Received: 2 August 2022 | Revised: 12 April 2023 | Accepted: 25 April 2023

DOI: 10.1002/cli2.55

Climate Resilience and Sustainability
Interdisciplinary Approaches Towards Solutions for Climate Change
Open Access
RMetS

ORIGINAL ARTICLE

Building climate resilience through crop residue utilization: Experiences of Ghanaian smallholder farmers

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Funding information
Royal Society, London, Grant/Award Numbers: FCG\R1\211025, FLR\R1\201640

Abstract

A major limiting factor affecting the uptake of conservation agriculture practices in smallholder farming systems in sub-Saharan Africa is the limited availability of sufficient crop residues for use as surface mulch. This paper assesses the trade-offs in crop residue utilization among smallholder farmers and its implications for soil management in the face of climate change risks in northern Ghana. The paper triangulated data from 350 household surveys with participatory key informant interviews from seven selected communities in three districts of northern Ghana. The problem confrontation index (PCI) was adopted to identify and rank the challenges associated with farmers' decision to use crop residues, while a multivariate probit model was used to analyse and predict the factors that influence farmers' choice of crop residue management practices. Results showed that crop residues were used as cooking fuel in households (21%), livestock feed (21%), left on the farm to decompose as mulch (34%) or burned to clear the land (24%). Key challenges identified included high labour cost (PCI = 404), high labour intensity (PCI = 388), the cost and transport for collection and storage of externally sourced crop residue (PCI = 383) and the low benefit from crop residue to farm output/soil fertility (PCI = 339). Results from the multivariate probit model revealed that household and farm variables, institutional and socio-psychological factors, and experience of some climate shocks all influence farmers' choice of crop residue management practices. Crop residue use and management practices adopted were determined by factors including the crops being grown, challenges faced by farmers and the management options available. The study recommends the need for the Government of Ghana to empower farmers through the provision of technical knowledge and machinery for the sustainable utilization of crop residues due to the high labour intensity and cost associated with such practices.

KEYWORDS
climate-smart agriculture, food security, land management, livelihood sustainability, soil health, West Africa

1 INTRODUCTION

Climate change poses a serious challenge to many countries in sub-Saharan Africa (SSA), where rain-fed agricultural systems provide the livelihoods for millions of households (Intergovernmental Panel on Climate Change [IPCC], 2022). It is expected that future temperature increase and uncertain rainfall patterns will amplify existing stress on food production, water resources and health (IPCC, 2018). These climatic changes and associated risks could have considerable ramifications for the attainment of regional goals including the Africa Agenda 2063 and global goals including the Sustainable Development Goals and the commitments made under the Paris Climate Agreement (Antwi-Agyei et al., 2018).

The adverse consequences of climate change are expected to be more devastating especially in the arid and semi-arid regions such as the Sudan savannah agro-ecological zone (SSZ) in West Africa, where mixed crop–livestock production systems are already constrained by water scarcity and soil degradation (Callo-Concha et al., 2013). Poor water retention capacity and decline in soil organic matter and nutrient contents are major factors which adversely impact crop and fodder production leading to the inadequacy of food for people and livestock (Food and Agricultural Organization [FAO] and Intergovernmental Technical Panel on Soils [ITPS], 2015). This could compromise food production in this region that provides two-thirds of food for the African continent (Reynolds et al., 2015).

In Ghana, climate change manifests itself through increasing temperatures, erratic rainfall regimes and extreme weather events including severe droughts and floods across all the agro-ecological regions (Asante & Amuakwa-Mensah, 2014). Climate change and its associated risks are expected to adversely affect the production of food crops as well as the livelihood assets of most farming households in Ghana, particularly those in rural areas who depend mainly on agriculture for their livelihood (Atiah et al., 2021; Baffour-Ata et al., 2021).

Given the impacts of climate change on agricultural systems, adaptation mechanisms have become increasingly imperative for building household and community resilience in SSA. Therefore, increasing the capacity of soils to retain and supply water and nutrients to crops is essential for sustainable food production in the region. A range of sustainable land management interventions labelled as climate-smart agriculture (CSA) are increasingly being promoted to sustainably increase agricultural productivity and incomes, enhance resilience and adaptation to climate change and reduce greenhouse gas emissions (Dougill et al., 2021; Faurès et al., 2013; Lipper et al., 2014). One of the major CSA practices that have shown promise in reversing soil degradation and enhancing the resilience of agricultural systems to climate stress is conservation agriculture (CA) (Eze et al., 2020; Steward et al., 2018). CA involves the combined practices of minimum soil disturbance, permanent organic soil surface cover and crop diversification (Pittelkow et al., 2015; Food and Agriculture Organisation [FAO], 2009).

Notwithstanding the contribution of CA in improving food security and livelihood, particularly through enhanced carbon sequestration and improved yields (Anghinoni et al., 2021; Joshi et al., 2021), several factors impede its uptake and benefits for sustainable agriculture. One major factor limiting CA practices in smallholder farming systems that characterize SSA is the unavailability of sufficient crop residues used as soil surface mulch (Rusinamhodzi et al., 2016). We define crop residues to cover the remnants or stubbles from all types of crops that include roots, stubble, leaves and whole stalks of crops (Islam et al., 2021). Crop residues have multiple uses such as feed for livestock, fuel and building material. Studies have demonstrated the significant role played by agricultural crop residues in crop production via the prevention of soil erosion whilst maintaining soil fertility and enhancing soil water retention for sustainable crop cultivation (Toklu et al., 2017). However, the competing uses of crop residues lead to insufficient residues being made available as organic amendments on the soil. Several studies (e.g., Baudron et al., 2014; Mekonnen & Kohlin, 2009; Valbuena et al., 2015) have attributed the low adoption of CA in SSA to the availability of multiple crop residue management practices. It is, therefore, important to identify the sources, current uses and the severity of challenges associated with crop residues utilization by farmers since this will help explain the low application of crop residues as mulch in dryland farming systems of Ghana.

In mixed crop-livestock systems, feeding livestock with crop residues is the major competitor to the retention of crop residues as soil surface mulch (Jaleta et al., 2013). However, prioritizing the use of crop residues for feeding livestock can lead to the off-take of organic matter and nutrients, which further deepens the existing soil fertility problems and low crop and fodder productivity in the SSZ of West Africa. Although some determinants of crop residue utilization in the SSZ have been theoretically identified (see Valbuena et al., 2015), there remains a lack of empirical case studies on the implications of crop residue utilization trade-offs for soil fertility management in West Africa.

It is also important to understand the socioeconomic conditions and factors under which farming households make decisions on the utilization of crop residues for crop improvement purposes. This is necessary for the uptake of such interventions and how policies can be used to upscale CSA interventions to inform land management decisions and appropriate policies for a resilient agriculture and food security. Thus, using the SSZ in northern Ghana, this paper aims to provide a comprehensive understanding of the trade-offs in crop residue utilization among smallholder farmers and its implications for soil fertility management in African dryland farming systems. Specifically, the paper seeks to (i) identify the key sources and utilization of crop residues in dryland farming systems of northern Ghana; (ii) determine the key challenges affecting farmers' decision to utilize crop residues on their farms; and (iii) assess the factors influencing the utilization of crop residues.

