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Factors affecting farmers' decision to harvest rainwater for maize production in Ghana

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Climate change, especially the variability of rainfall patterns, poses a threat to maize production in Ghana. Some farmers harvest rainwater and store it for maize production to cope with unpredicted rainfall patterns. However, there are only a few studies on the adoption of rainwater harvesting for maize production. This study analyses the factors that influence farmers' decision to harvest rainwater for maize production in Ghana. A probit regression model is applied for the empirical analysis, using primary data from 344 maize farmers. The results show that 38% of the farmers harvest rainwater. We found that male farmers, farmers with primary education, large-scale farmers, experienced farmers, and those with access to weather information are more likely to harvest rainwater, while older farmers, those with limited access to extension services and labor, and those who perceive changes in rainfall pattern and amount of rainfall are associated with a lower probability to harvest rainwater for maize production. The findings suggest that enhancing farmers' access to weather information and extension services and improving awareness of climate change are needed to promote the adoption of rainwater harvesting. For gender inclusiveness in the adoption of rainwater harvesting, policies need to consider the needs of women.

KEYWORDS

rainwater harvesting, water management, climate change, maize production, adaptation strategies, Ghana

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Introduction

Climate change has negatively influenced the food security status of many nations, especially developing countries with the limited adaptative capacity to its impacts. Rainfed agriculture practiced by more than 90% of farmers in Sub-Saharan Africa (SSA) is now unreliable (Falkenmark et al., 2001; IFPRI, 2010; Biazin et al., 2012). IPCC (2014) projects that the erratic nature of rainfall could impact food security negatively. The adoption rate of irrigation in SSA was <5% as of 2010 (IFPRI, 2010), probably due to the capital costs involved (Biazin et al., 2012). The current global situation has extended water challenges beyond the arid regions to the humid regions and has affected both domestic and agricultural water supply. The reliable and accessible water resource is key to climate change adaptation. Meeting the hydroclimatic deficiencies of crop production improves soil quality and controls plant damage during dry periods (Falkenmark et al., 2001). Climate change is projected to increase the incidence of extreme events, such as floods and droughts with negative consequences on food production. Changing rainfall patterns is already harming crop production (van Meijl et al., 2018). Global warming is increasing the rate of soil moisture and nutrient loss and consequently, reducing crop yields, including maize (Islam et al., 2016; Gbegbelegbe et al., 2017; Srivastava et al., 2017). The effect of climate change on the occurrence of dry spells could collapse rainfed agriculture in several regions worldwide (Mbilinyi et al., 2005; Srivastava et al., 2017).

Rainwater harvesting is an adaptation strategy that could help to mitigate the impact of climate change, especially in water-scarce areas. It is an ancient technique of collecting and storing water for immediate or later use that dates far back as 2000 BC in several parts of Africa, Israel, and India (Fewkes, 2012). It is practiced all over the world but more commonly in rural areas than urban (Akter and Ahmed, 2015). Currier (1973) defines this environmentally friendly technique as the collection of natural precipitation from a designed watershed or catchment for profitable usage. Further research has expanded the definition to include storage and efficient use of the resources also known as rainwater management (Falkenmark et al., 2001; Biazin et al., 2012). Kahinda and Taigbenu (2011) classified rainwater harvesting into four groups based on catchment surface: (i) *in situ* rainwater harvesting; (ii) *ex situ* rainwater harvesting; (iii) domestic aboveground tank; and (iv) domestic underground tank rainwater harvesting.

Sustainable irrigation methods have been reported to improve water productivity in drought-prone areas and rainfed agriculture systems (Nikolaou et al., 2020). In SSA, an average of 78% of rainfall is lost to surface runoff, soil evaporation, and deep percolation (Rockström et al., 2002). This situation tends to be aggravated under severe climate scenarios for food security, especially in dry areas worldwide (Falkenmark et al., 2001). Hence, rainwater harvesting has the potential to supplement both scarce surface and groundwater resources (Aladenola and Adeboye, 2009). Rainwater harvesting and management has been cited as one of the climate change adaptation strategies globally (Cai and Rosegrant, 2003; Pandey et al., 2003; Gandure et al., 2013; IPCC, 2014) and also in Ghana (Bessah et al., 2021a,b). Effective rainwater harvesting could mitigate floods, improve infiltration and percolation to recharge groundwater, and make sufficient water available for crop production (Cai and Rosegrant, 2003; Pandey et al., 2003; Darabi et al., 2021). Akroush and Dehehibi (2015) projected that the adoption rate of rainwater harvesting by barley farmers in the Jordanian Badia could increase to 93% in about 12 years from the year of study.

