Food and Humanity 5 (2025) 100687

Contents lists available at ScienceDirect

Food and Humanity

journal homepage: www.editorialmanager.com/foohum/journal_overview.html

Why do food crop farmers have potential, but still under-produce pulses in Ghana?

Daniel Adu Ankrah [a], Nana Afranaa Kwapong [b,*], Fred Fosu Agyarko [c], Enoch Kwame Tham-Agyekum [d], Seth Awuku Manteaw [c]

[a] University of Ghana, Department of Agricultural Extension, School of Agriculture, College of Basic and Applied Science (CBAS), P. O. Box LG 68, Legon, Accra, Ghana
[b] University of Lincoln, Lincoln Institute for Agri-food Technology, United Kingdom
[c] Council for Scientific and Industrial Research (CSIR), Institute for Scientific and Technological Information (INSTI), P. O. Box M32, Accra, Ghana
[d] Kwame Nkrumah University of Science and Technology (KNUST), Department of Agricultural Economics, Extension and Agribusiness, P.M.B Kumasi, Ashanti Region, Ghana

ARTICLE INFO

Keywords:
Ghana Living Standards Survey
Farmers
Pulses production
Ghana

ABSTRACT

Pulses are generally "orphan crops" that remain under-produced and less targeted in most countries south of the Saharan specifically, Ghana, even though they contribute immensely to protein needs and integrates well into climate smart agriculture (CSA). Pulses in this study refers to underutilized African pulse crops such as groundnuts/peanut, and beans (small beans, bambara beans, broad beans/peas (cowpeas). Pulses constitute an important food security crop, and most re-assuring, farmers have the potential to produce optimum yields. However, achieving potential production has remained a mirage for several decades. The tendency of smallholder farmers producing pulses as well as the drivers that hinder production potentials demand attention and policy action. The neglect thwarts the attainment of the Sustainable Development Goal (SDG)– 2 of zero hunger. Especially given the emerging importance of the potential benefits in investing in orphan pulse crops, especially in relation to CSA, food sovereignty, and rural development. Relying on the Ghana Living Standards Survey Seventh round (GLSS 7), this article answers dual research questions of: What is the probability of a smallholder producing underutilized African pulse crops? What factors hinder production? Using classical count regression and zero inflated regression estimations, the findings show that socioeconomic, geography, and demographic factors hinder production. Specifically, households in the middle belt (Ashanti, Bono East, Bono, Ahafo regions) are more unlikely to produce a tonne of pulse annually relative to households in the southern sector (Greater Accra, Volta, Oti, Eastern, Central, Western and Western North regions). Farming households in the northern belt (Upper West, Savannah, Northern, North-East, Upper East regions) have a greater affinity toward pulses production. Urban households are less likely to produce pulses in comparison to rural households. Household heads with no formal education and low English literacy show a higher probability of producing pulses. Poor households are more likely to produce pulses. The middle age and aged farm households show a higher probability to produce pulses compared to the youth. Efforts by agricultural extension and advisory services are encouraged to address hindrances that affect pulses production along co-constituted axes of socioeconomic, spatial, and demographic factors to boost underutilized African pulse crops production.

1. Introduction

Despite the recognized potential for pulse production in Ghana and many sub-Saharan African (SSA) countries, output remains low. This article explores the underlying factors responsible for this paradox. Over several decades, policy interventions for pulse production in Ghana have remained sparse and unfocused, resulting in pulses being referred to as an ’orphan crop’. Previous efforts through the Planting for Food and Jobs (PFJ) phase one and two (PFJ 2.0) programme, attempted to address this structural problem through the incorporation of pulses as part of the priority crops under the PFJ (Asante et al., 2025). A most recent government flagship programme known as the feed Ghana programme (FGP) seeks to promote and consolidate gains in pulses production. Comparatively, the tree crops (cocoa, oil palm, mango,

* Corresponding author.
E-mail address: nkwapong@lincoln.ac.uk (N.A. Kwapong).

https://doi.org/10.1016/j.foohum.2025.100687
Received 20 December 2024; Received in revised form 2 June 2025; Accepted 23 June 2025
Available online 26 June 2025

cashew), and cereals (maize, rice) have seen a lot of policy drive and action in bridging yield gaps (Achterbosch et al., 2014). This article probes the factors that account for the low production and the likelihood of a smallholder farmer producing pulses in different agro-ecological zones in Ghana using the Ghana Living Standards Survey seventh round (GLSS 7).

Pulses, also known as legumes, generally refer to edible dried seeds of the legume family Leguminosae (Tadele, 2019). Examples of pulses in Ghana include cowpea, soybeans, bambara beans, groundnut, and pigeon pea. Approximately 6.5 million metric tonnes of pulses are produced yearly covering a land area of an estimated 14.5 million hectares globally (Boukar, Belko, et al., 2019). West African countries, particularly Nigeria and Niger, dominate pulse production in sub-Saharan Africa (SSA), accounting for approximately 80 % of the region's output over a 14-year period (Boukar, Belko, et al., 2019). Despite this, Nigeria continues to import cowpea, highlighting persistent production-consumption gaps. Nigeria produces substantial (2.14 million metric tonnes) pulses annually, the United States of America (USA), China, Serbia, Peru, and Sri Lanka, are among the top producers of cowpea (FAOSTAT, 2017). Even though Nigeria produces substantial amounts of pulses, the country imports cowpea from the neighbouring countries, including Cameroon, Chad, and the Republic of Niger. Cowpea yields are low (less than 600 kg ha1) – compared to the attainable yield of 1500–2500 kg ha1 (ICRISAT, 2017). Globally, soybeans production comes first, peanut follows next, dry beans, and other pulses (Semba et al., 2021). In the Caribbean and Latin America, the average individual consumption of legumes, daily, falls within 1–34 g in Latin America, 1 – 33 g in sub-Saharan Africa, 1 – 34 g in south Asia, and less than 3 g in Caucasus and central Asia (FAO, 2023; Rawal & Bansal, 2019; Akibode & Maredia, 2011).

In Ghana various crops are grown in six agroecological zones - Deciduous Forest zone, Forest transitional zone, Sudan Savannah, Guinea Savannah, Coastal Savannah, and the Rain Forest zone (Agyekum et al., 2023). As mentioned earlier, historically, there has been a neglect for African pulses contributing to it being classified as an under-utilized pulse crop. The neglect stems from the fact that the cash crops contribute significantly to Ghana's gross domestic product (GDP) relative to pulses. Consequently, the pulses do not get the needed attention with regards to subsidies of agro-inputs, production and marketing. The major production of pulses takes place in northern Ghana typified by the Sudan Savannah and Guinea Savannah agroecological zones. The rainfall pattern lies within May and October with an average precipitation of 900 – 1100 mm. This implies that pulses constitute the first crops harvested in the geographic space. It addresses the food scarcity gap in the region. This is complemented by production in the savannah zones covering Ashanti, Bono, Ahafo, Bono East, Volta, Oti and Eastern regions. Regarding under-utilized African pulses, groundnut and cowpea are the most popular in Ghana. Every year, Ghana produces 143,000 metric tonnnes averagely on a land area of approximately 156,000 ha, placing Ghana as the fifth highest cowpea producer in Africa (Haruna et al., 2018). The production of pulses in Ghana saw a surge from 12,000 tonnes to 418,454 tons from 1969 to 2018 . This represented an annual growth rate of 15.68 %. Notwithstanding the rise in the production of pulses over time, domestic demand remains unmet. The usage of underutilized African pulses in Ghana is largely limited to domestic cooking with minimal utilization for industrial purposes (Agyekum et al., 2023). The low production of African pulses and as well as the limited industrial use points to some current challenges. Emerging questions such as what to do to take advantage of the unmet demand and opportunities? Which administrative regions and agroecology's can farmers be encouraged to produce pulses? What structural inequalities can be addressed to promote pulses production continue to linger on. Our study attempts to deepen understanding on how African orphan pulses can be promoted.