2 | STUDY AREA AND RESEARCH DESIGN

2.1 | Description of the study area

The study was conducted in the West Mamprusi municipality in the North East Region, the Bongo district and Bolgatanga municipality in the Upper East Region of Ghana (Figure 1). The selected districts lie within the Sudan savannah agro-ecological zone and have a unimodal rainfall pattern that lasts from May/June to September/October. These regions were selected because they are greatly affected by climatic shocks such as floods, droughts and fluctuations in average temperatures. Three districts, namely West Mamprusi municipality, Bongo district and Bolgatanga municipality were selected because of their high vulnerability to drought and associated risks coupled with a large percentage of their population relying on rain-fed agriculture as their main source of livelihood (Antwi-Agyei et al., 2012, 2015a).

The study used a multistage sampling procedure to select respondents for the study communities. In the first stage, two regions (North East Region and Upper East Region) were purposively selected because of their relatively high vulnerability to climatic shocks (Asante & Amuakwa-Mensah, 2014; Klutse et al., 2020). In the second stage, three districts (West Mamprusi municipality, Bongo district and Bolgatanga municipality; Table 1) with substantial livestock and crop farmers were selected based on expert advice of regional agricultural development officers. Subsequently, with the aid of district agricultural officers, Sagadugu and Minima in the West Mamprusi municipality, Yikene and Zaare in the Bolgatanga municipality and Ayelbia, Sinabisi and Feo-Asabere in the Bongo district were selected. The final stage involved a random walk method to select smallholder farmers for the study.

2.2 | Research design and data collection

This study adopted a cross-sectional study design involving 350 farming households to understand trade-offs in crop residue utilization among smallholder farmers. We used a cross-sectional design because the data used in our study were collected at a single point in time (Oslen and St. George, 2004). A survey was conducted to collect data from 350 randomly selected smallholder farmers using the Census and Survey Processing System (CSPro) software (Ponnusamy, 2012) in the seven farming communities (Table 2). The survey was conducted from August 2021 to September 2021 in the study communities using locally trained enumerators and interpreters. The survey instrument comprised sections on the socioeconomic characteristics of the farmers, decision on crop residue utilization based on the theory of planned behaviour (Ajzen, 1991),[1] sources of crop residue and uses of crop residue. The questionnaire also solicited farmers' responses on the severity of challenges in their decision to use crop residues on their farms. The severity of each challenge was rated using the Likert scale ranging from 1 to 5 (where 1 = very low, 2 = low, 3 = moderate, 4 = high and 5 = very high). Questionnaires were administered at the convenience of the farmers with the face-to-face engagement mostly lasting between 45 minutes to 1 hour. Enumerators translated and asked the questions in the various local languages and recorded the responses in the English language.

Expert and key informant interviews were also conducted to explore the key issues emerging from the questionnaire surveys. Experts and key informants were selected based on their long-standing understanding of environmental change and agricultural planning decisions-making in the dryland farming system setting in northern Ghana. A total of 15 expert and key informant interviews were conducted. Experts and key informants interviewed for the study included the district directors of agriculture, agricultural extension officers, leaders

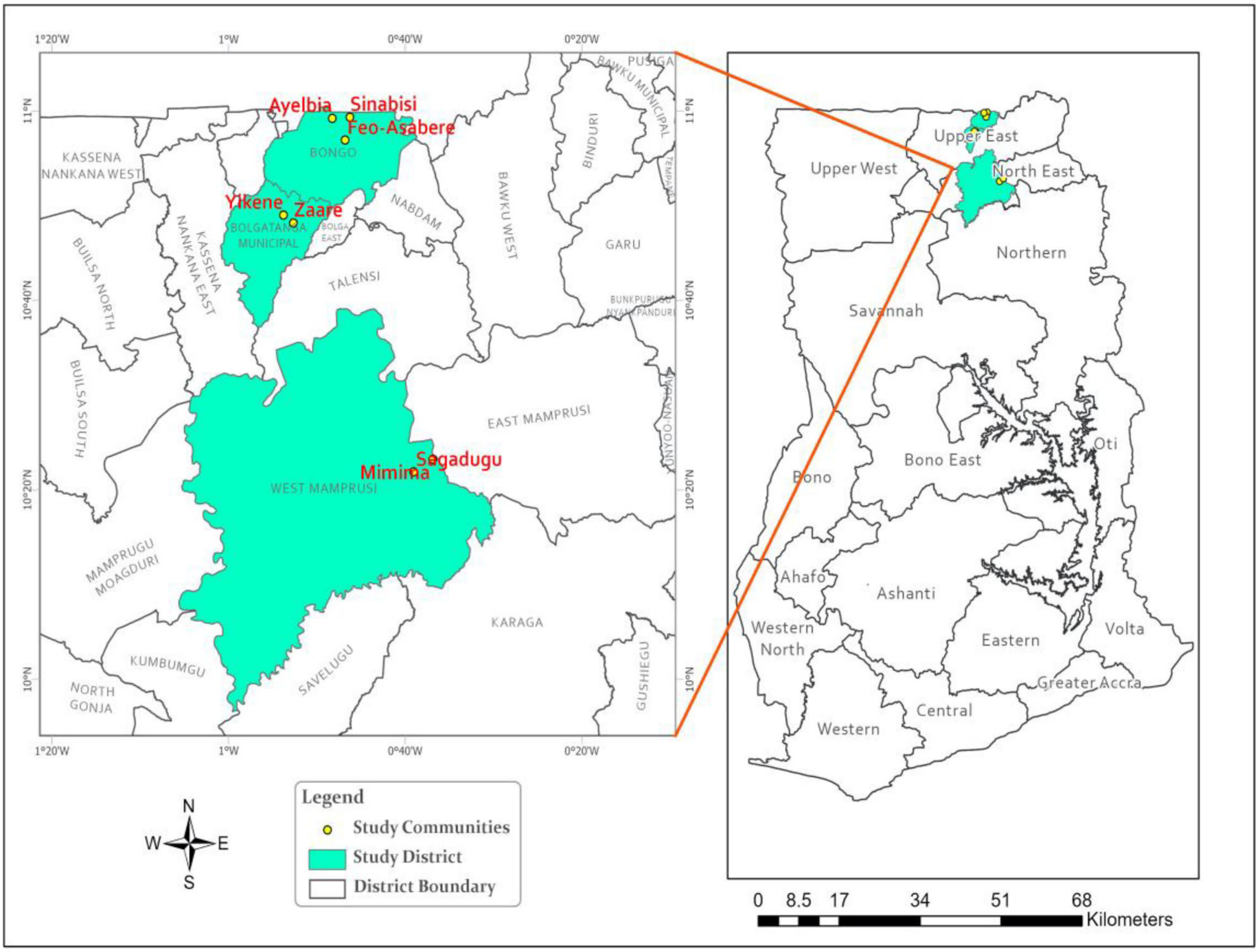

FIGURE 1 Location of study communities.