Despite the vast potential of rainwater harvesting to curb the impact of climate change on agriculture, the adoption has been low in SSA (Biazin et al., 2012; Kimani et al., 2015). However, most of the studies on the adoption of rainwater harvesting are in Asia while there is limited evidence on factors affecting smallholder farmers' decision to harvest rainwater for crop production in Sub-Saharan Africa. In Asia, Campisano et al. (2017) reported that local regulations and economic constraints were the main reason for the varying degree of rainwater harvesting adoption globally. Other challenges under the local regulations or policies are the environment and social and technical know-how of the system (Lee et al., 2016). Akroush et al. (2017) found that educational level and years of farming experience significantly positively influenced the adoption of rainwater harvesting while the land tenure system had a negative significant influence on the likelihood of adoption in Jordan. In the Loess Plateau of China, He et al. (2007) showed that educational level, size of labor force, available extension services, and right perception of technology had a significant positive correlation with the adoption of rainwater harvesting while age and distance between storage tank of rainwater and point of use showed a significant negative correlation. Adhikari et al. (2018) found that educational level, physical assets, and membership in organizations had a significant positive correlation with the decision to adopt the rainwater harvesting technique in the Makwanpur district of Nepal. Biazin et al. (2012) reported that the geographical and geopolitical locations influenced the adoption of rainwater harvesting and management. Evidence from Baguma et al. (2010) shows that experience in rainwater harvesting, membership in associations involved in rainwater harvesting, and access to instruction manuals on the usage of harvested rainwater significantly influenced the management of this resource.

In SSA, Kimani et al. (2015) showed that gender, literacy level, social and economic status, and technical knowledge of rainwater harvesting technologies significantly influenced the adoption of the technology by farmers in Kenya. Siraj and Beyene (2017) found that farming experience, education, family size, labor availability, distance to market, and external support significantly influenced farmers' decision to adopt rainwater harvesting technology in Ethiopia. Lutta et al. (2020) found that access to extension services and training, monthly income, land ownership, social group membership, and availability of active agricultural labor significantly influenced the adoption of rainwater harvesting technologies in Kenya. Mangisoni et al. (2019) found that the adoption of rainwater harvesting technologies in Malawi was significantly correlated with land slope and quality, farm size, soil texture, land tenure security, education, and support from extension services. Mekuria et al. (2020) showed that education, family size, farming experience, participation in technology demonstrations, and association membership significantly influenced the adoption of rainwater harvesting technologies in Ethiopia.

Given the contextual differences in countries in Asia and Africa, lessons from other countries, especially Asia cannot be used to formulate policies to promote the adoption of rainwater harvesting in Ghana. Effective promotion of rainwater harvesting requires a context or country-specific study. Our paper, therefore, aims to bridge this knowledge gap in SSA by analyzing the factors that influence smallholder maize farmers' decision to harvest rainwater for irrigation in Ghana.

The rest of the paper is structured as follows. Section 2 describes the conceptual framework that guided the empirical analysis. The analytical method and source of data are also presented in Section 3. The fourth section shows the results of the study while the last section provides key conclusions and policy implications.

Conceptual framework

The study is positioned with the random maximum utility theory framework, which indicates that economic agent chooses an option that maximizes their utility subject to constraints (Watson et al., 2020). In the context of this study, farmers are more likely to adopt rainwater harvesting if it maximizes their utility subject to constraints related to the farmers. Studies from Asia and some African countries have shown that the adoption of rainwater harvesting is influenced by different contextual factors (Li et al., 2020; Llewellyn and Brown, 2020; Kimbi et al., 2021).