This study emphasizes the environmental significance of pulses. Legumes contribute substantially to climate change mitigation due to their low greenhouse gas (GHG) emissions and their role in enhancing soil carbon sequestration (EAT-Lancet Commission, 2020; Tadele, 2019). Given that legumes contributes 5–7 times less GHGs relative to other food crops, they have the ability to reduce inputs from fossil energy into the ecosystem, and they additionally help sequester carbon in soils (Punia et al., 2020; Rani et al., 2020). Pulses are rich in proteins, dietary fiber, vitamins, antioxidants, and essential amino acids, making them critical in addressing malnutrition and non-communicable diseases. Cowpea consumption, for example, has been linked to reduced risks of hypertension, cholesterol, and diabetes (Awika & Duodu, 2017; Jayathilake et al., 2018). For instance, the consumption of cowpeas lowers the risk of high blood pressure and cholesterol (Jayathilake et al., 2018). Pulses additionally, reduce the related risks of developing cancer and diabetes (Awika & Duodu, 2017; Jayathilake et al., 2018). Pulses contain the required nutrients that addresses malnutrition among children (Stephenson et al., 2017). Ironically, inadequate protein, appears to be one of the most common causes for malnutrition in Africa. And indeed, ending all forms of malnutrition is one of the most important targets under the sustainable development goals (SDGs).

Pulses enhance soil fertility through biological nitrogen fixation, thereby reducing the dependence on costly inorganic fertilizers (Yusuf & Dianda, 2014). For instance, cowpea can contribute up to 125 kg N ha^{-1} per season (Kermah et al., 2018). Inorganic fertilisers are prohibitively expensive for most smallholder farmers. Legumes in crop rotation replenishes lost nutrients and reduces the intensive use of fertilisers (Stagnari et al., 2017). They additionally reduce pest and disease cycle through crop rotation thus consequently improving crop production (Foyer et al., 2016). Economically, pulses are considered as important cash crops with additional use in livestock production through animal feed composition that provides income for farmers.

Existing literature attributes the low productivity of pulses to a range of agronomic, environmental, infrastructural, and socioeconomic constraints, including low-yielding varieties, pest infestations, drought stress, and limited access to credit and storage infrastructure (Aboki & Yuguda, 2013; Daryanto et al., 2015; Horn & Shimelis, 2020; Horn et al., 2015; Ibro et al., 2014; ICRISAT, 2017; Kabambe et al., 2013; Maredia et al., 2019; Sheoran et al., 2022; Singh et al., 2013). In Ghana, empirical studies on the constraints facing pulse production are limited. Notably, pulses are predominantly cultivated in the northern and savannah regions where unimodal rainfall patterns and early harvest cycles make them essential for bridging seasonal food gaps (Wahaga, 2019; Amikuzino & Donkoh, 2012; Al-Hassan & Diao, 2007).

Despite the demonstrated health, environmental, and economic benefits of pulses, production among smallholder farmers in Ghana remains sub-optimal. This study seeks to address two core research questions: First, what are the key constraints to pulse production in Ghana? and second, what is the likelihood of a smallholder farmer producing pulses based on geographic location? To this end, we utilize the nationally representative Ghana Living Standards Survey (GLSS 7) to estimate production probabilities and identify constraints using count and zero-inflated regression models.

The remainder of the article proceeds as follows: the next section – Section 2 gives an overview of the sources of data and variables in the underlying estimation model. Section 3 sheds light on the results and discusses the findings within the related body of knowledge. Section 4 draws on the policy implications of the findings. The final section (Section 5) concludes and offers policy recommendation worthy of consideration.

2. Materials and methods

2.1. Data sources and variables

This study relied on the GLSS 7 - a detailed multipurpose national household survey that evaluates the living standards of Ghanaians. The GLSS 7 dataset was used in addressing our study's research objectives on pulse production, particularly in the context of orphan crops in sub-Saharan Africa (SSA) because it is national in scope covering all areas in Ghana. This implies that all agroecological zones that support the production or otherwise of pulses production are captured in our study to deepen understanding of the drivers and factors that hinder production. The GLSS-7 brings on an additional value to offering disaggregated crop-level analysis. The GLSS 7 data was collected over a period of one year i.e. October 22, 2016, to October 17, 2017. Pulse production was self-reported in the GLSS 7. We note that the issues captured then may not be reflective of current production dynamics, especially post-COVID-19 and recent government policy shifts. However, we note that Ghana's agri-food system has not change structurally over time, thus our results bring to the fore to some useful implications for policy and practice. See Page 4 under the methodology section. The data cover all sixteen (16) administrative regions of Ghana. (Ghana Statistical Service, 2018). Our study takes inspiration from the Ghana Statistical Service, by categorizing the 16 administrative regions into three belts, i.e. Southern belt covers farmers that produces pulses in the Greater Accra, Volta, Oti, Eastern, Central, Western and Western North regions. The southern belt covers coastal savanna, evergreen, deciduous forest. The southern belt, especially the Greater Accra Region makes the southern belt the most economically endowed region with a lot of economic opportunities (jobs and income generating activities). Given the agroecological zones, pulses production is generally supported in the administrative regions with the evergreen and deciduous forests. The southern belt is the most culturally more diverse and cosmopolitan in nature. It is densely populated and thus consumes more pulses rather than production.

Middle belt - Farmers in the Ashanti and Bono East, Bono, Ahafo regions. The middle belt covers deciduous forest, and the transitional zone. The agroecological zones in the middle belt supports the production of pulses similar to the southern belt. Relatively it is not densely populated compared to the southern belt.

Northern belt - Farmers in the Upper West, Savannah, Northern, North-East, Upper East regions. The northern belt covers the Guinea savanna and the Sudan savanna agroecological zones. The northern belt offers the agroecological zone that supports the optimum production of pulses. Consequently, the bulk of pulses are produced within the northern belt. Economic opportunities in terms of jobs and employment are limited in the belt. It is the most deprived and economically poor relative to the southern and middle belts.

Our study included all farming households in all sixteen (16) regions. The farming households selected for analysis stood 15,045. The dependent variable was the number of tonnes of pulses produced yearly by a farming household. The study's explanatory variables included demographic, socioeconomic, environmental factors (See Table 1 below). The age category of 15–35 years is based on the African Youth Charter of the African Union (AU), 2006 and the Ghana Statistical Service (2018).

Table 1
variable description.

Variable	Category	Type	Description	Aprori Expectation	Literature
No. of tonnes produced yearly	All Ghanaian Farming households	Dependent Variable	Number of tonnes of pulses produced yearly by farming households.	+ /-	(Reddy et al., 2024; Agyekum et al., 2023).
Sector	1 = Southern		Farmers in Greater Accra, Volta, Oti, Eastern, Central, Western and Western North regions	+ /-	(Agyekum et al., 2023; Kermah et al., 2018; Nimoh & Asuming-Brempong, 2012)
	2 = Middle	Independent Variable	Farmers in the Ashanti, Bono East, Bono and Ahafo regions	+ /-	(Agyekum et al., 2023; Kermah et al., 2018)
	3 = Northern		Farmers in the Upper West, Savannah, Northern, North East, Upper East regions	+	(Osei-Asibey et al., 2022; Maredia et al., 2019; Wahaga, 2019; et al., 2018; Awunyo-Vitor et al., 2013).
Age	1 = 15–35		Household heads who are youth	-	(Agyekum et al., 2023)
	2 = 36–60	Independent Variable	Household heads who are middle age	+ /-	(Enimu & Onome, 2018; Gebru et al., 2020; Kgosikoma et al., 2018; Nimoh & Asuming-Brempong, 2012).
	3 = Above 60		Household heads who are aged	+ /-	(Anang et al., 2022; Mulwa et al., 2017; Mwinkom et al., 2021; Tambo, 2016).
Education	0 = Never		Farmers with no formal education	+ /-	(Anum et al., 2022; Kgosikoma et al., 2018)
	1 = Educated	Independent Variable	Farmers with a least formal education	+ /-	(Anum et al., 2022; Kgosikoma et al., 2018)
English Literacy	0 = Poor		Farmers who do not understand English language	-	(Anum et al., 2022; Nimoh & Asuming-Brempong, 2012)
	1 = Good	Independent Variable	Farmers who do understand English language	+ /-	(Wahaga, 2019; Kgosikoma et al., 2018; Nimoh & Asuming-Brempong, 2012)
Residence	0 = Rural		Farmers Residing in a rural area	+	(Kermah et al., 2018; Abu, & Soom, 2016; Al-Hassan & Diao, 2007).
	1 = Urban	Independent Variable	Farmers residing in an urban area	-	(Abu, & Soom, 2016; Al-Hassan & Diao, 2007).
Wealth status	1 = Very poor		Non-food and food consumption of US $ 99 yearly	-	(Osei-Asibey et al., 2022; Wahaga, 2019)
	2 = Poor	Independent Variable	Non-food and food consumption of US$ 64.25 yearly	+ /-	(Jinbaani et al., 2023; Al-Hassan & Diao, 2007)
	3 = Non-poor		Non-food and food consumption above US $64.24 yearly	+ /-	(Anang et al., 2022; Wahaga, 2019; Al-Hassan & Diao, 2007)
Pulse	-	Independent Variable	Tonne of pulse produced by a household	+ /-	(Reddy et al., 2024; Kermah et al., 2018).