TABLE 1 Characteristics of study districts

Item	West Mamprusi municipal	Bongo district	Bolgatanga municipal
Coordinates			
Longitude	0°35' W and 1°45' W	0°W and 1°30'W	0°30'W and 1°00'W
Latitude	9°55' N and 10°35' N	10°30'N and 11°N.	10°30N and 10°50'N
Estimated population	175,755	120,254	139,864
Agro-ecological zone	Sudan savannah ecological zone	Sudan savannah ecological zone	Sudan savannah ecological zone
Average annual rainfall (mm)	950 –1200	600 –1400	800 –1100
Main livelihood activities	Crop farming, livestock rearing	Crop farming, livestock rearing	Crop farming, livestock rearing
Main crops	Maize, rice, sorghum, millet, soybeans, groundnuts, cowpea and yam	Millet, sorghum, groundnut, rice, maize	Millet, sorghum, rice, maize, groundnut, cowpea, soybean and Bambara beans
Main types of livestock	Cattle, chicken, goat, guinea fowl, sheep	Cattle, chicken, goat, guinea fowl, sheep	Cattle, chicken, goat, guinea fowl, sheep, pig
Average animal per keeper	14	10.8	13
Cropping season	Late April to Late October	May to mid-October	May to October

Source: Ghana Statistical Service (2014a, 2014b, 2014c, 2021).

TABLE 2 Characteristics of study communities

Item	West Mamprusi municipal		Bongo district			Bolgatanga municipal	
	Sagadugu	Mimima	Ayelbia	Sinabisi	Feo-Asabere	Yikene	Zaare
Total sample from district/municipality	87 (24.86%)		88 (25.14%)			175 (50.00%)	
Sample from communities	38	49	46	20	22	87	88
Percentage of sample	10.86%	14.00%	13.14%	5.71%	6.29%	24.86%	25.14%

of farmer-based organizations and farmers with several years of experience. The Humanities and Social Sciences Research Ethics Committee of the Kwame Nkrumah University of Science and Technology, Ghana, provided the ethical approval for this study. Formal consent for participation in the study was obtained verbally from each study participant.

2.3 | Data analysis

Descriptive statistics were used to identify the major sources of crop residues, the various uses of crop residues, and factors responsible for burning as a crop residue management option. The major crops cultivated in the study communities served as the basis for identifying the major sources of crop residue in this study. Crops such as millet, rice, maize, soybeans and groundnuts have been identified as the principal crops grown in northern Ghana. Ericsson and Nilsson (2006) argue that crop production can be used to adequately estimate crop residues. To this effect, we proceeded based on the assumption that the main sources of crop residues are a function of the major crops cultivated in the study communities. The Welch's *t*-test was used to test for gender differences in the four main uses of crop residues. The Welch *t*-test was appropriate for this study because the assumption of equal variance of the student *t*-test did not hold given the difference in the sample size of male and female smallholder farmers (Delacre et al., 2017).

To identify the challenges associated with farmers' decision to use crop residues in the study communities, the problem confrontation index (PCI) was adopted for this study. The PCI is used to rank challenges and constraints faced by farmers, and its utility has been explored in several studies (e.g., Antwi-Agyei et al., 2021; Kabir et al., 2019; Ndamani & Watanabe, 2015). Farmers were required to rank 17 challenges associated with crop residue management on a 5-point weighting scale. The scale provided five alternative responses (very high, high, medium, low and very low) for each of the selected challenges. The weights assigned for the responses were: 'Very high' = 5, 'High' = 4, 'Medium' = 3, 'Low' = 2, and 'Very low' = 1. The PCI for the overall sample and gender-wise were then computed using the mathematical model:

$$\text{PCI} = (P_{vh} \times 5) + (P_h \times 4) + (P_m \times 3) + (P_l \times 2) + (P_{vl} \times 1), \quad (1)$$

where P_{vh} is the total number of farmers that regard the severity of the challenge as very high, P_h is the total number of farmers that regard the severity of the challenge as high, P_m is the total number of farmers that regard the severity of the challenge as medium, P_l is the total number of farmers that regard the severity of the challenge as low, and P_{vl} is the total number of farmers that regard the severity of the challenge as very low.

A multivariate probit model was used to analyse the factors that influenced farmers' choice of crop residue management practices. The model was deemed appropriate because the choice of crop residue management practices was not mutually exclusive (i.e., a farmer can simultaneously choose multiple crop residue management practices). This model was preferred to other econometric models because of its robustness in establishing a correlation between unobserved disturbances, which may arise from the complementarities and substitutabilities between the various crop residue management practices (Green, 2012).

Several crop residue management options were identified through an extensive review of the literature. It was observed that crop residue was an important resource for smallholder farmers in SSA. Smallholder farmers in the sub-region manage their crop residues by either leaving them on the farm as mulch, selling them, used as feed (especially in mixed farming systems) or other purposes (including cooking fuel, construction materials and burnt) (Valbuena et al., 2012, 2015). This list of crop residue management practices was presented to key informants in the study communities for validation, and it was established that, smallholder farmers in the study communities managed their crop residues through four main ways (i.e., left on the farm to decompose as mulch, used as livestock feed, used as cooking fuel or burnt). This then formed the basis for the selection of four crop residue management options used in our study.

Given a set of crop residue management practices, say, ($j = K, L, M, N$), where K is leaving the crop residues to decompose on the farm, L is using the crop residues as livestock feed, M is using the crop residues as cooking fuel and N is burning, a farmer is faced with the decision on the mix of practices to adopt. The adoption of jth crop residue management practice is hypothesized to be determined by farmer and farm characteristics, as well as, institutional, climate and socio-psychological factors.

Following Martey and Kuwornu (2021), the selection of crop residue management practice j by farmer k is defined as y_{jk}. The decision of farmer k to adopt practice j ($y_{jk} = 1$) or not ($y_{jk} = 0$) is given by

$$y_{jk} = \begin{cases} 1 \; if \; y_{jk} = x'_{jk}\beta + \varepsilon_{jk} \geq 0, \; x'_{jk}\beta \geq -\varepsilon_{jk} \\ 0 \; if \; y_{jk} = x'_{jk}\beta + \varepsilon_{jk} < 0, x'_{jk}\beta < -\varepsilon_{jk} \end{cases}, \quad (2)$$

where β is a vector of estimators and ε_{jk} is a vector of error terms which is normally distributed, y_{jk} is the dependent variable representing $leave\_to\_decompose\_on\_farm_k$, $livestock\_feed_k$, $cooking\_fuel_k$, and $burn_k$ which are dichotomous variables that assume a value of 1 when farmer k chooses to leave the crop residues to decompose on the farm, use the crop residues as livestock feed, use them as cooking fuel or burn the crop residues respectively. X'_{ij} is the combined effect of the explanatory variables.