In our study, we categorize the contextual factors as socioeconomic, institutional, community infrastructure, and perception of climatic factors. These factors are also expected to correlate with maize farmers' adoption of rainwater harvesting as shown in Figure 1. The socioeconomic factors included in the study are gender, educational level, age, household size, farm size, experience in maize farming, labor availability, and location of farms. Men are expected to have a higher probability to harvest rainwater for crop irrigation compared to women, due to gender inequality issues related to resource access and opportunities (Sandström and Strapasson, 2017). Mangisoni et al. (2019) found that men were more likely to adopt rainwater harvesting technologies than women in Malawi. Studies have shown that educated farmers tend to use water management practices such as rainwater harvesting (Kimani et al., 2015; Siraj and Beyene, 2017; Mekuria et al., 2020). Education enables farmers to acquire relevant technical information which increases their probability to adopt rainwater harvesting technology (Siraj and Beyene, 2017; Mekuria et al., 2020). Similar to these studies, we hypothesize education to be positively correlated with farmers' decision to harvest rainwater in Ghana. Age is expected to be negatively associated with the adoption of rainwater harvesting. Older farmers are observed to be risk-averse and reluctant to adopt water management practices (Mekuria et al., 2020). Water management methods, especially rainwater harvesting, are labor intensive and cannot be easily implemented by the elderly, especially if they do not have sufficient labor to support them. Labor availability and household size are expected to positively influence rainwater harvesting. This hypothesis is supported by a previous study (Mekuria et al., 2020) that reported that farmers with large households were associated with a higher probability to adopt rainwater harvesting in Ethiopia. Large households tend to provide cheap labor in rural areas (Lutta et al., 2020). Farming experience is hypothesized to positively influence the adoption of rainwater harvesting. More experienced farmers use their knowledge acquired over time to analyse the benefit obtained from water management methods. Evidence from Mekuria et al. (2020) showed that more experienced farmers tended or leaned to adopt rainwater harvesting technology in Ethiopia. Farmers with large farms are expected to harvest rainwater for crop irrigation. In most rural areas, landholdings are an indicator of wealth; hence, farmers with large farms are wealthy and can afford to hire labor and purchase materials required for the storage of the water. Mangisoni et al. (2019) showed that land size positively correlated with the adoption of rainwater harvesting technology in Malawi.

Extension constraint, land tenure constraint, and attendance of training workshops on adaptation strategies are the institutional variables captured in the study. Farmers with limited access to extension services are expected to have a lower probability to harvest rainwater for irrigation. Extension agents provide farmers with advice on how they can cope with climate variability. Mangisoni et al. (2019) found that farmers with access to the extension were more likely to adopt rainwater harvesting technologies in Malawi. Land tenure constraint is expected to be negatively correlated with the adoption of rainwater harvesting. Land tenure security is important for investments in water management, as farmers with secure land titles are certain to reap the investment on the land (Kimani et al., 2015).

The community infrastructure encompasses access to electricity and access to tarred roads, which are expected to be positively correlated with the adoption of rainwater harvesting. The perception of climatic factors consists of access to weather information, perceived changes in rainfall time,