Source: Data computation based on the GLSS7, 2017.

Wealth status – The wealth categorization is based on the Ghana Statistical Service (2018) report that uses consumption poverty. The consumption poverty focuses on the segment of population whose standard of living falls short below a specific consumption basket, known as the poverty line. Our study follows a consumption-based standard of living measure that is widely used in most countries. It covers the average over a period of one year and it is adjusted to inflation. The poverty line is set at that level of the minimum consumption requirement. This yielded the underlisted classifications:

1. Very poor - Non-food and food consumption of US $ 99 yearly
2. Poor - Non-food and food consumption of US$ 64.25 yearly
3. Non-poor - Non-food and food consumption above US$64.24 yearly

Overall, the explanatory variables captured in Table 1 ties into the broader narrative of pulse crops as neglected yet critical to food and nutritional security in Ghana and SSA (see Agyekum et al., 2023). It is important to note that the industrial use remains under-explored even though it shares great potential to provide decent jobs. Thus, our study seeks to achieve the underlisted objectives:

(1) What are the key constraints to pulse production in Ghana as a case for African orphan crops? and
(2) What is the likelihood of a smallholder farmer producing pulses based on geographic location?

2.2. Statistical models

We present the statistical techniques used in analysing the data. Four estimation approaches (Poisson, Negative Binomial, zero-inflated negative binomial (ZINB), and zero-inflated Poisson (ZIP) regressions) were employed to model the count and zero-inflated data. Our study resorted to the zero-inflated models because they are the most methodologically appropriate given the data structure (e.g., prevalence of non-producers of pulses i.e. the over-abundance of zeros in the count data and overdispersion). The ensuing sections present these models in turns (See also Table 2 & Fig. 1).

2.2.1. Poisson regression model

In statistical modelling, count data fits well with a Poisson regression model. The dependent variable (count data) must be a non-negative integer to qualify for fitting the Poisson regression model. In this study, the dependent variable is the number of tonnes of pulses produced yearly by a household. This variable satisfies the condition of being a count and non-negative variable. Considering a Poisson model, a farming household's probability is denoted as i producing y_i number of tonnes of pulse annually is given by:

Table 2
Descriptive statistics of the explanatory variables.

Variable	Category	Frequency (N)	Percent (%)
Sector	Southern	4822	32.05
	Middle	2182	14.5
	Northern	8041	53.45
Age	15–35	3179	21.13
	36–60	8530	56.7
	Above 60	3336	22.17
Education	Never	5814	38.64
	Educated	9231	61.36
English Literacy	Good	3682	24.47
	Poor	11363	75.53
Residence	Urban	1400	9.31
	Rural	13645	90.69
Wealth status	Very poor	4147	27.56
	Poor	4158	27.64
	Non-poor	6740	44.8

Source: GLSS 7 household Survey, 2017.

$$p(y_i) = \frac{\exp(-\lambda_i)\lambda_i^{y_i}}{y_i!}, y_i = 0, 1, 2, \ldots\ldots(\lambda_i > 0) \quad (1)$$

where $p(y_i)$ is the probability of a farming household producing a tonne of pulse in a year. The Poisson model has its parameter equal to its expectation and variance. Thus $E(Y_i) = Var(Y_i) = \lambda$

2.2.2. Negative binomial regression model

The Poisson-gamma - an extension of the Poisson model, is also known as the negative binomial model. This model addresses the challenges associated with over dispersion that the Poisson has limitation addressing. The negative binomial model has an assumption that the Poisson parameter takes a gamma probability distribution. The is obtained by rewriting the Poisson parameter for every observation where $\lambda_i = \exp(\beta X_i + \varepsilon_i)$ where $\exp(\varepsilon_i)$ forms the gamma-distributed error term with mean 1 and variance K. The introduction of the gamma-distributed error term $\exp(\varepsilon_i)$ cause a difference between expectation and the variance. Thus,

$$Var(y_i) = E[y_i][1 + K[y_i]] + K\{E[y_i]\}$$

The negative binomial regression for a farming household i is given as

$$p(y_i) = \binom{y_i + r - 1}{y_i} p^r (1-p)^{y_i}, r = 0, 1, 2, \ldots \quad (2)$$

where the parameter p, is the probability in trial. It computed as $p = \frac{r}{\lambda_i + r}$.

2.2.3. Zero-Inflated Models

In statistical analysis, most of the overdispersion cases encountered are because of the prevalence of zero counts in datasets. This peculiar case cannot be modelled by the two aforementioned classical models (Poisson and Negative binomial models). Such a situation can be handled adequately by the zero inflated models. We employ the zero inflated negative binomial and zero inflated Poisson models.

These ZI models permits the researcher answer two questions:

1. *What predicts whether or not the event occurs*"
2. *If the event occurs, what predicts frequency of occurrence?* (Lord, 2006).

In a nutshell, these models present two equations, one predicting the occurrence of the count, while the other predicts the frequency (Lord, 2006). Additionally, these models have statistical advantage over the classical models (negative binomial and Poisson models). These models has the ability to estimate the majority of zeros and the distribution of positive counts concurrently (Mullahy, 1986).

2.2.4. Zero-Inflated Poisson (ZIP) regression model

The Zero-Inflated Poisson regression accommodates the excess zeros that the classical models inadequately accommodate. This disaggregates the model into two forms, the positive counts as against the zero counts. Considering our dataset, the ZIP will model a farming household that did not produce a tonne of pulse versus those that produced at least one tonne of pulse by either a probit or a logit model that accounts for the likelihood of a farming household which either produced a zero tonne of pulse or at least one tonne of pulse.

The ZIP model assumes the number of tonnes of pulse produced yearly $y_i = (y_1, y_2, \ldots, y_n)$ to be a sample of independent, but not necessarily identically distributed random variables. In this model, we assume that

$p(y_i) \sim P_o(\lambda_i)$ with probability η_i.

$$Thus, p(Y = y_i) = \begin{cases} (1-\eta_i)\frac{\exp(-\lambda_i)\lambda_i^{yi}}{y_i!} \text{ when} y_i > 0 \\ \eta_i + (1-\eta_i)\exp(-\lambda_i) \text{ when} y_i = 0 \end{cases} \quad (3)$$