The error terms from the multivariate probit model jointly follow a multivariate normal distribution (MVN) with zero conditional mean. The variance is normalized to unity, where $(\varepsilon_L, \varepsilon_M, \varepsilon_N) \approx \mathrm{MVN}(0, \Omega)$ and the symmetric covariance matrix Ω ($n\times n$ correlation matrix) is defined as

$$\Omega = \begin{bmatrix} 1 & \rho KL & \rho KM & \rho KN \\ \rho LK & 1 & \rho LM & \rho LN \\ \rho MK & \rho ML & 1 & \rho MN \\ \rho NK & \rho NL & \rho NM & 1 \end{bmatrix} \quad (3)$$

The non-zero off-diagonal elements in the covariance matrix represent the unobserved correlation between stochastic components of the different crop residue management practices. The resulting correlation coefficients establish the complementary (i.e., positive correlation) and substitution associations (negative correlation) among the various crop residue management practices.

The qualitative data from expert and key informant interviews were transcribed, categorized and interconnected with the quantitative survey data to build a narrative to develop a comprehensive understanding of the trade-offs in crop residue utilization among smallholder farmers and its implications for soil fertility management. Content analysis was used to reveal the themes that emerged from the qualitative data (Antwi-Agyei & Stringer, 2021; Creswell & Creswell, 2017).

2.4 | Choice of explanatory variables

Variables selected for the study were informed by previous studies. Farmers' adoption decisions (in this case, crop residue management options) have been noted to be significantly influenced by household characteristics such as gender, age and marital status (see Lopes et al., 2020; Martey & Kuwornu, 2021). Several factors classified as farm characteristics (e.g., distance to farm, farm size and years of farming) and institutional factors (e.g., land tenure security, access to extension, access to credit, access to input market and membership of a farmer-based organization) significantly affect farmer decisions, particularly with regard to selecting an appropriate crop residue management practice (see Langyintuo & Mungoma, 2008; Lopes et al., 2020; Martey & Kuwornu, 2021). Experiencing climatic shocks (such as erratic rainfall patterns, drought and invasive weeds) inform farmers' choice of adaptation practices such as the management of crop residues (see Alhassan et al., 2019; Sadiq et al., 2019).

Socio-psychological factors significantly influence farmers' adoption of agricultural practices especially when such practices have both social and environmental consequences (Meijer et al., 2015). The management of crop residues on farms is demonstrated to have significant environmental consequences. Three socio-psychological variables (i.e., attitude, subjective norm and perceived behaviour control) derived from the theory of planned behaviour (Ajzen, 1991) were used in the study. Studies such as Atta-Aidoo et al. (2022) and Dessart et al. (2019) have established the importance of socio-psychological factors in examining farmers' adoption of sustainable agricultural practices. Multiple correspondence analysis was used to create an index for each of the three variables based on questionnaires adopted and modified from Taylor & Todd (1995) and Shih & Fang (2004). We applied the Burt approach to multiple correspondence analysis and used principal normalization, which scales the coordinates by principal inertias (STATA, 2015). Results of the multiple correspondence analysis are presented in the Appendix.

3 | RESULTS

A total of 350 farmers comprising 198 females and 152 males were included in the survey (Table 3). In terms of education, more males (n = 100; 65.79%) reported having some form of formal education than female farmers (n = 76; 38.38%). Results showed that on-farm agricultural livelihood activities provided the source of income to the majority of study respondents.

TABLE 3 Socio-demographic characteristics of respondents

		Gender	
Variables	**Total (*n* = 350) (100%)**	**Females (*n* = 198) (56.57%)**	**Males (*n* = 152) (43.43%)**
Education			
No formal education	174 (49.71%)	122 (61.62%)	52 (34.21%)
Formal education	176 (50.29%)	76 (38.38%)	100 (65.79%)
Source of income			
On-farm	286 (81.71%)	158 (79.80%)	128 (84.21%)
Off-farm	64 (18.29%)	40 (20.20%)	24 (15.79%)
Farm size (in hectares)			
≤2	241 (68.86%)	161 (81.31%)	80 (52.62%)
3–10	104 (29.71%)	35 (17.67%)	69 (45.40%)
≥11	5 (1.43%)	2 (1.01%)	3 (1.98%)
Age			
≤30	95 (27.14%)	49 (24.75%)	46 (30.26%)
31–50	198 (56.57%)	107 (54.04%)	91 (59.87%)
51–70	52 (14.86%)	40 (20.20%)	12 (7.89%)
≥71	5 (1.43%)	2 (1.01%)	3 (1.98%)
Years of farming			
≤5	80 (22.86%)	51 (25.76%)	29 (19.08%)
6–15	121 (34.57%)	64 (32.32%)	57 (37.50%)
16–30	117 (33.43%)	63 (31.82%)	54 (35.53%)
≥31	32 (9.14%)	20 (10.10%)	12 (7.89%)
Marital status			
Unmarried	68 (19.43%)	150 (75.75%)	132 (86.84%)
Married	282 (80.57%)	48 (24.24%)	20 (13.16%)
Access to credit			
No	280 (80.00%)	149 (75.25%)	131 (86.18%)
Yes	70 (20.00%)	49 (24.74%)	21 (13.82%)

Source: Survey data (2021).

TABLE 4 Frequencies and percentages of main sources of crop residues

	Overall		Female		Male	
Crops	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Millet	149	42.57	73	48.03	76	38.38
Rice	112	32.00	48	31.58	64	32.32
Maize	86	24.57	30	19.74	56	28.28
Soybean	1	0.29	1	0.65	0	0.00
Groundnut	2	0.57	0	0.00	2	1.02
Total	350	100	152	100	198	100

Source: Survey data (2021).

Results indicated that millet serves as the main source of crop residue among both male and female farmers in the study area (Table 4). Rice was the second major source of crop residue among both female and male farmers in the study areas. Maize was the third major source of crop residue among the farmers, while soybean and groundnut provided crop residues for a limited number of farmers.

Crop residues were identified to be managed in four main ways: (i) cooking fuel in households, (ii) utilized

TABLE 5 Frequencies and percentages of the main uses of crop residue

Main use of crop residues	Overall		Female		Male	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Leave to decompose	120	34.29	68	34.34	52	34.21
Burn	83	23.71	41	20.71	42	27.63
Livestock feed	74	21.14	40	20.20	34	22.37
Cooking fuel	73	20.86	49	24.75	24	15.79
Total	350	100	198	100	152	100

Source: Survey data (2021).

as livestock feed, (iii) left on the farm to decompose and (iv) burned to clear the land. The majority of farmers reported that they left their crop residues to decompose on their farms. 'Our farmers are now gradually understanding the need to leave crop residues on the farm. They now realize the soil fertility-enhancing benefits of leaving crop residues on the farm after harvesting' (key informant interview, Bongo district).

