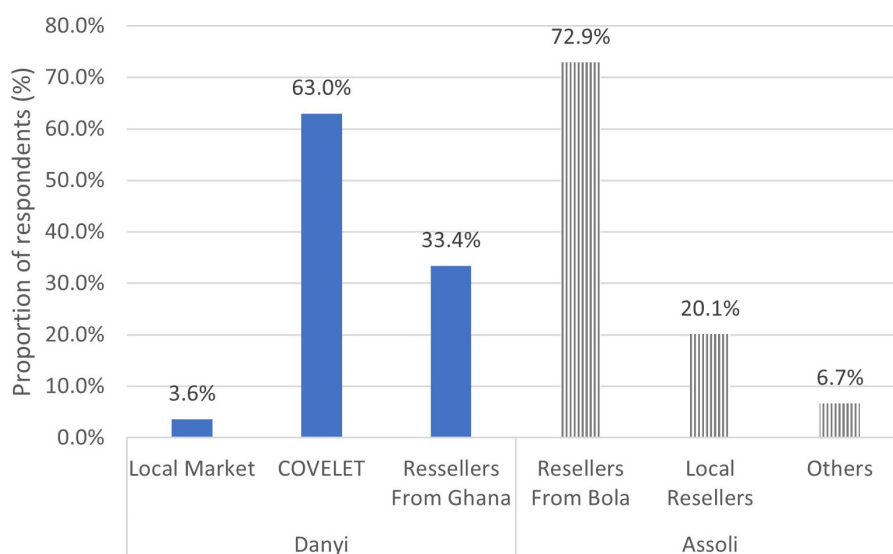


FIGURE 5
Types of buyers collecting bean pods from farmers.

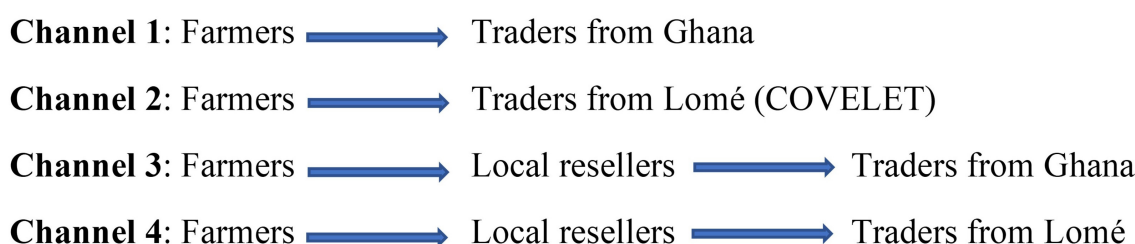


FIGURE 6
Trading channels in the study area.

Membership in farmer organization and access to financial services were positively correlated ($r = 0.21$, $p = 0.0106$).

4 Discussion

4.1 Cropping system

Crop sequences and management techniques from planting to harvest play major roles in determining both yield and quality (Waha et al., 2020; Qiu et al., 2022). In this study, vegetable dominated the cropping system in the study areas with cabbage, melon, pepper and French beans being the most common. Among these key crops French bean stands out as an important crop according to farmers. Farmers in Danyi also grow avocado, coffee and pineapple; whereas avocado, mango, and orange are commonly cultivated alongside beans in Assoli. The results in this study confirms that French bean cultivation is more important in Danyi than in Assoli.

Production equipment is largely basic in both study areas. Machetes are used for land clearing, whereas dabas and hoes