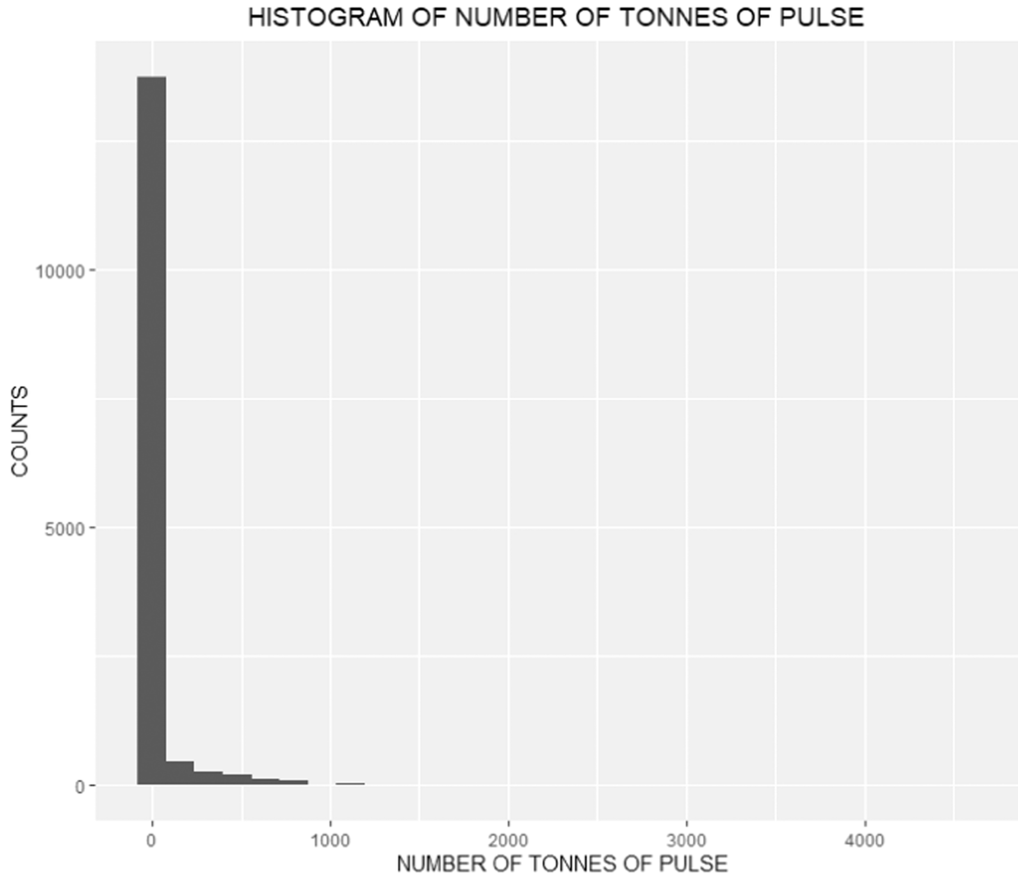

Fig. 1. Number of tonnes of pulse produced by farming households in Ghana.

$\lambda_i > 0 \text{and} 0 \leq \eta_i < 1$

The variance and the expectation of the ZIP model is presented as $Var(Y_1) = \lambda_i + \left(\frac{\eta_i}{1+\eta_i}\right)\lambda_i^2$ and $E(Y_i) = (1 - \eta_i)\lambda_i$ respectively.

2.2.5. Zero-Inflated Negative Binomial (ZINB) regression model

The ZINB regression model has the same the ZIP distribution, it is a combination of distributions. The ZINB involves two different data generation processes. Suppose that each individual farming household that produces tonnage of pulses in a year is separated into two possible cases. We assume that for every observation, two possible cases exist. First, case "A" occurs, assuming a farming household produces zero tonne of pulse in a year. Second, however, if case "B" (a farming household produces at least a tonne of pulse in a year) occurs, these counts (including zeros) are modelled by the negative binomial model. If we further assume that case "A" occurs with probability η and "B" occurs with probability $1 - \eta$. Hence, the probability distribution of the ZINB is given by:

$$p(Y = y_i) = \begin{cases} (1 - \eta_i)\dfrac{\Gamma(y_i + \tau)}{y_i!\Gamma(\tau)}\left(1 + \dfrac{\lambda_i}{\tau}\right)^{-r}\left(1 + \dfrac{\lambda_i}{\tau}\right) \text{when} y_i > 0 \\ \eta_i + (1 - \eta_i)\left(1 + \dfrac{\lambda_i}{\tau}\right)^{-r} \text{when} y_i = 0 \end{cases} \quad (4)$$

The variance and the expectation of the ZINB model are given as $Var(Y_i) = (1 - \eta_i)\lambda_i\left(1 - \eta_i\lambda_i + \frac{\lambda_i}{\tau}\right)$ and $E(Y_i) = (1 - \eta_i)\lambda_i$ respectively.

Model Specification

The model for the two classic models (Poisson and Negative Binomial) can be expressed as

$$\log(\mu_i) = \beta_0 + \beta_1 \text{Age}_i + \beta_2 \text{Education}_i + \beta_3 \text{EnglishLiteracy}_i + \beta_4 \text{Residence} +_i \beta_5 \text{Region}_i + \beta_6 \text{PovertyStatus}_i$$

Also, the zero-inflated models (ZIP and ZINB) can be as the following:

Where:

$$\log\left(\frac{\pi_i}{1 - \pi_i}\right) = \gamma_0 + \gamma_1 \text{Age}_i + \gamma_2 \text{Education}_i + \gamma_3 \text{EnglishLiteracy}_i + \gamma_4 \text{Residence} +_i \gamma_5 \text{Region}_i + \gamma_6 \text{PovertyStatus}_i$$

- μ_i is the expected number of pulses produced by households,
- π_i is the probability that household iii is in the always-zero group,
- β and γ are vectors of regression coefficients.

In summary, our four models are the most appropriate because of the data structure (e.g., prevalence of non-producers of pulses i.e. the overabundance of zeros in the count data and overdispersion). Our study seeks to understand within the broader marginalization of African pulses, some theoretical drivers. Specifically, our study seeks to

(1) Identify the key constraints to pulse production in Ghana as a case for African orphan crops? and
(2) Estimate the likelihood of a smallholder farmer producing pulses based on geographic location?

3. Results

3.1. Exploratory analysis

As earlier mentioned in the methods section, our study focused on only farming households in the GLSS 7 dataset. Table 2 below gives a description of the independent variables (i.e., socioeconomic, demographic, and geographic factors) used in the study.

Ghana's middle sector recorded the least (14.5 %) production of pulses, while the northern sector represents substantial (53.45 %) farming households involved in pulses production. This finding aligns with earlier findings (Nimoh & Asuming-Brempong, 2012; Wahaga, 2019) that indicated that the majority of pulses are produced in the five administrative regions in northern Ghana. Beyond this finding, this article adds on to knowledge about the tendency to produce pulses in different spatial location.

The middle age category that falls within 36–60 years, was highest (56.7 %) with regards to the household heads, next (22.17 %) households above 60 years and the least (21.13 %) being the youth. This implies that pulses have less participation by the youth. Generally, farming in Ghana tends to be dominated by the aged and middle-aged farmers, raising questions about the sustainability of farming. An estimated 35 % of household heads, do not have formal education, whereas an appreciable proportion (61.4 %) of household heads, had formal education. Given that farming is generally a rural phenomenon in the global south, with its corresponding limited economic and social facilities in place, most farmers who participate in farming may have low formal education. Again, a quarter (25 %) of the household heads had literacy in English (i.e. they could either read or write the English language – Ghana's official language), whilst majority (75.5 %) of household heads could neither read nor write the English language. This goes in to support the related findings (Kwapong et al., 2021; Anang et al. 2022, Dokyi, Asante & Donkor, 2022; Ankrah et al., 2023) of the low level of formal education among farming households in Ghana. We observe that most (90.7 %) farming households are located in the rural areas, with only few of the farming households located in Ghana's urban areas. The data show that most households involved in farming are non-poor, indeed, an estimated 44.8 % of farming households consume approximately US$ 164 yearly on non- food and food commodities. And those classified to be very poor (non-food and food consumption of US $99 yearly) constitute just over a quarter (27.6 %) of Ghana's farming households.

3.2. Estimation of coefficients

In this study, we assessed the determinants of pulses production (measured in tonnes) among Ghanaian farming households using two classical count models and two zero-inflated models. Even though Table 3 and Fig. 1 clearly indicate that the response variable exhibits a large proportion (which warrants the inclusion of zero inflated models), we formally tested the inclusion of the inclusion of zero inflated models using the Vuong test. Assessing ZINB vs. NB, the Vuong test gives a very low p-value [Vuong z-statistic (AIC-corrected): 83.71 ($p < 2.2e\text{-}16$)]; indicating that ZINB fits the data better. Again, we employed two performance measures (AIC and BIC) to assess the four models (see Table 4). This strongly indicates that the ZINB model fits the data better compared to the others. Also, the overdispersion parameter (θ) is highly significant ($\log(\theta) = 0.212$, $p < 0.001$), confirming the presence of overdispersion in the count data and justifying the use of negative binomial model over a Poisson alternative.

More so due to the sets of effects from the ZINB mode, we can practically benefit policy makers by targeting interventions more precisely. Thus, by improving productivity among producers through the count model; and by understanding and addressing barriers to entry for non-producers through the zero model.

Furthermore, we diagnosed the ZINB model for multicollinearity menace (assessing the presence of high intercorrelations among independent variables in the model). As presented Table 6, all standardized GVIF values are close to 1 and well below the commonly used threshold of 2. This suggests a negligible degree of multicollinearity among the independent variables. Consequently, it can be concluded that multicollinearity is not a concern in this model and does not compromise the validity or interpretability of the estimated regression coefficients.

Nonetheless, an important concern in analyses such as this, is the potential presence of endogeneity—which can be due to omitted

Table 4
Performance measures of models.