Additionally, a male farmer indicated that

> the extension officers have educated us on the need to leave crop residues on the farm. Leaving crop residues on the farm is good for our soil and many of us now leave the residues to decompose on the farm. By the time we are starting the next season, you realize the residues have decomposed and enriched the soil for good crop development and yield. (key informant interview, Bolgatanga)

Our results further indicated that burning of residues was the second most used crop residue management practice among all farmers. More male farmers reported of burning their crop residues compared to female farmers (Table 5). Farmers who reported using crop residues on their farm as feed for their livestock was high among male farmers compared to female farmers. In relation to the use of crop residues as cooking fuel, more female farmers reported using their crop residues as cooking fuel compared to their male counterparts. 'Sometimes it is difficult to find firewood in these communities and most of the women here tend to use crop residues for cooking in our homes' (female farmer key informant interviews, Bongo district).

About a quarter of farmers reported employing burning as the means of managing crop residues on their farms. Table 6 presents the five main reasons why farmers decide to burn their crop residues. More than half of the farmers reported burning their crop residues to prepare their farmlands for seeding (i.e., they opted to burn their crop residues due to the short interval between harvesting and planting). A key informant indicated:

> We often produce so much crop residues which become a nuisance on the farm especially when you want to prepare the land for another planting session. To address this, most of our farmers burn the residues to make way for land preparation. (key informant interview, Bolgatanga)

Gender-wise, few more female farmers burn their crop residues to prepare their farmlands than male farmers. The second reason assigned for crop residue burning was the excessive amount of crop residue on the farmland. Slightly more male farmers resorted to crop residue burning due to labour scarcity in properly disposing of residues than female farmers. The absence of appropriate crop residue management technologies was reported as the fourth main reason for burning crop residues on farmlands in the study areas. Social influence was reported by less than 5% of farmers as the reason for burning crop residues on their farmlands.

Table 7 indicates that there are significant gender differences in the use of crop residues. The results revealed that significantly more male farmers left their crop residues on the farm to decompose as mulch. Again, significantly more male farmers opted to burn the crop residue on the farm than female farmers. On the other hand, significantly more female farmers used their crop residues as cooking fuel than their male counterparts.

In terms of challenges that affect the decision of both male and female farmers to use crop residue on their farms, the results showed that the high labour cost associated with utilizing crop residue was ranked as the highest challenge (PCI = 404). The high labour intensity associated with utilizing crop residues was ranked by male farmers as the second highest (PCI = 173) challenge while female farmers ranked it as the third highest challenge (PCI = 215) affecting farmers' decision to use crop residue on the farm

TABLE 6 Frequencies and percentages for reasons for burning crop residues

Reason for burning	Overall		Female		Male	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Land preparation	43	51.81	23	56.10	20	47.62
Excess crop residue	17	20.48	8	19.51	9	21.43
Labour scarcity	13	15.66	5	12.20	8	19.05
Absence of technology	7	8.43	3	7.32	4	9.52
Social influence	3	3.61	2	4.88	1	2.38
Total	83	100	41	100	42	100

Source: Survey data (2021).

TABLE 7 Welch *t*-test comparing the choice of crop residue used by male and female farmers

	Female		Male		*t*-test	*p*-value
	Mean	*SD*	*Mean*	*SD*		
Leave to decompose on the farm	0.92	0.02	0.99	0.01	−3.14	0.00
Burn	0.04	0.01	0.09	0.02	−1.91	0.02
Livestock feed	0.63	0.03	0.66	0.04	−0.64	0.52
Cooking fuel	0.64	0.03	0.51	0.04	2.54	0.01

Source: Survey data (2021).

(Table 8). A farmer remarked: 'managing crop residues on the farms has always been a problem for farmers in this community. We, therefore, resort to burning to clear the way for the new planting season' (male farmer, Key informant interviews, Walewale). The cost and transportation for collection and storage of crop residue in cases where such residues are externally sourced were highly ranked by both male and female farmers. Whereas female farmers ranked low benefit from crop residue to farm output (PCI = 203) and low benefit from crop residue to soil fertility (PCI = 200) as the fourth and fifth challenges, respectively, male farmers ranked the relevance of mineral or elements from residue type to the needs of the crop to be planted in the next season (PCI = 138) and low benefit from crop residue to farm output (PCI = 136) as the fourth and fifth challenges that affect their decision to use crop residues on their farms.

Other challenges that affect farmers' decision to use crop residues on their farms included a slow rate of decomposition, inadequate education from extension officers on crop residue utilization, as well as crop residues creating a conducive environment for pests, diseases and weeds (Table 8). An expert provided this characteristic remark in an expert interview:

> although our farmers are advised and encouraged to leave their crop residues on the farm. They have been educated on the benefits of leaving such crop residues on the farms for improved soil fertility management. Nonetheless, most of them are reluctant to do that because of the notion that crop residues harbor pest and other diseases that might affect their farm crops. (extension officer, expert interview, Bolgatanga)

The least ranked challenges that affected farmers' decision to use crop residues on their farms were social conflict from burning crop residue on the farm, environmental problems from burning crop residue on the farm, and health problems from burning crop residue on the farm.

During the expert interview, extension officers related the livestock rearing system as a major problem for crop residue management in the study communities. An expert remarked: 'the livestock rearing system in northern Ghana is not helping the management of crop residues because cattle will always consume crop residues left on farms'. Others highlighted that it takes a long time to derive the benefits of crop residues on the farm: 'Adaptation of CSA practices is a long-term investment on the land, but landowners will always take back their lands if they realized that tenants have improved the soil fertility significantly through CSA practices and are getting good yield'.

The results of the multivariate probit regression (Equation 2) are presented in Table 10. The log-likelihood value of −402.16 and the Wald chi-square value of 223.91 ($p < 0.01$) indicate a good model fit which implies that the predictors significantly explained the dependent variables. The test of independence between the choice of a crop residue management practice, which is given by the likelihood ratio test ($\rho_{21} = \rho_{31} = \rho_{41} = \rho_{32} = \rho_{42} = \rho_{43}$), is statistically significant at 1% level, indicating the goodness

TABLE 8 Problem confrontation index (PCI) for the severity of challenges affecting farmers' decision to use crop residue on their farms

		Overall		Female		Male	
S/N	Challenge	PCI	Rank	PCI	Rank	PCI	Rank
1	High labour cost	404	1	227	1	177	1
2	High labour intensity	388	2	215	3	173	2
3	Cost and transport for collection and storage of crop residue (if the residue is sourced externally)	383	3	216	2	167	3
4	Low benefit from crop residue to farm output in the next season	339	4	203	4	136	5
5	Low benefit from crop residue to soil fertility over time	332	5	200	5	132	6
6	Nutrients from residue type do not meet the needs of the crop to be planted in the next season	326	6	188	6	138	4
7	Climatic conditions (rainfall and temperature variability) on crop cultivation	307	7	183	7	124	7
8	The types of crops cultivated determine the distribution of crop residues available at the end of the season	281	8	162	10	119	8
9	Slow rate of decomposition	272	9	163	9	109	10
10	Inadequate education from extension officers on crop residue utilization	272	9	170	8	102	11
11	Low benefit from crop residue to weed intensity	268	11	155	11	113	9
12	Inadequate crop residues for use as mulch	233	12	142	12	91	13
13	Creates a conducive environment for pests and diseases	223	13	131	13	92	12
14	Creates a conducive environment for weed	176	14	98	14	78	14
15	Social conflict from burning crop residue on the farm	158	15	88	15	70	16
16	Environmental problems from burning crop residue on the farm	151	16	78	17	73	15
17	Health problems from burning crop residue on the farm	150	17	80	16	69	17

Source: Survey data (2021).

of fit of the model. Hence, there exist differences in the crop residue management practice selection behaviour among farmers, which is given by the likelihood ratio statistics.