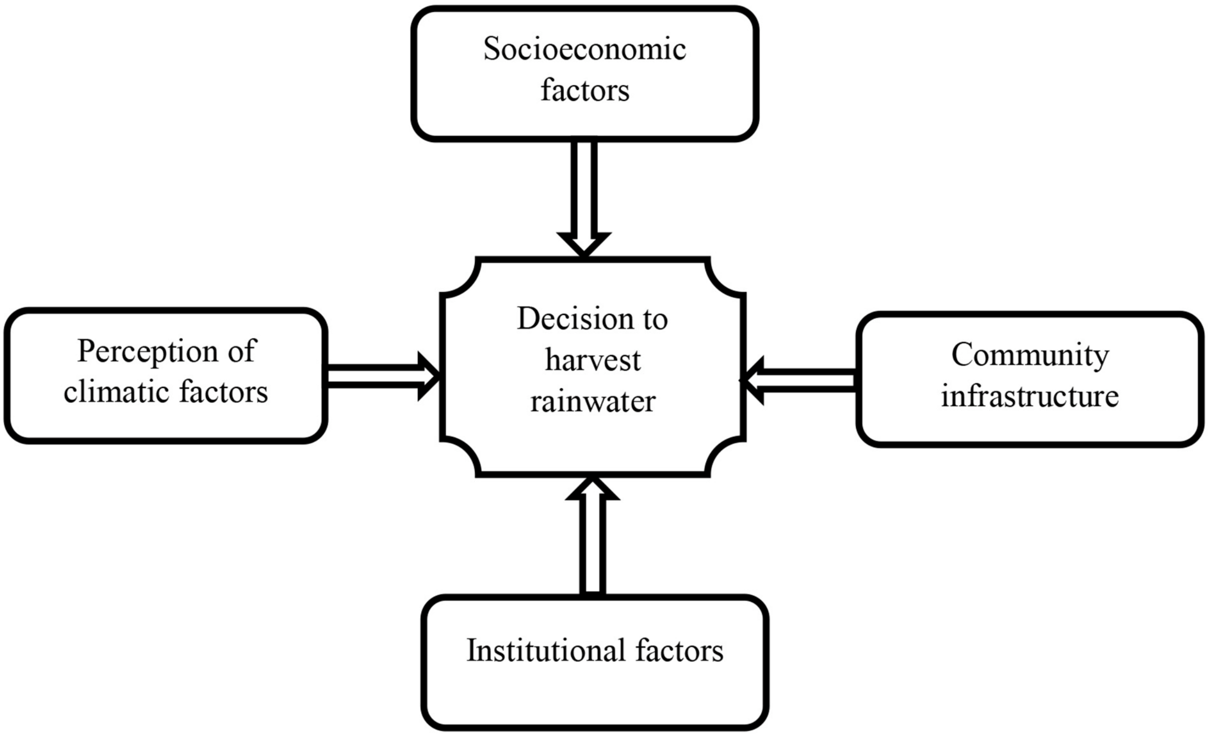

FIGURE 1
Conceptual framework. Source: Authors' design.

and perceived reduction in the amount of rainwater. Farmers with such knowledge can adequately prepare to cope with climate variability by harvesting and storing rainwater for crop irrigation.

Materials and methods

Empirical model specifications

Based on the conceptual framework, farmers' decision to harvest rainwater for maize production is expressed as a function of their socioeconomic, institutional, community infrastructure, and perception of climatic factors, which is given as:

$$Rainwater_{\mathrm{i}} = f(Socioeconomic,\ community\ infrastructure,\ insitutional,\ climatic) \quad (1)$$

The decision to harvest rainwater is a binary choice, which is analyzed in the literature using binary choice models such as logit, probit, or linear probability model. However, the linear probability model is criticized to predict probabilities outside the range of 0 to 1. Hence, most studies on the adoption of agricultural innovations apply either logit or probit regression models (Kimbi et al., 2021). These models tend to generate similar results. In this paper, the probit regression model is applied in the empirical analysis. Empirically, the probit regression model for the analysis of farmers' decision to harvest rainwater is specified as:

$$\begin{aligned} Rainwater_i &= \alpha + \sum_{j=1} \gamma_j\ Socioeconomic_{ij} \\ &+ \sum_{j\,=\,1} \lambda_j\ Infrastructur\ e_{ij} + \sum_{j\,=\,1} \omega_j Institutional_{ij} \\ &+ \sum_{j=1} \varpi_j Climatic_{ij} + \xi_i,\ i = 1, 2, ...347 \end{aligned} \quad (2)$$

where $Rainwater_i$ denotes a binary decision to harvest rainwater for maize production, 1 if a farmer harvest rainwater for maize cultivation and 0 otherwise. $Socioeconomic_{ij}$ denotes a set of socioeconomic factors such as gender, age, educational levels, farm size, farm experience, household size, labor constraint, settlement, and regional dummies. Gender represents 1 if a farmer is a male and 0 for a female. Age is the age of farmers (years). Educational levels represent the highest level of education attained by farmers, and they include no formal education, basic education, senior high education, and tertiary education. Each of these categories is included in the model as a dummy variable and no formal education is used as a base category. Farm size is the size of farmers' maize farms in hectares. Farm experience is the number of years that the farmer has been cultivating maize. Labor constraint represents perceived limited availability of labor for agricultural production, 1 if a farmer perceived that there is limited labor available for agricultural production and 0 otherwise. Settlement equals 1 if a farmer is a native of the community and 0 otherwise. Regional dummies represent three location variables, Ashanti, Eastern, and Central regions of Ghana: each of these location variables is included in the model as a dummy variable and the Ashanti region is used as a base category. $Infrastructure_{ij}$ denotes variables representing community infrastructure, and they include access to electricity and tarred road. Access to electricity equals 1 if a farmer has access to electricity and 0 otherwise. Access to tarred road presents the nature of road leading to major markets in farmers' community, 1 if the road is tarred and 0 otherwise. $Institutional_{ij}$ is a set of institutional variables such as extension constraint and land tenure constraint. Extension constraint represents 1 if a farmer perceives to have limited access to extension services and 0 otherwise. Land tenure constraint equals 1 if a farmer perceives land tenure problem as a constraint to maize production and 0 otherwise. $Climatic_{ij}$ is a set of perceived climate factors, namely access to weather information (1 if a farmer has access to weather information and 0 otherwise), perceived changes in rainfall time (1 if a farmer perceives changes in rainfall pattern and 0 otherwise), and perceived decrease in rainfall amount (if a farmer perceives a decline in rainfall amount and 0 otherwise).