Models	Degree of freedom	AIC	BIC
ZINB	21	30337.47	30497.47
ZIP	20	517340.1	517492.4
Negative binomial	11	3132531	3132615
Poisson	10	3135363	3135439

Table 3
Results of positive counts using different count data models for pulses produced.

	ZNGBM		ZIP		NGB		POISSON	
Variables	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Intercept	5.368***	0.125	5.416***	0.007	1.841***	0.007	1.841***	0.007
Region (Middle)	0.348***	0.100	0.330***	0.005	0.003***	0.005	0.003***	0.005
Region (North)	0.146*	0.068	0.117***	0.004	0.826***	0.003	0.826***	0.006
Residence (Urban)	−0.717***	0.158	−0.775***	0.012	−2.138***	0.012	−2.139***	0.017
Education (No)	−0.094	0.052	−0.114***	0.002	0.051***	0.003	0.051***	0.002
English Literacy (No)	0.059	0.064	0.077***	0.004	0.245***	0.004	0.246***	0.004
Poverty status (Poor)	0.271***	0.061	0.280***	0.004	0.778***	0.004	0.778***	0.004
Poverty status (Non-poor)	0.546***	0.067	0.549***	0.004	1.058***	0.004	1.058***	0.004
Age Category (Middle)	0.270***	0.066	0.235***	0.003	0.663***	0.003	0.663***	0.004
Age category (Aged)	0.109	0.077	0.055***	0.004	0.437***	0.004	0.438***	0.0044

***$P < 0.001$, **$P < 0.01$, *$P < 0.05$, Std. Error. = Standard error variables, measurement errors, or simultaneous causality, potentially biasing coefficient estimates. In mitigating this, we conducted rigorous endogeneity tests by implementing control function approaches with instrumental variables for potentially endogenous regressors, such as education and poverty status.

The diagnostic tests revealed no significant evidence of endogeneity affecting our main explanatory variables. Specifically, the residual terms from the first-stage models were statistically insignificant in the second stage count and zero-inflation components, indicating that the endogenous regressors did not bias the estimation. Consequently, we opted to present results from the more parsimonious zero-inflated negative binomial model (ZINB) excluding control function adjustments. This approach provides unbiased, consistent, and more interpretable estimates while maintaining model parsimony.

Therefore, all interpretations, policy implications, and recommendations are based on the ZINB model, which includes key predictors such as region, residential location, education, English literacy, wealth status, and age categories. The discussion of ZINB results is presented in the two sets of effects; first, the count model proceeded by the zero-inflated model.

In this study, we employed two performance measures (AIC and BIC) to assess the four models. Table 4 clearly shows that the ZINB model recorded the least for both the AIC and the BIC.

Table 5 presents the zero inflated estimates, the regional sector and residential location of a household are significant factors that accounts for a household to produce a zero tonne of pulse. On the other hand, covariates such as English literacy, educational status, poverty status, and age category constitute significant factors responsible for a household to at least produce one of a tonne of pulse in a year.

3.2.1. Count model

The conditional (count) component of the Zero-Inflated Negative Binomial (ZINB) model identifies the determinants of pulse production (in tons) among Ghanaian farming households that are actively engaged in production (see Table 4). The conditional part of the model explains the count outcome—the tonnes of pulses produced—among those households that are actively engaged in production.

The "Region" significantly influences pulse output. Households in the middle belt exhibit a positive and statistically significant association

Table 5
Results of zero counts based on ZINB and ZIP models.

	ZINB		ZIP	
Variables	Estimate	Std. Error	Estimate	Std. Error
Intercept	3.719***	0.139	3.721***	0.139
Region (Reference = Southern)				
Middle	0.305***	0.113	0.304***	0.113
Northern	−0.881***	0.073	−0.881***	0.073
Residence (Reference = Rural)				
Urban	1.493***	0.177	1.494***	0.177
Education (Reference = Never)				
Educated	−0.233***	0.063	−0.233***	0.063
English literacy (Reference = Poor)				
Good	−0.217***	0.075	−0.217***	0.075
Poverty status (Reference = Very Poor)				
Poor	−0.518***	0.073	−0.518***	0.073
Non-poor	−0.594***	0.075	−0.594***	0.075
Age category (Reference = Youth)				
Middle-Aged	−0.475***	0.076	−0.475***	0.076
Aged	−0.422***	0.088	−0.422***	0.088

***P < 0.001, **P < 0.01, *P < 0.05, Std. Error. = Standard error

Table 6
Variance Inflation Factor (VIF).

Predictor	GVIF	Degree of Freedom (DF)	GVIF^(1/(2*DF))
Region	1.24	2	1.055
Residence	1.006	1	1.003
Education	1.26	1	1.123
English Literacy	1.212	1	1.101
Poverty Status	1.162	2	1.038
Age Category	1.02	2	1.005

with production volume ($\beta = 0.349$, $p < 0.001$). This coefficient implies that, all other things being equal, households in this region produce approximately 42 % more pulses than those in the southern belt ($e^{0.349} \approx 1.42$). Similarly, households in the Northern belt show a modest but significant increase in production ($\beta = 0.146$, $p = 0.033$), reflecting a 16 % higher yield compared to the Southern Region.

This regional effect may reflect agroecological differences, variation in rainfall, or region-specific extension services (Dziwornu et al., 2024). For instance, Northern Ghana, characterized by relatively favourable agro-climatic conditions for legume crops and targeted agricultural investment programs, has been found to outperform southern regions in pulse production (Ferreira et al., 2022). These findings support the need for regionally tailored agricultural policies and interventions.

We observe that households in urban areas are significantly less likely to produce large quantities of pulses ($\beta = -0.717$, $p < 0.001$), producing approximately 51 % less than their rural counterparts ($e^{-0.717} \approx 0.488$). This result is not surprising, given the spatial constraints and limited access to arable land in urban settings. As established by Diao et al. (2019), rural households are often more integrated into the agricultural economy, benefiting from land tenure systems, social networks, and traditional knowledge that support production.

The effect of education on pulse production is marginally significant ($\beta = -0.094$, $p = 0.073$). Households with lower education levels produce approximately 9 % less than those with higher education. Even though education often impacts technology adoption and agricultural innovation positively (Appiah-Twumasi & Asale, 2024; Anang et al., 2022), its limited effect here may reflect the subsistence nature of pulse farming, where practical experience and traditional knowledge may outweigh formal education (Fumey et al., 2022).

English literacy, on the other hand, is not statistically significant ($\beta = -0.059$, $p = 0.358$), suggesting that language proficiency does not meaningfully affect pulse output. Practically, the informal sector (including farming) in Ghana is less English-intensive, with local languages being increasingly common (Taluah, 2016). Opoku and Hanson (2008) established that farmers in Ghana often rely on local languages for daily communication and agricultural practices, suggesting that English proficiency is not critical for effective farming.

Poverty status emerges as a robust predictor of production. Poor households produce 31 % more pulses than the poorest group ($\beta = 0.271$, $p < 0.001$), while non-poor households produce 73 % more ($\beta = 0.547$, $p < 0.001$). These results corroborate existing literature indicating that wealthier households typically have better access to inputs such as quality seeds, fertilizers, and hired labour (Issahaku et al., 2020). They are also more resilient to market and climate shocks, allowing them to maintain or increase production. This finding underscores the interdependence between poverty reduction and agricultural development—policies that improve household wealth can simultaneously improve agricultural productivity.

Households headed by middle-aged individuals produce significantly more pulses than those headed by younger adults ($\beta = 0.271$, $p < 0.001$), corresponding to a 31 % increase. This may reflect greater farming experience, more stable household dynamics, and higher physical capacity compared to both the younger and older cohorts (Kwapong et al., 2021). The coefficient for the aged group is not statistically significant ($\beta = 0.105$, $p = 0.173$), suggesting that older household heads may experience constraints related to labour and energy, despite their experience.

3.2.2. Zero-inflated model

We discuss the estimates obtained from the zero-inflation component of the ZINB model (see Table 5). It estimates the probability that a household is an excess zero producer, i.e., a household that is structurally not engaged in pulse production. Unlike the conditional model, which explains the extent of production among those who produce, this part distinguishes between true zeros (households that would never produce) and sampling zeros (households that might have produced but did not, due to stochastic variation). This distinction is crucial in agricultural household studies where zero outputs are common due to structural barriers rather than choice or chance. The interpretation and discussions hence centers on the factors associated with a structural disengagement from pulse production.