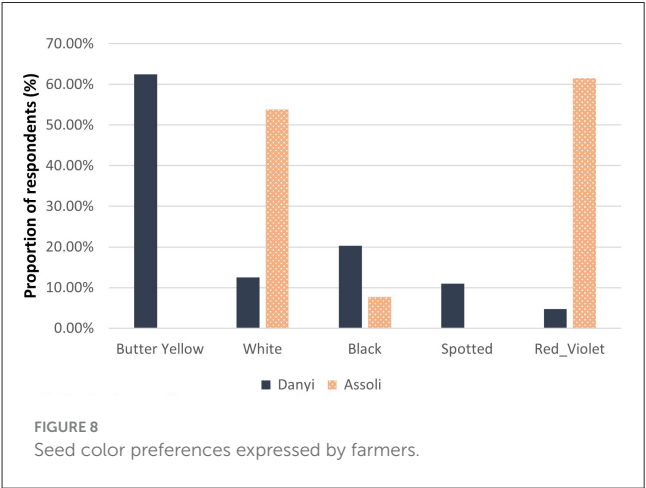
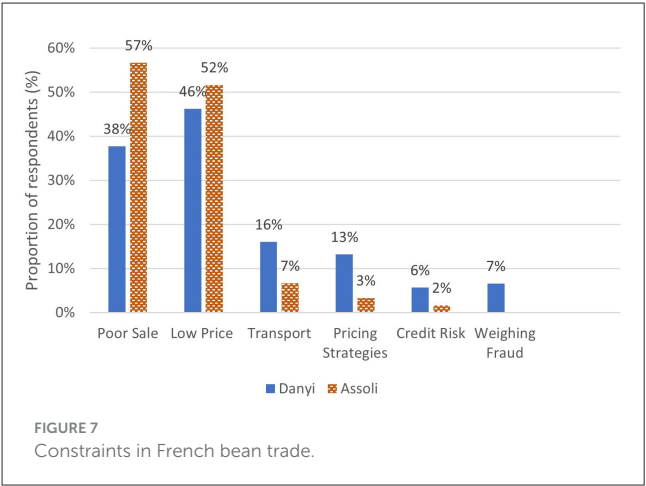
are used in plowing and weeding respectively, making French bean cultivation labor intensive. Similar patterns were observed in groundnut production in Togo (Banla et al., 2018). These findings highlight the need for greater investment in agricultural tools and mechanization if productivity improvements are to be achieved in the country (Daum and Birner, 2020). A notable difference between the two areas is the use of irrigation equipment, which is available only in Danyi during the off-season. This suggests that tailored interventions are needed to address the diverse conditions faced by smallholder bean producers in Togo.

The two main labor sources used in French bean production in Togo are hired labor and family labor. In Danyi, casual labor is predominantly used throughout cropping operations, whereas in Assoli, family labor is equally important. These results contrast with those of other countries where the use of hired labor in bean production is rare (Farrow and Muthoni Andriatsitohaina, 2020). The greater reliance on hired labor in Danyi is likely linked to multiple cropping seasons, increasing labor demand beyond what family members alone can provide. In both areas, family members are more involved in postharvest operations. Mutual

TABLE 5 Constraints mentioned by respondents at the cropping stage.

Constraints	Danyi		Assoli		Study area	
	RF*	SRI	RF	SRI	RF	SRI
Diseases	79.55	175.5	4.05	7.5	45.06	183
Insects	60.23	104.5	28.38	54	45.68	158.5
Erratic rainfall	20.45	35.5	6.76	13.5	14.20	49
Animals	11.36	21	1.35	3	6.79	24
Labor	3.41	5	8.11	15	5.56	20
Soil fertility	3.41	7.5	2.70	6	3.09	13.5
Staking	1.14	1.5	14.86	30	7.41	31.5
Quality seeds	2.27	6	2.70	4.5	2.47	10.5

*RF, relative frequency; SRI, score of relative importance.



labor support was reported only in Assoli. Gender disaggregation analysis revealed that men are mostly engaged in labor-intensive activities such as plowing, weeding, and transport, whereas women handle sowing, harvesting, and postharvest activities, which are less physically demanding. Similar patterns were observed in East Africa (Nakazi et al., 2017).

TABLE 6 Farmer preferred characteristics.

Traits	Danyi		Assoli	
	RF	SRI	RF	SRI
Germination vigor	1.72%	6	–	—
Biomass	1.72%	3	–	–
High pod yield	62.07%	173.25	53.88%	33
High market value	3.45%	3.75	38.46%	27
Disease resistance	46.55%	73.5	7.69%	3
Insects resistance	20.69%	37.5	38.46%	22
Good taste	3.45%	6.75	–	–
Long pod	36.21%	82.5	30.76	21
Long duration	1.72%	3	–	–
Short duration	12.07%	33	–	–
Bunch type	6.90%	15.75	–	–
Nice pods looking	6.90%	11.25	15.28	4.5
Drought rest	10.34%	21.75	30.76	9
Staggered product	8.62%	15	–	–
Shelf life	3.45%	4.5	15.38	6

RF, relative frequency; SRI, score of relative importance.

TABLE 7 Correlations between factors.

Correlation	<i>r</i>	<i>p</i> value
Farming experience – Age	0.56	<0.0001
Farming experience – Education level	–0.21	0.0195
Mean Bean land area cultivated – Access to Extension Service	0.19	0.0192
Access to extension services – Access to financial services	0.17	0.0286
Access to extension services – membership in farmer organization	0.31	0.0001
Membership in farmer organization – access to financial services	0.21	0.0106

r = Pearson's correlation.