The probability of a farmer harvesting rainwater for maize production conditions on socioeconomic, institutional, community infrastructure, and perception of climatic factors is given as:

$$\Pr(Rainwater_i = 1) = \Pr(Rainwater_i > 0) = \Pr(\xi_i > -\beta X_{ij}) = 1 - \Phi(-\beta X_{ij}) \quad (3)$$

where β is a vector of the coefficients and X_{ij} is a vector of the explanatory variables. The coefficients of covariates do not provide information on the magnitude of the correlations of the dependent variable with the independent variables. Hence, the marginal effects which represent a change in

$$\frac{\partial \Pr(Rainwater_i = 1)}{\partial X_{ij}} = \frac{\partial E(Rainwater_i|X_{ij})}{\partial X_{ij}} = \Omega(X_i\beta)\beta (4)$$

Survey data

The study used a primary dataset collected from maize farmers located in three regions (Ashanti, Central, and Eastern) in the Pra River Basin in Ghana in 2019 (Figure 2). This basin presents the highest dense settlement in the nation and the majority of the inhabitants are farmers. The climatic and agro-ecological zones in the basin are suitable for agriculture. Three levels of sampling were done in this study. First, spatial random sampling was done in ArcGIS 10.3 using the random point generation technique to select 10 districts in the Pra River Basin. Five of the districts fell within the Ashanti region [Amansie West, Atwima Mponua, Bosomtwe, Adansi North (now Adansi Asokwa), and Obuasi (now Obuasi East)]; three were within the Central region (Assin North, Twifo Ati Morkwa, and Twifo Heman Lower Denkyira) and the remaining two in the Eastern region [Atiwa (now Atiwa West) and East Akim (now Abuakwa South)] of Ghana, as shown in Figure 2. The percentage yield performance of maize in the Twifo Heman Lower Denkyira, Amansie West, Atiwa, East Akim, Atwima Mponua, Bosomtwe, Adansi North, Assin North, and Obuasi districts were +33.3, +30.0, +27.1, +20.3, −19.8, −32.8, −36.5, −54.7, and −36.5, respectively, in relation to the national average of 1.92 t/ha (MoFA, 2016).

In the second level of sampling, three communities located along rivers in each district were purposely (closeness to the river) selected. This was done to assess the impact of climate change on both rainfall and dry season cropping. Research has shown that lack of access to water is a hindrance to climate change adaptation, especially in the mono-modal climate (Savannah agro-ecological) zones of Ghana (Fagariba et al., 2018). The Yamane simplified formula for proportions was adopted to determine the number of respondents (farmers) to interview (Yamane, 1967). The total population of crop farming households in the 10 districts was 165,195 inhabitants from the 2010 population census (GSS, 2013).

The determined sample size from Yamane (1967) simplified formula of proportion for precision (e) ±5% was 399. Fourteen respondents (household heads) were randomly sampled from each of the three communities. Four communities were not accessible during the survey period due to flooded roads during the data collection period. A total of 344 respondents (Ashanti region = 172, Central region = 111 and Eastern region = 61) were interviewed in person from the 10 districts in April and May 2019. A questionnaire with both open- and closed-ended questions was structured for data collection. The language used for the questionnaire administration was Twi, which is the local language commonly spoken in the Ashanti region. The questionnaire was pre-tested at Barekese, in the Atwima Nwabiagya district of the Ashanti Region. A total of 12 households were interviewed during the pre-test and the outcome was used to restructure the questionnaire to the current format used for this study.