Using the southern belt as the baseline category for "Region", households found in the Middle belt are significantly more likely to be non-producers ($\beta = 0.305$, $p = 0.007$). This translates to a 36 % increase in the odds of not engaging in pulse farming compared to those in the southern belt ($e^{0.305} \approx 1.36$). This finding contrasts with the conditional model, suggesting that while active producers in the middle belt achieve higher output, a substantial proportion of households are structurally excluded from participation. This bifurcation may result from land fragmentation, urban encroachment, or socioeconomic transitions in peri-urban zones (Abdulai et al., 2022; Toku et al., 2021).

Conversely, households found in the northern belt are significantly less likely to be structural non-producers ($\beta = -0.882$, $p < 0.001$), with their odds of non-participation reduced by about 58 % ($e^{-0.882} \approx 0.414$). The northern belt has long been characterized by a strong agrarian base and government-supported agricultural programmes, including those targeting legume cultivation (MoFA, 2021), which likely foster broader participation in pulse production. The northern belt has been neglected of economic development for a long while, so recent efforts have been targeted to bridge development gaps. Non-governmental organisations (NGOs) have visible presence in the zone. Most NGOs promote the cultivation of pulses as a cheap protein alternative.

Urban residency is strongly associated with zero production ($\beta = 1.493$, $p < 0.001$), indicating that urban households are over four times more likely ($e^{1.493} \approx 4.45$) to be structurally excluded from pulse farming. This result aligns with related theoretical expectations that indicates that urban residents face challenges accessing arable lands, are saddled with limited storage facilities and may prioritize non-agricultural livelihoods (Afriyie et al., 2020). This structural disengagement underscores the urban-rural divide in agricultural participation and highlights the importance of targeted interventions such as urban farming or home farming policies or peri-urban land allocation schemes.

Interestingly, less educated households are less likely to be in the structural zero group ($\beta = -0.234$, $p < 0.001$). This suggests that despite lacking formal education, these households are more engaged in pulse production. This might reflect reliance on farming as a primary livelihood in the absence of formal employment opportunities, a pattern echoed in several African contexts (King & Palmer, 2010).

On the other hand, English literacy is positively associated with structural non-participation ($\beta = 0.218$, $p = 0.004$), indicating that literate households are about 24 % more likely to be disengaged from pulse production. This seemingly inconsistent finding could reflect those English-literate individuals may change from manual farming toward "white-colour" formal employment or small-scale enterprises, particularly in urban or peri-urban areas (Abdulai et al., 2021).

Poverty status significantly affects pulse production participation. Both poor ($\beta = -0.519$, $p < 0.001$) and non-poor ($\beta = -0.595$, $p < 0.001$) households are less likely to be in the zero-group compared to the extremely poor (reference category). Specifically, the odds of structural disengagement are 40 % lower for the poor and 45 % lower for the non-poor. These findings align with empirical evidence that extremely poor households face acute capital and resource constraints (e.g., land, seeds, labour), preventing them from engaging in even subsistence farming (Issahaku et al., 2020). In contrast, households with slightly more means can afford the initial investment required for production.

Finally, the variable "Age" statistically impacts pulse production. The middle-aged ($\beta = -0.475$, $p < 0.001$) and aged household heads ($\beta = -0.422$, $p < 0.001$) are significantly less likely to be non-producers than younger heads. Middle-aged individuals, often at the peak of their labour capacity and with accumulated agricultural experience, are well-positioned to engage in pulse production (Kwapong et al., 2021). Older adults, while potentially limited in labour, may still rely on household labour or social capital to maintain farming activities, especially in traditional settings where agriculture remains a culture and a main to livelihood activity.

4. Conclusion and policy recommendation

The question of why potential exists to produce pulses, but pulses remain under-produced in Ghana and most countries in sub-Saharan Africa (SSA) forms the thrust of this article. Pulses include underutilized African pulse crops such as groundnuts/peanut, and beans (small beans, bambara beans, broad beans/peas (cowpeas). Essentially, this study estimates the likelihood of smallholder food crop farmers producing pulse as well as the driver's hindering production in Ghana using a nationally representative dataset from the Ghana Living Standards Survey seventh round (GLSS7). This is because of the emerging importance of the potential benefits in investing in orphan pulse crops, especially in relation to CSA, food sovereignty, and rural development.

The findings show that socioeconomic factors (wealth status), geography, and demographic factors (age, level of formal education, literacy in English) hinder pulses production. Particularly, households in the middle belt are more unlikely to produce a tonne of pulse annually relative to households in the southern sector. Farming households in the northern belt have a greater affinity toward pulses production. Urban households are less likely to produce pulses in comparison to rural households. In terms of geography, farm households in the northern belt of the country are more likely to produce pulses relative to the middle and southern belts. The spatial production associated with pulses strongly correlates with the structural neglect of pulses where the production typically takes place in the northern belt – a zone that has since time immemorial has suffered developmental neglect. Household heads with no formal education and low English literacy show a greater probability of producing pulses. This finding contradicts most studies that argue that education improves technology adoption inclusive of the propensity to move into the production of new crops. Poor households are more likely to produce pulses. Even though the finding on education and wealth status contradicts the adoption literature, it points to a "necessity cultivation" of underutilized crops, in line with subsistence-driven resilience strategies among marginal households—a well-documented dynamic in SSA orphan crop production. The middle age and aged farm households show a higher probability of producing pulses compared to the youth. This finding has implication for targeting the youth into agriculture to ensure sustainable production.

We employed the classical count regression and zero inflated regression models to show that the zero inflated models had lower AIC and BIC than the classical count models. Thus, the ZI models performed better than the Poisson and the Negative binomial regression models in terms of the performance measures employed. Even though the ZI models performed better, the overall best model amongst the four is the zero inflated negative binomial model. We contribute to the methodological rigour in using these count models in the agricultural sector, given the nature of the data especially the non-production of pulses (zero counts), thus open further avenues for its use in agriculture.

Efforts by agricultural extension and advisory services are encouraged to be targeted to address hindrances that affect pulses production along co-constituted axes of socioeconomic, spatial, and demographic factors to boost pulses production in Ghana and sub-Saharan Africa (SSA).

Policy implications

This article shows the probability of a smallholder farmer's propensity to produce pulses in a specific agroecological location in Ghana as well as the factors that limits the production of pulses. This study appears to be the first to use a nationally representative survey to shed evidence in this direction using four (Poisson, zero-inflated Poisson (ZIP), zero-inflated negative binomial (ZINB) and Negative Binomial regressions) estimation approaches to estimate the zero-inflated and count data. This remains important because these model choice accounts for excess zeros (i.e. the non-production of pulses and overdispersion in pulse production in Ghana. The policy implication is to understand why some geographical spaces in Ghana do not produce pulses, especially when there is potential, yet still there is generally sub-optimal production. The take-home message is for the Ministry of Food and Agriculture (MoFA) to target addressing the factors that hinder pulses production by agroecological zones and administrative regions. This can potentially be extended to other countries in sub-Saharan Africa (SSA) where pulses production remains low.

The model shows that households in the middle belt are more unlikely to produce a tonne of pulse annually relative to households in the southern sector. Farming households in the northern belt have a greater affinity toward pulses production. This is a structural challenge in pulses production that appears skewed towards northern Ghana even though the middle belt and southern belt have the potential to produce pulses in commercial quantities. Policy makers are encouraged to target the middle and southern belt of the country particularly through the government's new flagship programme – feed Ghana programme (FGP) to harness the untap potentials to be derived from pulses production in other agro-ecological zones aside northern Ghana.

There is a less likelihood of urban households producing pulses as compared to rural households. This implies that policy makers can target rural households to leverage their comparative advantage and the vast land available for the commercial production of pulses to supply the urban areas that are less likely to produce pulses. Given the rapid urbanization and less lands available in urban areas that can support commercial production, public and private sector actors are encouraged to target rural spaces for pulses production.

Pulses have some positive externalities beyond its consumption, specifically pulses contribute significantly to climate action through the nitrogen fixation and its low contribution to greenhouse gas (GHG) emissions. In the current dispensation where the mitigation of GHG emissions takes center-stage, the Ministry of Food and Agriculture (MoFA) is encouraged to advance policies, and action plans that incentivises pulses production in addressing the sustainable development goal 2 (zero hunger) and SDG-13 (climate action). The government of Ghana and other governments in sub-Saharan Africa (SSA) can consider instituting a minimum support price and guaranteed procurement for smallholder farmers. Additionally, input subsidies can be scaled up for pulses production as rightly supported by the related literature (Reddy et al., 2024).