With respect to varieties, farmers identified ten French bean ecotypes. In Danyi, *Beurre* and *Noire* are the most cultivated, appreciated for their high yields, shiny pods, and staggered production enabling multiple harvests. These two varieties are bush bean type varieties that are preferred for their market appeal despite their increased susceptibility to pests and diseases. In Alledjo, *Koufoulmou*, *Noire-grimpant*, and *Mélange*, all climbing types, are favored for their relatively high yields and prolonged production but require more days to maturity. However, Danyi farmers avoid climbing types because of their shorter pod length, rapid loss of freshness, and fibrous texture, making them less marketable. Similar diversity was reported at the village level in Benin by Missihoun et al. (2017). These varietal preferences reflect adaptations to differing agroecological conditions in Togo. Climbing beans are known to be more tolerant to abiotic and biotic stresses, whereas bush types require fewer production

inputs (Farrow and Muthoni Andriatsitohaina, 2020). These results suggest that breeding programs in Togo should prioritize environment-specific French bean varieties tailored to local farming systems and market preferences.

4.2 Production inputs

Access to inputs is a key factor in ensuring agricultural productivity and food security (Obayelu et al., 2021; Rogna, 2024). This study revealed differences in the use of agriculture inputs such as seeds, fertilizers, and pesticides between the two production study areas.

Regarding seeds, the study highlights the absence of a formal seed system for French bean production in Togo. In Danyi, farmers normally reserve specific rows of French bean fields during harvest for seed production for next season. The size of the plots reserved often depends on the market of fresh pods. Market accessibility due road inaccessibility can also push farmers to convert their production fields into seed production plots. Farmers interested in seed production in Alledjo often plant later in the rainy season to avoid damage on mature pods caused by heavy rains. Harvested seeds are stored in glass bottles or cotton bags and placed on wooden supports to protect them from humidity. Most farmers rely heavily on informal seed systems, either by using their own saved seed or purchasing seeds from an unofficial source which is consistent with findings from Breen et al. (2024) who reported that most smallholder legume farmers in Sub-Saharan Africa still depend on informal seed system. Nevertheless, by building on existing informal structures, strengthening bean seed systems holds significant potential for improving both food and seed security for smallholder farmers in Togo (Wattnem, 2016).

Fertilizers also play a critical role in agricultural productivity particularly in areas with declining soil fertility (Vanlauwe et al., 2023). This study revealed a sharp contrast in fertilizer use between the two districts. Farmers in Danyi use fertilizers extensively in bean cropping whereas in Assoli fertilizers are rarely applied. This could be explained by a lack of knowledge about fertilizer use in legume cultivation in Assoli, where farmers are more familiar with fertilizer application for cereal crops. A similar pattern was reported in cowpea production in Nigeria, where despite recognizing the benefits of fertilizers, farmers cited high costs, poor availability, and limited awareness as barriers to fertilizer use in legume cropping (Mohammed et al., 2020).

With fertilizers increasingly regarded as central to the future of sustainable agriculture (Venugopalan et al., 2022; Arora et al., 2024), the low use of chemical fertilizers in Assoli presents an opportunity to promote more sustainable practices. Furthermore, the continued production of beans without chemical fertilizers supports the idea that grain legumes can contribute to food and environmental security while maintaining long-term soil fertility (Meena and Lal, 2018; Yan et al., 2023). In Danyi, farmers frequently cross the border to purchase fertilizers better suited for their needs from Ghana, and some even source seeds from Burkina Faso. These practices reveal the existence of significant informal cross-border trade for agricultural inputs between Togo and neighboring countries, supporting the findings of Bouët et al. (2020) who

estimated that agricultural commodities make up most informally traded goods across sub-Saharan African borders.

4.3 French bean consumption and commercialization

French bean varieties are the most widely produced bean type in the study areas with less than 20% of the total production consumed by farmer households themselves. Green pods are typically consumed boiled and sometimes mixed with rice in local dishes. Approximately 30% of farmers also reported using French bean seeds as food, although they unanimously acknowledged the long cooking time and unpleasant taste which discourages frequent consumption of these seeds.

Despite slight differences in the consumption of green pods between study areas, more than 80% of the production is sold by farmers. A significant proportion of the harvest is sold either at local markets or to traders who often purchase directly from the fields, a practice likely motivated by farmers' need for immediate of money. Similar patterns were reported in other African countries by Muoni et al. (2019) and Agoyi et al. (2019) who reported that while farmers recognize the nutritional benefits of grain legumes, economic incentives often lead them to prioritize income generation over household consumption thereby favoring the sale of their legume produce. The price of French bean pods varied considerably between seasons. During the rainy season, a surplus of green pods leads to a noticeable decline in market prices compared to those harvested in dry season when prices rise due to limited supply (Iowa, 2025).

4.4 Production constraints, preferred characteristics and opportunities

Farmers often contend with multiple constraints linked to their environmental and socioeconomic conditions (Jellason et al., 2021). In this study diseases and insect pests were identified as the most significant biotic constraints by farmers. Commonly reported disease symptoms include leaf rust, leaf rot, wilting, defoliation, and premature plant death. Among insect pests, locusts, worms, and whiteflies were the most frequently mentioned. These findings align with those of previous studies, where insects and diseases were ranked as the primary biotic constraints in common bean production areas (Ronner and Giller, 2013; Laizer et al., 2019).