Results showed the correlation matrix of the multivariate probit model of farmers based on their crop residue management practices (Table 9). The third, fourth and fifth columns show how farmers combine different crop residue management practices. A negative correlation coefficient between the error terms of two crop residue management practices suggests that they are substitutes/competing, and a positive correlation coefficient indicates complementarity. The study found a positive relationship between leaving the residue to decompose on the land and using the residues as livestock feed which implies that farmers who leave residues to decompose on the land also use some residues as livestock feed. The correlation between leaving residues to decompose on the farm and using residues as cooking fuel was positive indicating complementarity between the two practices. The correlation between leaving residues to decompose on the farm and burning residues was positive, indicating that the two practices were used together. The correlation between

TABLE 9 Correlation matrix derived from the MVP model

Choice of crop residue management practice	Decompose on farm	Livestock feed	Cooking fuel	Burning
Decompose on farm	1	0.34	0.17	0.05
Livestock feed		1	0.31	0.18
Cooking fuel			1	−0.13
Burning				1

using residues as livestock feed and burning residues was positive, indicating that farmers who used some residues as livestock feed were more likely to burn crop residues.

The probability of leaving crop residues to decompose on the farm is about 144% less likely among female farmers than male farmers (Table 10). Female farmers were estimated to be about 49% more likely to use their crop residue as cooking fuel than male farmers. Farmers whose main source of income was from off-farm activities were about 127% less likely to leave their crop residues to decompose on the farm and were about 65% more likely to burn their crop residues than farmers whose main income source was from on-farm activities. It was estimated that older farmers were approximately 3% less likely to burn their crop residues. Results further indicated that the distance from a farmer's home to the farm increases the probability of leaving the crop residues to decompose on the farm by about 1% while reducing the likelihood of using the crop residues as livestock feed by less than 1% and using the residues as cooking fuel by about 1%. The years of farming increase the probability of using crop residues as livestock feed by about 3% and the likelihood of burning crop residues by about 4%, whereas farm size reduces the probability of using residues as livestock feed by about 8%.

Socio-psychological factors such as the attitude of the farmer decrease the farmers' likelihood of using the residues as livestock feed by about 16% and using the residues as cooking fuel by 21%. Subjective norm which measures the pressure exerted on the farmer by the society decreases the likelihood of using crop residues as livestock feed by approximately 25% and increases the likelihood of burning crop residues by about 46% (Table 10). Perceived behaviour control which measures the farmers' control over the use of crop residues increases the farmers' likelihood of leaving the residues to decompose on the farm by approximately 30% and reduces the likelihood of using the residues as livestock feed by about 15%. Farmers who have legal security over their farmlands are about 111% more likely to leave their crop residues to decompose on their land compared with farmers without legal land tenure security. Farmers with access to extension services are about 57% less likely to use their residues as cooking fuel than farmers without access to extension services. Access to credit is estimated to reduce the probability of using residues as livestock feed by 46% and using residues as cooking fuel by about 98% but increases the likelihood of burning crop residues by about 65%. The results show that experiencing erratic rainfall increases the likelihood of leaving the residues to decompose on the farm by about 67% (Table 10). Farmers who have experienced drought are approximately 151% more likelihood to leave crop residues to decompose on the farm and are about 36% more likely to use residues as livestock feed, but are about 65% less likely to use their residues as cooking fuel.

4 | DISCUSSION

4.1 | Crop residues management practices on the farm

The study identified that the majority of crop residues available to northern Ghanaian farmers originated from three main crops (i.e., millet, rice and maize). Millet is a widely grown crop in the savannah agro-ecological zone due to its ability to flourish on marginal lands with low rainfall conditions (Kanton et al., 2015). About 10% more female farmers regarded millet as their main source of crop residue because most female farmers tend to cultivate millet due to its low input requirements. Because female farmers have limited access to resources, they prefer to cultivate crops that require less commitment of resources such as fertilizer. Additionally, females are mostly in charge of household food preparation and as such cultivate more millet due to its food security implication for the household as millet is used in the preparation of most local delicacies such as "*Hausa koko*" and "tuo-zaafi" as well as drinks like "*fula*", "*zom koom*" and "*zirkom*" (Ghana Tourism Authority, 2016). With regard to rice and maize, more male farmers reported them to be their source of crop residue. Male farmers tend to cultivate rice and maize because they are commercially viable crops which continue to experience increasing demands. The increase in the cultivation of maize in the savannah agro-ecological zone is due to the increase in demand for maize by consumers from southern Ghana, the poultry industry, and beer breweries (Mangnus & van Westen, 2018).

TABLE 10 Multivariate probit estimates of factors influencing the choice of crop residue management

Factors	Alternative crop residue management options			Burning
	Decompose on farm	Livestock feed	Cooking fuel	
Household factors				
Gender (1 = female)	−1.44 (0.51) ***	−0.09 (0.16)	0.49 (0.17) ***	−0.43 (0.31)
Source of income (1 = off-farm income)	−1.27 (0.41) ***	−0.12 (0.20)	0.18 (0.22)	0.65 (0.36) *
Age	0.00 (0.02)	−0.01 (0.01)	0.00 (0.01)	−0.03 (0.02) *
Marital status (1 = married)	−0.05 (0.43)	−0.08 (0.20)	−0.62 (0.23) ***	−0.13 (0.39)
Farm factors				
Years of farming	−0.02 (0.02)	0.03 (0.01) ***	0.01 (0.01)	0.04 (0.02) **
Distance to farm (in miles)	0.01 (0.00) ***	−0.00 (0.00) **	−0.01 (0.01) **	−0.03 (0.02)
Farm size (in hectares)	−0.02 (0.08)	−0.08 (0.03) **	−0.03 (0.04)	0.02 (0.06)
Socio-psychological factors				
Attitude	−0.07 (0.19)	−0.16 (0.09) *	−0.21 (0.10) **	0.06 (0.18)
Subjective norm	−0.31 (0.19)	−0.25 (0.10) **	−0.12 (0.10)	0.46 (0.19) **
Perceived behaviour control	0.30 (0.15) **	0.15 (0.08) *	0.06 (0.10)	−0.16 (0.18)
Institutional factors				
Land tenure security (1 = legal security)	1.11 (0.54) **	−0.20 (0.21)	−0.29 (0.23)	−0.04 (0.46)
Access to extension service (1 = Yes)	0.45 (0.46)	−0.17 (0.18)	−0.57 (0.19) ***	0.11 (0.37)
Access to credit (1 = Yes)	−0.12 (0.41)	-0.46 (0.20) **	−0.98 (0.20) ***	0.65 (0.35) *
Access to input market (1 = Yes)	−0.46 (0.47)	−0.18 (0.21)	0.25 (0.23)	1.42 (0.68) **
Farmer organization member (1 = Yes)	−0.64 (0.42)	0.04 (0.18)	−0.17 (0.19)	−0.87 (0.35)
Climate factors				
Experienced erratic rainfall (1 = Yes)	0.67 (0.40) *	0.22 (0.17)	0.28 (0.19)	0.14 (0.36)
Experienced flood (1 = Yes)	0.06 (0.35)	0.08 (0.17)	0.59 (0.19) ***	0.10 (0.36)
Experienced drought (1 = Yes)	1.51 (0.48) ***	0.36 (0.17) **	−0.65 (0.20) ***	−0.27 (0.36)
Experience invasive weed (1 = Yes)	−0.94 (0.46) **	0.07 (0.19)	0.29 (0.21)	0.36 (0.46)
Constant	5.19 (1.85)	1.13 (0.70)	0.34 (0.78)	−2.28 (1.59)
Log Likelihood value	−458.15			
Wald chi-square (76)	187.66***			
Number of observations	350			
Likelihood ratio test Ho: $\rho_{21} = \rho_{31} = \rho_{41} = \rho_{32} = \rho_{42} = \rho_{43} = 0$; $Chi^2(6) = 18.73$ ***				