Finally, policy makers need to be aware that household heads with no formal education and low English literacy show a higher probability of producing pulses. Additionally poor households are more likely to produce pulses. The middle age and aged farm households show a higher probability to produce pulses compared to the youth. This implies that policy action should be directed at households with no formal education, low English literacy, poor households who are middle age and aged with adequate extension and advisory services to ensure sustained production of pulses in Ghana.

Study's limitation

Our study made use of a cross-sectional data – GLSS 7, however future studies are encouraged to use panel data involving other waves of the Ghana Living standards survey (GLSS 5 and 6) to understand structural changes over time and measure impact.

CRediT authorship contribution statement

Daniel Adu Ankrah: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nana Afranaa Kwapong:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Fred Fosu Agyarko:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Enoch Kwame Tham-Agyekum:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Seth Awuku Manteaw:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abdulai, I., Ahmed, A. O. B., & Kuusaana, E. D. (2022). Secondary cities under siege: Examining peri-urbanisation and farmer households' livelihood diversification practices in Ghana. *Heliyon, 8*(9), Article e10540. https://doi.org/10.1016/j.heliyon.2022.e10540

Abdulai, I. A., Enu-Kwesi, F., & Boateng, J. A. (2021). Landowners' willingness to supply agricultural land for conversion into urban uses in peri-urban Ghana. *Local Environment*, 1–15. https://doi.org/10.1080/13549839.2021.2002288

Aboki, E., & Yuguda, R. (2013). Determinant of profitability in cowpea production in Takum local Government area of Taraba State, Nigeria. *Journal of Agricultural Sciences, 4*(1), 33–37. https://doi.org/10.1080/09766898.2013.11884699

Abu, G. A., & Soom, A. (2016). Analysis of factors affecting food security in rural and urban farming households of Benue State, Nigeria. *International Journal of Food and Agricultural Economics (IJFAEC), 4*(1), 55–68.

Achterbosch, T.J., van Berkum, S., Meijerink, G.W., Asbreuk, H., & Oudendag, D. (2014). Cash crops and food security: Contributions to income, livelihood risk and agricultural innovation. LEI Wageningen UR..

Afriyie, K., Abass, K., & Adjei, P. O. W. (2020). Urban sprawl and agricultural livelihood response in peri-urban Ghana. *International Journal of Urban Sustainable Development, 12*(2), 202–218.

Akibode, S., & Maredia, M. (2011). Global and regional trends in production, trade and consumption of food legume crops. MSU.

Al-Hassan, R.M., & Diao, X. (2007). Regional disparities in Ghana: Policy options and public investment implications.

Amikuzino, J., & Donkoh, S. A. (2012). Climate variability and yields of major staple food crops in Northern Ghana. *African Crop Science Journal, 20*, 349–360.

Anang, B. T., Dokyi, E. O., Asante, B. O., & Donkoh, S. A. (2022). Technical efficiency of resource-poor maize farmers in northern Ghana. *Open Agriculture, 7*(1), 69–78.

Ankrah, D. A., Mensah, J., Anaglo, J. N., & Boateng, S. D. (2023). Climate variability indicators-scientific data versus farmers perception; evidence from southern Ghana. *Cogent Food & Agriculture, 9*(1), 2148323.

Anum, R., Ankrah, D. A., & Anaglo, J. N. (2022). Influence of demographic characteristics and social network on peri-urban smallholder farmers adaptation strategies-evidence from southern Ghana. *Cogent Food Agriculture, 8*(1), 2130969.

Appiah-Twumasi, M., & Asale, M. A. (2024). Crop diversification and farm household food and nutrition security in Northern Ghana. *Environment, Development and Sustainability, 26*(1), 157–185. https://doi.org/10.1080/23311932.2022.2130969

Asante, B. O., Prah, S., Ankrah, D. A., & Kwapong, N. A. (2025). Fruitless or Fruitful? Examining Ghana's Agricultural Inputs Subsidy and Household Welfare. *Review of Development Economics*.

Awika, J. M., & Duodu, K. G. (2017). Bioactive polyphenols and peptides in cowpea (Vigna unguiculata) and their health promoting properties: A review. *Journal of Functional Foods, 38*, 686–697. https://doi.org/10.1016/j.jff.2016.12.002

Awunyo-Vitor, D., Bakang, J., & Cofie, S. (2013). Estimation of farm level technical efficiency of small-scale cowpea production in Ghana. *Agriculture & Environment Science, 13*(8).

Boukar, O., Belko, N., Chamarthi, S., Togola, A., Batieno, J., Owusu, E., Haruna, M., Diallo, S., Umar, M. L., & Olufajo, O. (2019). Cowpea (Vigna unguiculata): genetics, genomics and breeding. *Plant Breeding, 138*(4), 415–424. https://doi.org/10.1111/pbr.12589

Daryanto, S., Wang, L., & Jacinthe, P.-A. (2015). Global synthesis of drought effects on food legume production. *PloS One, 10*(6), Article e0127401. https://doi.org/10.1371/journal.pone.0127401

Diao, X., Fang, P., Magalhaes, E., Pahl, S., Silver, J., & Silver, J. (2019). Cities and rural transformation: a spatial analysis of rural youth livelihoods in Ghana. *World Development, 121*, 172–204. https://doi.org/10.1016/J.WORLDDEV.2019.05.001

Dziwornu, M. G., Mponela, P., Inusah, S. S., Agyarko, F. F., Yeboah, S., Damba, O. T., & Abera, W. (2024). Institutional efforts and regional distribution of climate-smart agriculture initiatives in Ghana. *Climate Smart Agriculture*, Article 100038.

EAT-Lancet Commission. (2020). The EAT-Lancet Commission on Food, Planet, Health (EAT https://eatforum. org/eat-lancet-commission. Accessed, Issue. https://eatforum.org/eat-lancet-commission/.

Enimu, S., & Onome, G. E. (2018). Determinants of climate change adaptation strategies among farm households in Delta State, Nigeria. *Current Investigations in Agriculture and Current Research, 5*(3), 61–68.

FAO. (2023). The Future of Pulses in Sustainable Food Systems. Rome.

FAOSTAT. (2017). FAOSTAT ⟨http://www.fao.org/faostat/en/#data.QC⟩.

Ferreira, V., Almazán-Gómez, M.Á., Nechifor, V., & Ferrari, E. (2022). The role of the agricultural sector in Ghanaian development: A multiregional SAM-based analysis. *Journal of Economic Structures, 11*(1), 6.

Foyer, C. H., Lam, H.-M., Nguyen, H. T., Siddique, K. H., Varshney, R. K., Colmer, T. D., Cowling, W., Bramley, H., Mori, T. A., & Hodgson, J. M. (2016). Neglecting legumes has compromised human health and sustainable food production. *Nature Plants, 2*(8), 1–10.

Fumey, A., Agyeman-Boaten, S. Y., & Norman, S. B. (2022). Impact evaluation of households participation in agriculture on welfare in Ghana. *African Social Science and Humanities Journal, 3*(3), 1–21. https://doi.org/10.57040/asshj.v3i3.123

Gebru, G. W., Ichoku, H. E., & Phil-Eze, P. O. (2020). Determinants of smallholder farmers' adoption of adaptation strategies to climate change in Eastern Tigray National Regional State of Ethiopia. *Heliyon, 6*(7).

2018 Ghana living standards survey (GLSS7): Poverty trends in Ghana. (2018). (pp. 2005–2017).

Ghana Statistical Service. (2018). *The Ghana Living Standards Survey Seventh Round (GLSS7)*. Accra, Ghana: Ghana Statistical Service. Retrieved from ⟨https://www2.statsghana.gov.gh/nada/index.php/catalog/97⟩.

Haruna, A., Kombiok, J. M., Mohamed, A. M., Sarkodie-Addo, J., Larbi, A., & Rahman, N. A. (2018). Profitability of cowpea intercropped With maize in west Africa Guinea Savanna. *Journal of Agricultural Science, 10*(11), 185–189.

Horn, L., & Shimelis, H. (2020). Production constraints and breeding approaches for cowpea improvement for drought prone agro-ecologies in Sub-Saharan Africa. *Annals of Agricultural Sciences, 65*(1), 83–91.