Farmers demonstrated good awareness for these biotic stresses and often resorted to pesticide use, especially in Danyi where pesticide application was more prevalent than in Assoli. The most frequent insecticides used were K-Optimal, Sauveur, Cypercal, and Emacot, while fungicides included Condifor, Topsin, Callifor, SIDIME, Mancozeb, and Ivory (see Supplementary Material 3). Other key constraints include erratic rainfall, scarcity of wooden staking for climbing beans, animal damage (particularly in Danyi) and shortage of labor (notably in Alledjo).

Farmers reported several challenges in French bean business. The most challenging issue was price set by aggregators and traders often leading to unsatisfactory farm-gate prices. Others

constraints include payment defaults, credit risks, and weighing fraud. Farmers keep complaining of being unpaid after selling on credit and manipulatively inaccurate weighing practices by buyers. These constraints highlight the urgent need of restructuring the French bean market for fair pricing mechanisms and transparent marketing systems to improve farmer livelihoods in Togo.

Farmers' trait preferences for French bean are closely related to production constraints. The most preferred traits were high pod yield, disease resistance, and long pods. Other valued characteristics included insect resistance, drought tolerance, and staggered harvest capacity. Similar preferences were reported in bean production in Cameroon by Andukwa and Ntonifor (2021). One unwanted trait consistently mentioned by farmers was the presence of fibers in pods which affects both culinary and market quality. Consumers generally prefer tender and juicy pods as fibrous pods are tough and unpleasant to eat. These findings emphasize the importance of developing French bean varieties that combine tolerance to biotic and abiotic stresses with market and consumer preferred traits to support sustainable agriculture and improve food security in Togo.

The study also revealed that farmers receiving extension support were more likely to access financial services and membership in farmer organizations increased access to both extension and financial services. Key barriers limiting the adoption of improved French bean practices included a lack of farmer organization membership, limited access to quality seeds, insufficient extension services, and restricted financial access. Strong linkage between extension services and financial access through farmer groups and integrated policies are needed. Government should actively promote farmer cooperatives and strengthen public extension services (Aseete et al., 2023) to indirectly enhance farmers' access to financial resources and technical support.

5 Conclusion

This study provides valuable insights into the current state of French bean production systems in Togo with focus on districts of Danyi and Assoli. The results revealed notable differences in labor use, production practices, and access to inputs between the two study areas. Despite seed quality and availability limitation informal seed system remains the primary source of planting material for farmers in both districts. French beans are cultivated mainly for market purposes with farmers consuming only a small share of their harvest.

Major constraints to French bean production include pests, diseases and marketing challenges which limit both productivity and profitability. The study also highlighted farmers' preferred traits in French bean varieties which are largely shaped by market demands and production constraints. High yield, long pods, resistance to pests and diseases, drought tolerance and staggered harvest have emerged as the most potential traits.

Improving French bean production in Togo requires a multifaceted strategy involving the development of improved, market-preferred, environment-specific French bean varieties, strengthening local seed systems, enhancement extension services and farmer organizations, and the establishment of fair, transparent market systems to safeguard farmers' incomes and livelihoods.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The requirement of ethical approval was waived by Institut Togolais de Recherche Agronomique (ITRA) for the studies involving humans because No sensitive data were collected, and the study did not involve any procedures requiring formal ethical review under the guidelines of the Institut Togolais de Recherche Agronomique (ITRA), therefore, no formal ethics approval procedures was mandated for this study. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board also waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because The study did not involve any procedures requiring formal written consent under the guidelines of the Institut Togolais de Recherche Agronomique (ITRA), therefore, no formal written consent procedures was mandated for this study.

Author contributions

EB: Methodology, Formal analysis, Supervision, Visualization, Conceptualization, Project administration, Resources, Writing – original draft, Funding acquisition, Investigation, Validation, Writing – review & editing, Data curation. AS: Data curation, Methodology, Investigation, Writing – review & editing, Resources, Formal analysis. OU: Methodology, Writing – review & editing, Visualization, Conceptualization, Validation, Resources, Formal analysis. MT-K: Validation, Data curation, Visualization, Writing – original draft, Methodology, Formal analysis, Investigation, Software. EA: Resources, Investigation, Writing – review & editing, Data curation, Validation, Visualization, Methodology. KP: Writing – review & editing, Methodology, Conceptualization, Visualization, Validation. BT: Validation, Methodology, Investigation, Funding acquisition, Conceptualization, Writing – review & editing, Writing – original draft. LB: Conceptualization, Resources, Project administration, Writing – review & editing, Funding acquisition, Supervision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