Note: *, ** and *** indicate 10%, 5% and 1% significance levels. Numbers in parentheses indicate robust standard error.

Most study respondents indicated that they left their crop residues to decompose on the farm. This practice seems to be the commonest practice among both male and female farmers who mostly abandon their farms immediately after harvesting until the next growing season. Despite the soil fertility-enhancing benefit of leaving crop residues on the farm, this practice may be a temporal management strategy until the next crop growing season. Farmers usually burn crop residues that do not decompose at the start of the next cropping season because such residues may interfere with tillage and succeeding operations for the subsequent crop (Goswami et al., 2020; Turmel et al., 2015). Although burning residues has been noted to cause reduced soil fertility through increased soil temperature which reduces bacterial and fungal population (Bhuvaneshwari et al., 2019), farmers still consider burning as the quickest and cheapest means of clearing excess residues on their farms (Chawala & Sandhu, 2020; Lopes et al., 2020). The use of crop residues as a source of household cooking fuel reduces the quantity of residues retained on the farm to serve as mulch and this may have a negative effect on soil quality in the long term as a result of reduced water infiltration (Baudron et al., 2012). Results showed that farmers also use crop residues to feed their livestock, a common practice in northern Ghana because almost every household in the savannah agro-ecological zone of Ghana owns livestock. It is observed that farmers use their crop residues as feed for their livestock mostly in cases where the farmers own livestock to reduce the cost of feeding the livestock through the purchase of feeds (Raza et al., 2022).

Despite the negative impact of crop residue burning on the fertility of the soil, farmers regard burning as essential because in addition to clearing residues, burning further control weeds, insects and diseases directly and indirectly by changing their natural habitat (Pathak et al., 2011). Farmers also view residue burning on-farm as an inexpensive and traditional way of land preparation (Keil et al., 2021).

Excess crop residue was the second major reason for the burning of residues by farmers. In most cases, farmers adopt several residue management practices in order to handle their residues but when there is excess after utilizing the residues in several other ways, burning becomes the last option adopted by farmers to manage the crop residues on the farm. The scarcity of labour in properly managing crop residues was the third reason farmers burn their residues. The sustainable management of crop residues on-farm is a labour-intensive endeavour and as such, the scarcity of labour to undertake such residue management leaves excess residues which can only be managed through burning (Lohan et al., 2018; Venkatramanan et al., 2021). Other farmers attributed their burning of crop residue to the absence of appropriate crop residue management technology (Shyamsundar et al., 2019). This is because farmers in the study area just like most farmers in SSA are unaware of the existence of crop residue management technologies. Such findings resonate with Lopes et al. (2020), who suggested that crop residue burning is a herd behaviour among farmers.

4.2 | Challenges associated with the use of crop residues

Results showed that several challenges inhibit farmers' decision to utilize crop residue on their farms. The high labour cost and labour intensity associated with crop residue utilization were highly ranked challenges affecting farmers' decision to use crop residues on their farms. These challenges are prevalent in larger farms because retaining crop residues for use requires additional labour which adds to the cost of production (Chen et al., 2019). For example, the decision to retain crop residue for use on the farm requires farmers to protect the residues from stray animals such as cattle from grazing on the residues on the farm. Such protection requires additional labour to either carry residues to the homestead after harvesting and then bring them back to the field at planting or fencing the farm (Rusinamhodzi et al., 2015). Additionally, retaining crop residue for incorporation into the soil is a labour-intensive endeavour as suitable crop residue managing machinery is not available (Goswami et al., 2020; Lohan et al., 2018).

The cost and transport for collection and storage of crop residue especially if the residues are sourced externally was an important challenge identified by the farmers. Residues from millet and maize are noted to be bulky and therefore provide a significant challenge in terms of transportation (Gurmessa et al., 2016). Farmers who decide to acquire additional crop residues to supplement those on their farms are faced with difficulties due to the high cost of transporting the residues to their farms (Atuhaire et al., 2014) and the significant loss of residues due to improper storage facilities (Tesfaye & Chairatanayuth, 2007). Farmers weigh the associated cost and benefit of acquiring residues from other farms before making a decision on transporting crop residues for use on their farms. Another challenge to the decision to utilize crop residues was the slow rate of decomposition. Rapid decomposition of crop residues reduces soil cover and may promote the emergence of weeds due to increased soil fertility (Ranaivoson et al., 2017); however, farmers tend to associate delayed decomposition with excessive residues and may opt for alternative management practices such as residue burning. Another key result highlighted in the expert interview relates to the long-term investments required to implement CSA interventions and the tendency for landowners to take back their lands when they realize tenant farmers have improved soil fertility through the use of CSA. This relates to land tenure issues which are a major obstacle to climate change adaptation practice in the Upper East Region of Ghana (see Antwi-Agyei et al., 2015b).

4.3 | Determinants of the various crop residue management practices

The adoption and use of sustainable land practices such as using crop residues for mulching are less likely to occur among female farmers. The low adoption rate of such sustainable practices among female farmers may be due to their limited access to finances, land and other farming inputs (Kristjanson et al., 2017; Makate et al., 2017; Nġombe et al., 2017). Decisions to adopt soil restorative practices are lower among females who normally operate smaller farm sizes and such decisions may be subject to the approval of their spouse (Kahimba et al., 2014; Ndiritu et al., 2014). Contrary to the assertions of Rahut et al. (2019) who indicated that females choose cooking fuels that are convenient and easy to use when deciding on their choice of cooking fuel, we argue that women were more likely to use crop residues as cooking fuel because it is a cheaper alternative and hence left fewer on their farms to decompose as mulch. The main source of income of the farmer played an important role in the farmers' choice of crop residue management practices. Farmers with a greater share of their income from non-farm activities face less agricultural risk and are less likely to adopt sustainable agricultural practices such as using crop residues for mulch (Valbuena et al., 2012). The marginal contribution farming makes to the income of farmers whose main income source is off-farm explains their affinity to burn crop residues rather than use them to better the fertility of their farmland.