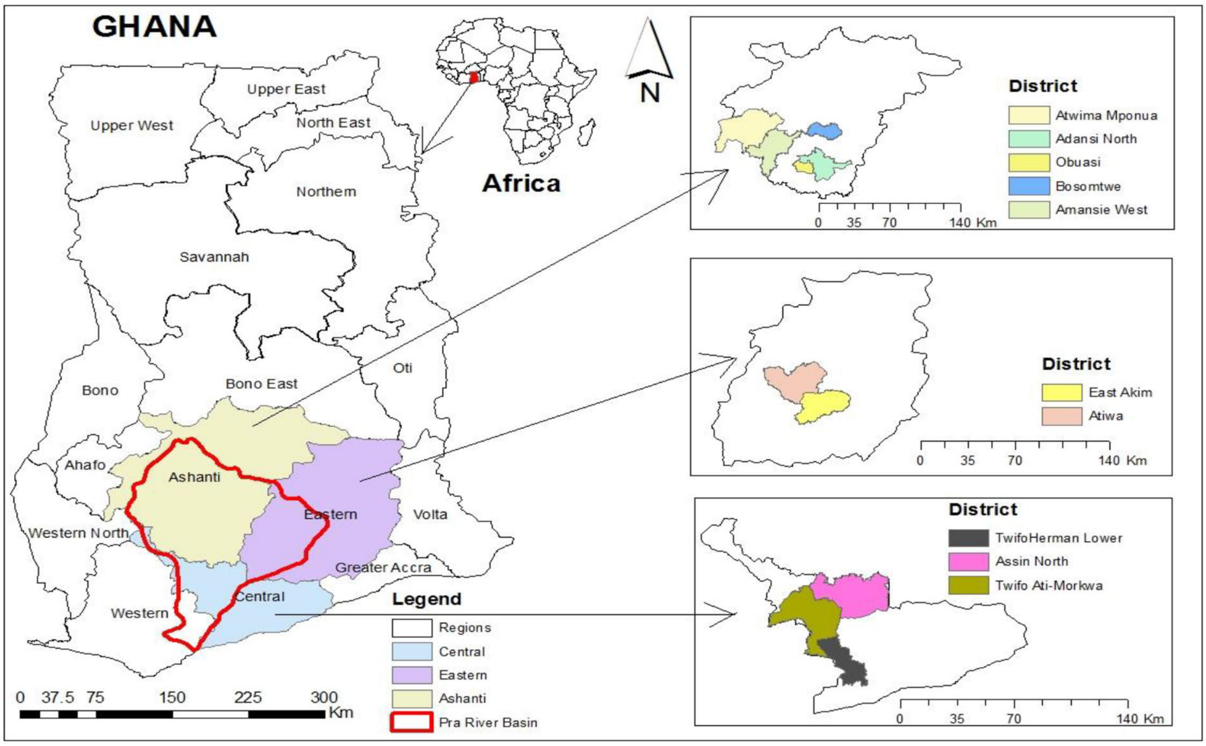

FIGURE 2
Map of Ghana and the studied regions. Source: Authors' design.

Results and discussion

Characteristics of the farmers

The characteristics of the farmers are presented in Table 1. All the contacted farmers depend on direct rainwater for their maize farms, only a few of them (38%) intentionally harvest and store rainwater to irrigate their maize. Even when they harvest rainwater, they may not necessarily use it for agricultural production but rather for domestic purposes such as drinking, washing, and cooking. This result is consistent with a previous study showing that most farmers in SSA do not store rainwater for agricultural production (Rockström and Falkenmark, 2015). Farmers adopted two types of rainwater harvesting techniques on their farms. The first technique is the fixing of roofing sheets as gutters on the tree crops to receive rainwater intercepted by the canopy of the tree. Containers are placed under the trees to receive the collected rains from two or three gutters per tree. This technique is mostly practiced by cocoa farmers in the study area. The second technique is the fixing of gutters on the shade structures in the farm just like for houses and collecting the rainwater at one point. The catchment then becomes the shade structure. Plastic drums were the common storage containers used by farmers.

In this study, adopters and non-adopters are used to refer to farmers who adopted rainwater harvesting and those who are not, respectively. The majority of adopters and non-adopters are males, which may indicate the male dominance in maize production in the study areas (Table 1). This result is consistent with previous studies (Ansah et al., 2014; Wongnaa et al., 2019) who reported that men dominated the maize farming in Southern Ghana. The mean age is similar for adopters and non-adopters. On average, farmers in both groups are older. This result is consistent with previous studies (Ansah et al., 2014; Wongnaa et al., 2019) that show that maize production is predominated by older people. Although few farmers had no formal education, the percentage is higher among non-adopters. The distribution of the educational levels of adopters and non-adopters shows that the farmers are educated, with the majority having attained secondary education, where they can read and write. The result also shows that mean differences in farm size, experience in maize farming, and household size are not statistically significant. However, it is observed that more of the non-adopters reported that they lack labor for maize production. Lack of labor may constrain farmers' ability to harvest rainwater.