References

- Agoyi, E. E., Kafoutchoni, K. M., Sossou, H. S., Allagbé, A. M. H., Assogbadjo, A. E., Sinsin, B., et al. (2019). Leguminous vegetables, production and marketing in southern Benin. *Int. J. Agron. Agric. Res.* 15, 30–41. Retrieved from <https://innspub.net/leguminous-vegetables-production-and-marketing-in-southern-benin>
- Andukwa, H. A., and Ntonifor, N. N. (2021). Farmers' knowledge and perception on common beans production constraints and their mitigation methods in the humid rainforest and Highland Savanna of Cameroon. *J. Exp. Agric. Int.* 43, 70–85. doi: 10.9734/jeai/2021/v43i230648
- Arora, P. K., Tripathi, S., Omar, R. A., Chauhan, P., Sinhal, V. K., Singh, A., et al. (2024). Next-generation fertilizers: the impact of bionanofertilizers on sustainable agriculture. *Microb Cell Fact.* 23:254. doi: 10.1186/s12934-024-02528-5
- Asete, P., Barkley, A., Katungi, E., Ugen, M. A., and Birachi, E. (2023). Public-private partnership generates economic benefits to smallholder bean growers in Uganda. *Food Security* 15, 201–218. doi: 10.1007/s12571-022-01309-5
- Ayilara, M. S., Abberton, M., Oyatomi, O. A., Odeyemi, O., and Babalola, O. O. (2022). Potentials of underutilized legumes in food security. *Front. Soil Sci.* 2:1020193. doi: 10.3389/fsoil.2022.1020193
- Banla, E. M., Dzidzienyo, D. K., Beatrice, I. E., Offei, S. K., Tongoona, P., Desmae, H., et al. (2018). Groundnut production constraints and farmers' trait preferences: a pre-breeding study in Togo. *J. Ethnobiol. Ethnomed.* 14, 1–14. doi: 10.1186/s13002-018-0275-y
- Bouët, A., Cissé, B., and Traoré, F. (2020). "Informal cross-border trade in Africa," in *Africa agriculture trade monitor*, eds. A. Bouët, S. P. Odjo, and C. Zaki. Washington (DC): International Food Policy Research Institute (IFPRI), 119–48. doi: 10.2499/9780896293908_05
- Boy, E., Haas, J. D., Petry, N., Cercamondi, C. I., Gahutu, J. B., Mehta, S., et al. (2017). Efficacy of iron-biofortified crops. *Afr. J. Food Agric. Nutr. Dev.* 17, 11879–92. doi: 10.18697/ajfand.78.HarvestPlus03
- Breen, C., Ndlovu, N., McKeown, P. C., and Spillane, C. (2024). Legume seed system performance in sub-Saharan Africa: barriers, opportunities, and scaling options. A review. *Agron. Sustain. Dev.* 44:20. doi: 10.1007/s13593-024-00956-6
- Considine, M. J., Siddique, K. H., and Foyer, C. H. (2017). Nature's pulse power: legumes, food security and climate change. *J. Exp. Bot.* 68, 1815–8. doi: 10.1093/jxb/erx099
- Cuartero, J., Pascual, J. A., Vivo, J. M., Özbolat, O., Sanchez-Navarro, V., Egea-Cortines, M., et al. (2022). A first-year melon/cowpea intercropping system improves soil nutrients and changes the soil microbial community. *Agric. Ecosyst. Environ.* 328:107856. doi: 10.1016/j.agee.2022.107856
- Daum, T., and Birner, R. (2020). Agricultural mechanization in Africa: myths, realities and an emerging research agenda. *Glob. Food Sec.* 26:100393. doi: 10.1016/j.gfs.2020.100393
- Direction des Statistiques Agricoles de l'Information et de la Documentation (2014). Principales caractéristiques de l'agriculture togolaise : 4^e recensement national de l'agriculture 2011–2014 (Vol. 4, module de base). *DSID*.
- Dutta, A., Trivedi, A., Nath, C. P., Gupta, D. S., and Hazra, K. K. (2022). A comprehensive review on grain legumes as climate-smart crops: challenges and prospects. *Environ. Chall.* 7:100479. doi: 10.1016/j.envc.2022.100479
- Farrow, A., and Muthoni Andriatsitohaina, R. (2020). *Atlas of Common Bean Production in Africa, 2nd Edn.* Pan-Africa Bean Research Alliance (PABRA); International Center for Tropical Agriculture (CIAT). Available online at: <https://alliancebioversityciat.org/publications-data/atlas-common-bean-production-africa-2nd-ed>
- Fernández, J. A., Ayastuy, M. E., Belladonna, D. P., Comezaña, M. M., Contreras, J., Maria Mourão, I., et al. (2022). Current trends in organic vegetable crop production: practices and techniques. *Horticulturae* 8:893. doi: 10.3390/horticulturae8100893
- Finkelstein, J. L., Mehta, S., Villalando, S., Mundo-Rosas, V., Luna, S. V., Rahn, M., et al. (2019). A randomized feeding trial of iron-biofortified beans in school children in Mexico. *Nutrients* 11:381. doi: 10.3390/nu11020381
- Gebru, H. (2015). A review on the comparative advantages of intercropping to mono-cropping system. *J. Biol. Agric. Healthcare* 5, 1–13. Retrieved from <https://iiste.org/Journals/index.php/JBAH/article/view/22307>
- Geraldo, R., Santos, C. S., Pinto, E., and Vasconcelos, M. W. (2022). Widening the perspectives for legume consumption: the case of bioactive non-nutrients. *Front. Plant Sci.* 13:56. doi: 10.3389/fpls.2022.772054
- Hayat, I., Ahmad, A., Masud, T., Ahmed, A., and Bashir, S. (2014). Nutritional and health perspectives of beans (*Phaseolus vulgaris* L.): an overview. *Crit. Rev. Food Sci. Nutr.* 54, 580–92. doi: 10.1080/10408398.2011.596639
- Imam, Y. T., Ironi, E. A., Awoyale, W., Ajani, E. O., and Alamu, E. O. (2024). Application of legumes in the formulation of gluten-free foods: functional, nutritional and nutraceutical importance. *Front. Sustain. Food Syst.* 8:1251760. doi: 10.3389/fsufs.2024.1251760
- INSEED (2022). Cinquième recensement général de la population et de l'habitat (RGPH-5). *Bureau central de recensement*. 108.
- Iowa, PBS (2025). *Overproduction leads to low prices*. Iowa PBS Available online at: <https://www.iowapbs.org/iowapathways/artifact/1605/overproduction-leads-low-prices> [Accessed April 18, 2025].