Socio-psychological factors such as the attitude of the farmer towards crop residue utilization in relation to sustainable land management significantly influenced the practices adopted by farmers. Farmers' attitude towards retaining crop residue on the farm informed their decision to reduce their likelihood of using the crop residues for other off-farm activities. This is because farmers' attitude has been suggested by planned behaviour theorists to significantly enhance the adoption of conservative agricultural practices for sustainable livelihood (Bozorgparyar et al., 2018). Farmers' decision to retain crop residues on their farms to enhance soil fertility is significantly determined by social pressure exerted by co-farmers. Farmers are more inclined to burn their crop residues because crop residue burning has been noted to be a herd behaviour (i.e., determined by social influence and support) (Lopes et al., 2020). Perceived behaviour control, which measures farmers' perception of their capabilities to manage crop residues, significantly influences the retention of crop residues on the farm for mulch. Higher perceived capabilities by farmers to manage crop residues translated into greater affinity to retain crop residues on the farm as mulch (Atta-Aidoo et al., 2022; Borges et al., 2019; Tama et al., 2021).

Institutional factors such as access to credit and extension services positively influence crop residue retention on the farm by discouraging off-farm use of crop residues. Extension services provide farmers with relevant information on the importance of crop residue retention whereas credit provides additional resources necessary to offset the trade-offs associated with crop residue retention (Akinola et al., 2015). Land tenure security positively enhances the adoption of sustainable land practices such as crop residue mulching, this is because farmers with a secure sense of land ownership think of long-term benefits from the land and are willing to make investments in soil health (Walmsley & Sklencka, 2017).

Crop residue retention exhibits greater benefits to soil health during times of irregular rainfall and as such encourages farmers to adopt crop residue mulching (Mkoga et al., 2010). Drought diminishes the sources of livestock feed, and this confronts farmers with the trade-off of either using their residues for mulch or livestock feed, in the face of such trade-offs farmers allocate a proportion of residues as livestock feed relative to the benefits accrued from the livestock (Valbuena et al., 2015). The presence of invasive weeds, however, discourages farmers from retaining residues as these residues create enabling environments for such invasive weeds to thrive.

5 | CONCLUSION AND POLICY IMPLICATIONS

The study has highlighted the decision-making associated with the utilization of crop residues by smallholder farmers in dryland farming systems in rural Ghana. Findings suggested that study respondents utilized crop residues in several ways including (i) leaving it on the farm to decompose, (ii) feeding it to livestock and (iii) burning crop residues. Findings further indicated that farming households were aware of the benefits associated with crop residues on the farm. Nonetheless, there is complex decision-making in the choice to leave crop residue on the farm or feed it to livestock. The study revealed that farming households are confronted with a number of challenges associated with farmers' decision to utilize crop residues on their farms. Several factors informed farmers' decision to leave crop residue on the farm or feed it to their livestock. Policy-makers need to take cognizance of the local context and household characteristics in designing appropriate management strategies for crop residues to improve soil fertility and address climate change risks in vulnerable dryland farming systems. The Government of Ghana must empower farmers through the provision of technical knowledge and the machinery needed for the sustainable utilization of crop residues. This is because the high labour intensity and cost greatly impede farmers' efforts at sustainable utilization of crop residues on their farms. Additionally, the government needs to enforce land tenure agreements to improve the sustainable utilization of crop residues. This is because secured land tenure arrangements encourage farmers to adopt a more sustainable crop residue utilization method. Concerted efforts should also be made to increase access to extension services because increased access to extension services positively influence farmers' decision to adopt sustainable crop residue utilization methods. Given the importance of socio-psychological factors in relation to the choice of crop residue management practices by farmers, the design of environmental and agricultural policy should take cognizance of these factors to enhance the proper management of crop residues.

AUTHOR CONTRIBUTIONS

Philip Antwi-Agyei: Conceptualization; Formal analysis; Funding acquisition; Methodology; Project administration; writing–original draft; writing–review and editing. **Jonathan Atta-Aidoo**: Formal analysis; Methodology; writing—original draft; writing—review and editing. **Lawrence Guodaar**: writing—original draft; writing—review and editing. **Andrew Dougill**: Conceptualization; writing—original draft; writing—review and editing.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the study participants. This work was supported by the FLAIR Fellowships funded by the Royal Society, London [FLR\R1\201640] and a Royal Society FLAIR Collaboration Grant [FCG\R1\211025].

DATA AVAILABILITY STATEMENT

Data used for this study is available upon request.

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Note

[1]The theory of planned behaviour argues that the decision-making process of individuals is motivated not solely by economic incentives but also by socio-psychological factors, particularly when such decisions have social and environmental consequences. These factors are classified as attitude (an individual's favourable or unfavourable assessment of a behaviour); subjective norm (the perceived social influence from internal and/or external sources; and perceived behaviour control (the perceived easiness or difficulty in carrying out a behaviour).

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How to cite this article: Antwi-Agyei, P., Atta-Aidoo, J., Guodaar, L., & Dougill, A. (2023) Building climate resilience through crop residue utilization: Experiences of Ghanaian smallholder farmers. *Climate Resilience and Sustainability*, 2, e255. https://doi.org/10.1002/cli2.55

APPENDIX A

1.1MULTIPLE CORRESPONDENCE ANALYSIS FOR ATTITUDE TOWARDS CROP RESIDUE UTILIZATION

Dimension	Principal inertia	Percent	Cumulative percent
Dim1	0.43	52.16	52.16
Dim2	0.22	27.32	79.47
Dim3	0.12	15.23	94.70
Dim4	0.01	1.52	96.22
Dim5	0.00	0.04	96.26
Dim6	0.00	0.01	96.27

APPENDIX B

2.1MULTIPLE CORRESPONDENCE ANALYSIS FOR SUBJECTIVE NORM TOWARDS CROP RESIDUE UTILIZATION

Dimension	Principal inertia	Percent	Cumulative percent
Dim1	0.32	46.19	46.19
Dim2	0.17	24.67	70.86
Dim3	0.14	19.52	90.39
Dim4	0.02	3.32	93.71
Dim5	0.00	0.32	94.03
Dim6	0.00	0.00	94.03

APPENDIX C

3.1MULTIPLE CORRESPONDENCE ANALYSIS FOR PERCEIVED BEHAVIOUR CONTROL TOWARDS CROP RESIDUE UTILIZATION

Dimension	Principal inertia	Percent	Cumulative percent
Dim1	0.19	41.17	41.17
Dim2	0.13	26.83	68.00
Dim3	0.04	9.44	77.43
Dim4	0.03	6.42	83.85
Dim5	0.01	1.35	85.20
Dim6	0.00	0.60	85.80
Dim7	0.00	0.42	86.22
Dim8	0.00	0.38	86.60
Dim9	0.00	0.16	86.77
Dim10	0.00	0.02	86.79