TABLE 1 Characteristics of the farmers.

Variables	Adopters $N = 131(38\%)$	Non-adopters $N = 213(62\%)$	Mean difference	*t*-value
Socioeconomic factors				
Gender (Male = 1)	0.733 (0.444)	0.681 (0.467)	0.052	1.022
Age	50 (12)	48 (14)	2	1.389
No formal education	0.061 (0.240)	0.023 (0.152)	0.038*	1.78
Primary education	0.183 (0.388)	0.131 (0.339)	0.052	1.301
Secondary education	0.580 (0.495)	0.573 (0.496)	0.007	0.134
Tertiary education	0.069 (0.254)	0.085 (0.279)	−0.016	−0.528
Farm size (acres)	11 (7)	9 (8)	2	1.395
Experience in maize farming	23 (10)	21 (13)	2*	1.78
Household size	7 (3)	7 (4)	0	1.126
Lack of labor	0.061 (0.240)	0.502 (0.501)	−0.441***	−9.429
Ashanti region	0.527 (0.501)	0.484 (0.501)	0.043	0.776
Eastern region	0.206 (0.406)	0.160 (0.367)	0.046	1.095
Central region	0.267 (0.444)	0.357 (0.480)	−0.090*	−1.729
Community infrastructure				
Access to tarred road	0.275 (0.448)	0.333 (0.473)	−0.059	−1.137
Access to electricity	0.916 (0.278)	0.869 (0.339)	0.047	1.349
Institutional factors				
Lack of access to extension services	0.015 (0.123)	0.075 (0.264)	−0.060**	−2.434
Land tenure constraint	0.229 (0.422)	0.207 (0.406)	0.022	0.491
Perception of Climatic factors				
Rain time change	0.008 (0.087)	0.066 (0.248)	−0.058**	−2.579
Decreased rainfall amount	0.023 (0.150)	0.117 (0.323)	−0.094***	−3.147
Access to weather information	0.397 (0.491)	0.183 (0.388)	0.214***	4.480

*, **, *** represent 10%, 5%, and 1% statistical significance. The values in parentheses are robust standard errors estimated using the robust estimation approach. Source: Authors' computation.

The proportion of adopters and non-adopters in the Ashanti and Eastern regions is similar. There are more non-adopters in Central regions than adopters. Comparing across the regions, it is observed that the Ashanti region has more adopters than any of the regions.

With the institutional variables, there are lower proportions of adopters and non-adopters who have access to tarred roads. However, many of the adopters and non-adopters have electricity in their homes. A few percent of adopters and non-adopters lack access to extension services, but the percentage is higher for non-adopters compared to adopters.

In general, few farmers have access to weather information, similarly to findings obtained in other SSA countries, such as Tanzania (Sandström and Strapasson, 2017). Nevertheless, the percentage of adopters with access to weather information is higher than non-adopters. Access to weather information enables farmers to get information about weather forecasts in the future, which allows them to adequately prepare by adopting appropriate adaptation strategies like harvesting rainwater for maize production.

Factors affecting farmers' decision to harvest rainwater for maize production

The probit regressions' estimates of the factors influencing farmers' decision to harvest rainwater for maize production are presented in Table 2.

The variance inflation factor (VIF) and the Breusch–Pagan test were used to check for the presence of multicollinearity and heteroskedasticity in the model, respectively. The diagnostic result shows that the mean VIF is well below 10, indicating that multicollinearity is not a problem in the model. However, the Breusch Pagan chi-squared statistic is statistically significant at 1%, indicating the presence of heteroskedasticity in the model (Table 2). This problem was corrected by estimating the standard errors using the robust estimation approach. In addition, the Wald chi-squared statistic shows statistical significance, indicating that the variables included in the model jointly explain the variance in farmers' decision to harvest rain for irrigation. For policy implication, the marginal effects are discussed.

TABLE 2 Factors influencing farmer's decision to harvest rainwater for maize farming.