- Jellason, N. P., Robinson, E. J., Chapman, A. S., Neina, D., Devenish, A. J., Po, J. Y., et al. (2021). systematic review of drivers and constraints on agricultural expansion in sub-Saharan Africa. *Land* 10:332. doi: 10.3390/land10030332
- Jensen, E. S., and Carlsson, G. (2020). Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: a global-scale analysis. *Agron. Sustain. Dev.* 40, 1–9. doi: 10.1007/s13593-020-0607-x
- Jensen, E. S., Carlsson, G., and Hauggaard-Nielsen, H. (2020). Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: a global-scale analysis. *Agron. Sustain. Dev.* 40, 1–9.
- Jensen, E. S., Peoples, M. B., Boddey, R. M., Gresshoff, P. M., Hauggaard-Nielsen, H., Alves, J. R., et al. (2012). Legumes for mitigation of climate change and the provision of feedstock for biofuels and biorefineries: a review. *Agron. Sustain. Dev.* 32, 329–64. doi: 10.1007/s13593-011-0056-7
- Kawaka, F. (2022). Characterization of symbiotic and nitrogen fixing bacteria. *AMB Express* 12:99. doi: 10.1186/s13568-022-01441-7
- Knez, M., Ranić, M., and Gurinović, M. (2024). Underutilized plants increase biodiversity, improve food and nutrition security, reduce malnutrition, and enhance human health and well-being. Let's put them back on the plate! *Nutr. Rev.* 82, 1111–24. doi: 10.1093/nutrit/nuad103
- Kumar, S., Bamboriya, S. D., Rani, K., Meena, R. S., Sheoran, S., Loyal, A., et al. (2022). "Grain legumes: a diversified diet for sustainable livelihood, food, and nutritional security," in *Advances in legumes for sustainable intensification*. eds. R. S. Meena, G. Yadav M. K. Jhariya (Cambridge: Academic Press), 157–78. doi: 10.1016/B978-0-323-85797-0.00007-0
- Kumawat, A., Bamboriya, S. D., Meena, R. S., Yadav, D., Kumar, A., Kumar, S., et al. (2022). "Legume-based inter-cropping to achieve the crop, soil, and environmental health security" in *Advances in legumes for sustainable intensification*. R. S. Meena, G. Yadav, M. K. Jhariya (Cambridge: Academic Press), 307–28. doi: 10.1016/B978-0-323-85797-0.00005-7
- Laizer, H. C., Chacha, M. N., and Ndadikemi, P. A. (2019). Farmers' knowledge, perceptions and practices in managing weeds and insect pests of common bean in northern Tanzania. *Sustainability* 11, 4076–4087. doi: 10.3390/su11154076
- Lin, L. Z., Harnly, J. M., Pastor-Corrales, M. S., and Luthria, D. L. (2008). The polyphenolic profiles of common bean (*Phaseolus vulgaris* L.). *Food Chem.* 107, 399–410. doi: 10.1016/j.foodchem.2007.08.038
- Lisciani, S., Marconi, S., Le Donne, C., Camilli, E., Aguzzi, A., Gabrielli, P., et al. (2024). Legumes and common beans in sustainable diets: nutritional quality, environmental benefits, spread and use in food preparations. *Front. Nutr.* 11:1385232. doi: 10.3389/fnut.2024.1385232
- Mahmud, K., Makaju, S., Ibrahim, R., and Missaoui, A. (2020). Current progress in nitrogen fixing plants and microbiome research. *Plants* 9:97. doi: 10.3390/plants9010097
- Meena, R. S., and Lal, R. (2018). "Legumes and sustainable use of soils," in *Legumes for soil health and sustainable management*. (New York: Springer) 1–31. doi: 10.1007/978-981-13-0253-4_1
- Mendes, V., Niforou, A., Kasdagli, M. I., Ververis, E., and Naska, A. (2023). Intake of legumes and cardiovascular disease: a systematic review and dose-response meta-analysis. *Nutr. Metab. Cardiovasc. Dis.* 33, 22–37. doi: 10.1016/j.numecd.2022.10.006