Horn, L., Shimelis, H., & Laing, M. (2015). Participatory appraisal of production constraints, preferred traits and farming system of cowpea in the northern Namibia: Implications for breeding. *Legume Research: An International Journal, 38*(5).

Ibro, G., Sorgho, M. C., Idris, A. A., Moussa, B., Baributsa, D., & Lowenberg-DeBoer, J. (2014). Adoption of cowpea hermetic storage by women in Nigeria, Niger and Burkina Faso. *Journal of Stored Products Research, 58*, 87–96.

ICRISAT. (2017). Enhancing Cowpea Productivity and Production in Drought-Prone Areas of Sub-saharan Africa. ⟨http://tropicallegumes.icrisat.org/wp-content/uploads/2017/12/TL-III-Bulletin-10.pdf⟩.

Issahaku, H., Mahama, I., & Addy–Morton, R. (2020). Agricultural labour productivity and credit constraints: Implications for consumption in rural Ghana. *African Journal of Economic and Management Studies, 11*(2), 331–351.

Jayathilake, C., Visvanathan, R., Deen, A., Bangamuwage, R., Jayawardana, B. C., Nammi, S., & Liyanage, R. (2018). Cowpea: An overview on its nutritional facts and health benefits. *Journal of the Science of Food and Agriculture, 98*(13), 4793–4806.

Jinbaani, A. N., Owusu, E. Y., Mohammed, A. R., Tengey, T. K., Mawunya, M., Kusi, F., & Mohammed, H. (2023). Gender trait preferences among smallholder cowpea farmers in northern Ghana: lessons from a case study. *Frontiers in Sociology, 8*, Article 1260407.

Kabambe, V., Tembo, Y., & Kazira, E. (2013). Awareness of the parasitic weed Alectra vogelii (Benth.) amongst extension officers in three districts in Malawi. *American Journal of Experimental Agriculture, 3*(2), 432.

Kermah, M., Franke, A., Adjei-Nsiah, S., Ahiabor, B., Abaidoo, R. C., & Giller, K. (2018). N2-fixation and N contribution by grain legumes under different soil fertility status and cropping systems in the Guinea savanna of northern Ghana. *Agriculture, ecosystems Environment, 261*, 201–210.

Kgosikoma, K. R., Lekota, P. C., & Kgosikoma, O. E. (2018). Agro-pastoralists' determinants of adaptation to climate change. *International Journal of Climate Change Strategies and Management*. https://doi.org/10.1108/IJCCSM-02-2017-0039

King, K., & Palmer, R. (2010). *Planning for technical and vocational skills development*. UNESCO.

Kwapong, N. A., Ankrah, D. A., Anaglo, J. N., & Vukey, E. Y. (2021). Determinants of scale of farm operation in the eastern region of Ghana. *Agricultural and Food Science, 10*(1), 1–11. https://doi.org/10.1186/S40066-021-00309-6

Lord, D. (2006). Modeling motor vehicle crashes using Poisson-gamma models: Examining the effects of low sample mean values and small sample size on the estimation of the fixed dispersion parameter. *Accident Analysis Prevention, 38*(4), 751–766.

Maredia, M. K., Shupp, R., Opoku, E., Mishili, F., Reyes, B., Kusolwa, P., Kusi, F., & Kudra, A. (2019). Farmer perception and valuation of seed quality: Evidence from bean and cowpea seed auctions in Tanzania and Ghana. *Agricultural Economics, 50*(4), 495–507.

MoFA (Ministry of Food and Agriculture, Ghana). (2021). Agriculture Sector Progress Report.

Mullahy, J. (1986). Specification and testing of some modified count data models. *Journal of Econometrics, 33*(3), 341–365.

Mulwa, C., Marenya, P., & Kassie, M. (2017). Response to climate risks among smallholder farmers in Malawi: A multivariate probit assessment of the role of information, household demographics, and farm characteristics. *Climate risk management, 16*, 208–221.

Mwinkom, F. X., Damnyag, L., Abugre, S., & Alhassan, S. I. (2021). Factors influencing climate change adaptation strategies in North-Western Ghana: evidence of farmers in the Black Volta Basin in Upper West region. *SN Applied Sciences, 3*, 1–20.

Nimoh, F., & Asuming-Brempong, S. (2012). Resource use efficiency for cowpea production in Akatsi District of Ghana. *Asian Journal of Agriculture and Rural Development, 2*, 55–61, 393-2016-23890.

Opoku, G., & Hanson, J.Y. (2008). An Empirical Investigation into the Use of English as the Medium of Instruction in Primary Schools in Ghana, 11(1), 25–48.

Osei-Asibey, R. K., Wireko-Manu, F. D., Aidoo, R., Boakye-Achampong, S., Mills-Robertson, F. C., & Baributsa, D. (2022). Farmers' perception of the use and benefits of cowpea storage methods in Northern Ghana. *Sustainability, 14*(9), 5129.

Punia, H., Tokas, J., Malik, A., Rani, A., Gupta, P., Kumari, A., Mor, V. S., Bhuker, A., & Kumar, S. (2020). Solar radiation and nitrogen use efficiency for sustainable agriculture. *In resources use efficiency in agriculture* (pp. 177–212). Springer.

Rani, A., Rani, K., Tokas, J., Singh, A., Kumar, R., Punia, H., & Kumar, S. (2020). Nanomaterials for agriculture input use efficiency. *In resources use efficiency in agriculture* (pp. 137–175). Springer.

Rawal, V., & Bansal, P. (2019). Chickpea: Transformation in production conditions. In In. D. K. Navarro (Ed.), *The global economy of pulses* (pp. 21–36). FAO.

Reddy, A. A., Sanyal, S., & Pratap, A. (2024). Policies and Incentives to Promote Pulses: Indian Perspective. In *Potential Pulses: Genetic and Genomic Resources* (pp. 310–340). GB: CABI.

Semba, R. D., Ramsing, R., Rahman, N., Kraemer, K., & Bloem, M. W. (2021). Legumes as a sustainable source of protein in human diets. *Global Food Security, 28*, Article 100520.

Sheoran, S., Kumari, P., Kumar, S., Jangir, C. K., Sheoran, S., Jhariya, M. K., & Jakhar, S. R. (2022). Legumes for improving socio-economic conditions of farmers in rainfed agroecosystem. *In advances in legumes for sustainable intensification* (pp. 679–696). Academic Press.

Singh, D., Sharma, S., Lal, M., Ranwah, B., & Sharma, V. (2013). Induction of genetic variability for polygenic traits through physical and chemical mutagens in cowpea [Vigna unguiculata (L.) Walp]. *Legume Research: An International Journal, 36*(1).

Stagnari, F., Maggio, A., Galieni, A., & Pisante, M. (2017). Multiple benefits of legumes for agriculture sustainability: An overview. *Chemical and Biological Technologies in Agriculture, 4*(1), 1–13.

Stephenson, K. B., Agapova, S. E., Divala, O., Kaimila, Y., Maleta, K. M., Thakwalakwa, C., Ordiz, M. I., Trehan, I., & Manary, M. J. (2017). Complementary feeding with cowpea reduces growth faltering in rural Malawian infants: A blind, randomized controlled clinical trial. *The American Journal of Clinical Nutrition, 106*(6), 1500–1507.

Tadele, Z. (2019). Orphan crops: their importance and the urgency of improvement. *Planta, 250*(3), 677–694.

Taluah, A. R. (2016). The Teaching and Learning of the English Language in Ghana: Problems and Implications. *Imperial Journal of Interdisciplinary Research, 2*(5).

Tambo, J. A. (2016). Adaptation and resilience to climate change and variability in north-east Ghana. *International Journal of Disaster Risk Reduction, 17*, 85–94.

Toku, A., Osumanu, I.K., Owusu-Sekyere, E., & Amoah, S.T. (2021). Conflicting urban land uses at the fringes: issues and experiences of peri-urban farmers in an urbanizing city in Ghana. 1(7), 1–23. https://doi.org/10.1007/S43545-021-00136-3.

Wahaga, E. (2019). The adoption of improved cowpea varieties in Northern Ghana..

Yusuf, A., & Dianda, M. (2014). Productivity and biological nitrogen fixation as influenced by groundnut genotypes and nitrogen fertilizer in the northern Guinea and Sudan savannas of Nigeria. *Balance, 40*(30), 20.