- Ministère de la Coopération du Développement et de l'Aménagement du Territoire (2009a). Monographie de la préfecture de Danyi. République Togolaise.
- Ministère de la Coopération du Développement et de l'Aménagement du Territoire (2009b). Monographie de la préfecture d'Assoli. Ministère de la Coopération du Développement et de l'Aménagement du Territoire.
- Ministère de la Santé du Togo, Organisation mondiale de la Santé (2012). Rapport final de l'enquête STEPS Togo (2010). *Organisation mondiale de la Santé*.
- Missihoun, A. A., Milognon, H. W., Montcho, D., Agbo, R. I., Sedah, P., Agbangla, C., et al. (2017). Diversité variétale et gestion paysanne des haricots cultivés du genre *Phaseolus* cultivés au Centre et au Sud Bénin (en Afrique de l'Ouest). *J. Appl. Biosci.* 118, 1187–28.
- Mohammed, S. B., Mohammad, I. F., Pangirayi, T. B., Vernon, G., Dzidzienyo, D. K., Umar, M. L., et al. (2020). Farmers' knowledge, perception, and use of phosphorus fertilization for cowpea production in Northern Guinea Savannah of Nigeria. *Heliyon* 6:e05226. doi: 10.1016/j.heliyon.2020.e05207
- Mullins, A. P., and Arjmandi, B. H. (2021). Health benefits of plant-based nutrition: focus on beans in cardiometabolic diseases. *Nutrients* 13:519. doi: 10.3390/nu13020519
- Muoni, T., Barnes, A. P., Öborn, I., Watson, C. A., Bergkvist, G., Shiluli, M., et al. (2019). Farmer perceptions of legumes and their functions in smallholder farming systems in East Africa. *Int. J. Agric. Sustain.* 17, 205–18. doi: 10.1080/14735903.2019.1609166
- Nadeem, M. A., Yeken, M. Z., Shahid, M. Q., Habyarimana, E., Yilmaz H., Alsaleh A., et al. (2021). Common bean as a potential crop for future food security: an overview of past, current and future contributions in genomics, transcriptomics, transgenics and proteomics. *Biotechnol. Biotechnol. Equip.* 35, 759–787. doi: 10.1080/13102818.2021.1920462
- Nakazi, F., Njuki, J., Ugen, M. A., Aseete, P., Katungi, E., Birachi, E., et al. (2017). Is bean really a women's crop? Men and women's participation in bean production in Uganda. *Agric. Food Secur.* 6, 1–11. doi: 10.1186/s40066-017-0102-z
- Nassary, E. K., Baijuka, F. P., and Ndadikemi, P. A. (2019). Sustainable intensification of grain legumes optimizes food security on smallholder farms: a review. *Int. J. Agric. Biol.* 1–17. doi: 10.17957/ijab/15.1254
- Obayelu, A. E., Arowolo, A. O., Oyawole, F. P., Aminu, R. O., and Ibrahim, S. B. (2021). "The linkage between agricultural input subsidies, productivity, food security, and nutrition," in *Food security and nutrition*. (Cambridge: Academic Press), 107–24. doi: 10.1016/B978-0-12-820521-1.00005-8
- Peoples, M. B., Hauggaard-Nielsen, H., Huguenin-Elie, O., Jensen, E. S., Justes, E., Williams, M., et al. (2019). "The contributions of legumes to reducing the environmental risk of agricultural production," in *Agroecosystem diversity*. (Cambridge: Academic Press), 123–43. doi: 10.1016/B978-0-12-811050-8.00008-X
- Popoola, J. O., Ojuederie, O. B., Aworunse, O. S., Adelekan, A., Oyelakin, A. S., Oyesola, O. L., et al. (2023). Nutritional, functional, and bioactive properties of African underutilized legumes. *Front. Plant Sci.* 14:1105364. doi: 10.3389/fpls.2023.1105364
- Qiu, B., Hu, X., Chen, C., Tang, Z., Yang, P., Zhu, X., et al. (2022). Maps of cropping patterns in China during 2015–2021. *Sci. Data* 9:479. doi: 10.1038/s41597-022-01589-8
- Rani, K., Sharma, P., Kumar, S., Wati, L., Kumar, R., Gurjar, D. S., et al. (2019). "Legumes for sustainable soil and crop management" in *Sustainable management of soil and environment*. (Singapore: Springer Nature Singapore), 193–215. doi: 10.1007/978-981-13-8832-3_6
- Rodriguez, C., Carlsson, G., Englund, J. E., Flöhr, A., Pelzer, E., Jeuffroy, M. H., et al. (2020). Grain legume-cereal intercropping enhances the use of soil-derived and biologically fixed nitrogen in temperate agroecosystems: a meta-analysis. *Eur. J. Agron.* 118:126077. doi: 10.1016/j.eja.2020.126077
- Rogna, M. (2024). The contribution of agricultural inputs in reducing child stunting. *Agric. Food Secur.* 13:49. doi: 10.1186/s40066-024-00503-2
- Ronner, E., and Giller, K. E. (2013). Understanding farmer knowledge and site factors in relation to soil fertility management in common bean production in Tanzania. *Field Crops Res.* 149, 1–13.
- Santos, M. S., Nogueira, M. A., and Hungria, M. (2019). Microbial inoculants: reviewing the past, discussing the present and previewing an outstanding future for the use of beneficial bacteria in agriculture. *AMB Express.* 9, 1–22. doi: 10.1186/s13568-019-0932-0
- Soumare, A., Diedhiou, A. G., Thuita, M., Hafidi, M., Ouhdouch, Y., Gopalakrishnan, S., et al. (2020). Exploiting biological nitrogen fixation: a route towards a sustainable agriculture. *Plants* 9:1011. doi: 10.3390/plants9081011
- Stagnari, F., Maggio, A., Galieni, A., and Pisante, M. (2017). Multiple benefits of legumes for agriculture sustainability: an overview. *Chem. Biol. Technol. Agric.* 4, 1–13. doi: 10.1186/s40538-016-0085-1
- UNICEF (2018). UNICEF Annual Report (2017). United Nations Children's Fund.
- Vanlauwe, B., Amede, T., Bationo, A., Bindraban, P., Breman, H., Cardinael, R., et al. (2023). Fertilizer and soil health in Africa: The role of fertilizer in building soil health to sustain farming and address climate change.
- Venugopalan, V. K., Nath, R., and Chandran, S. (2022). Smart fertilizers—a way ahead for sustainable agriculture. *J. Plant Nutr.* 45, 2068–76. doi: 10.1080/01904167.2022.2046065
- Waha, K., Dietrich, J. P., Portmann, F. T., Siebert, S., Thornton, P. K., Bondeau, A., et al. (2020). Multiple cropping systems of the world and the potential for increasing cropping intensity. *Glob. Environ. Change.* 64:102131. doi: 10.1016/j.gloenvcha.2020.102131
- Wattmeh, T. (2016). Seed laws, certification and standardization: outlawing informal seed systems in the Global South. *J. Peasant Stud.* 43, 850–67. doi: 10.1080/03066150.2015.1130702
- Wilker, J., Navabi, A., Rajcan, I., Marsolais, F., Hill, B., Torkamaneh, D., et al. (2019). Agronomic performance and nitrogen fixation of heirloom and conventional dry bean varieties under low-nitrogen field conditions. *Front. Plant Sci.* 10:952. doi: 10.3389/fpls.2019.00952
- World Food Programme (2023). *Global Report on Food Crises*. Available online at: <https://www.fsplatform.org/sites/default/files/resources/files/GRFC2023-hi-res.pdf> (Accessed November 15, 2024).
- Yan, Z., Zhou, J., Liu, C., Jia, R., Mganga, K. Z., Yang, L., et al. (2023). Legume-based crop diversification reinforces soil health and carbon storage driven by microbial biomass and aggregates. *Soil Tillage Res.* 234:105848. doi: 10.1016/j.still.2023.105848