Variables	Coefficients (Robust standard errors)	Marginal effects (robust standard errors)
Socioeconomic characteristics		
Gender (Male = 1)	0.331*	0.086*
	(0.185)	(0.048)
Ln (Age)	−0.018**	−0.005**
	(0.009)	(0.002)
Primary education	0.504*	0.131*
	(0.277)	(0.073)
Secondary education	0.189	0.049
	(0.231)	(0.060)
Tertiary education	−0.221	−0.058
	(0.341)	(0.089)
Ln (Farm size)	0.209*	0.054*
	(0.119)	(0.031)
Ln (experience in maize farming)	0.397**	0.104**
	(0.193)	(0.049)
Ln (household size)	−0.196	−0.051
	(0.158)	(0.041)
Lack of labor	−1.534***	−0.400***
	(0.218)	(0.042)
Eastern region	−0.285	−0.074
	(0.242)	(0.062)
Central region	−0.572***	−0.149***
	(0.206)	(0.052)
Community infrastructure		
Access to tarred road	−0.163	−0.043
	(0.195)	(0.051)
Access to electricity	0.339	0.089
	(0.289)	(0.075)
Institutional factors		
Lack of access to extension services	−0.907*	−0.237*
	(0.497)	(0.125)
Land tenure constraint	0.177	0.046
	(0.203)	(0.053)
Climatic factors		
Rain time change	−1.282**	−0.335**
	(0.585)	(0.144)
Decreased rainfall amount	−0.894**	−0.233**
	(0.383)	(0.096)
Access to weather information	0.700***	0.183***
	(0.205)	(0.051)
Constant	−0.743	
	(0.570)	
Diagnostic results		
Wald chi-square	95.57***	
Breusch-Pagan test for heteroskedasticity	18.48***	
Variance inflation factor	1.44	
Observations	344	344

*, **, ***Represent 10%, 5%, and 1% statistical significance. The values in parentheses are robust standard errors estimated using the robust estimation approach. Source: Authors' computation.

Socioeconomic factors

Among the socioeconomic factors, gender (male), age, primary education, farm size, experience in maize farming, and location-specific variable (Central region) are statistically significant factors that influence maize farmers' decision to harvest rainwater for maize farming. Male maize farmers were found to be 0.086 more likely to harvest rainwater for maize production compared to their female counterparts (Table 2). The female counterpart due to their common responsibilities to the household observed in the study areas may turn to harvesting rainwater for domestic purposes than farming. Having water at home reduces the workload to be done by the females and children of the house in ensuring that there is water for cooking and other house chores. Gender was also a significant factor in the decision to adopt rainwater harvesting in Malawi (Mangisoni et al., 2019) and in Kenya (Kimani et al., 2015). However, in Kenya, women were more likely to adopt rainwater harvesting technology than men because the study considered rainwater harvesting for all activities including domestic chores.

As farmers increase in age, their probability to harvest rainwater for maize production reduces by 0.005 (Table 2). As farmers grow old, they often become more limited to keeping on water management activities for maize production as rainwater harvesting and usage are labor-intensive activities, unless they have employees or appropriate machinery to reduce drudgery. In contrast to Southern Ghana, age significantly positively correlated with farmers' decision to adopt rainwater harvesting technologies in Ethiopia (Mume and Kemal, 2014). As farmers expand their maize farms by an acre, they are 0.054 more likely to harvest rainwater to irrigate their farms (Table 2). Increasing farm size means increased investments in land acreage, input material, and crop management attracting more cost. Therefore, water is a vital resource for improved yield, it becomes a necessity to secure the investment in the expansion. This is in line with evidence from Mume and Kemal (2014) and Mangisoni et al. (2019).

The result also shows that a year increase in farmers' experience in maize production increases their probability to harvest rainwater by 0.104 (Table 2). This result shows that farmers with more experience in maize cultivation are more likely to harvest rainwater for irrigating their maize crops. Experienced farmers are more knowledgeable about weather patterns and how changes in rainfall patterns can affect their maize yields. Therefore, when rainfall patterns are erratic, they are more likely to capture rainwater and use it to irrigate their maize farms. Our result supports the finding of Akroush et al. (2017) who state that experienced farmers in Jordan were more inclined to adopt rainwater harvesting for their dryland activities (Akroush et al., 2017).

As expected, farmers who lack labor are 0.400 less likely to harvest rainwater for maize production compared to those who do have adequate labor (Table 2). Collecting and storing rainwater requires a lot of labor. Farmers who lack labor may be unable to harvest rainwater. Our empirical finding is consistent with Mume and Kemal (2014) who found that access to labor increased the likelihood of rainwater harvesting in Eastern Hararghe Low Land in Ethiopia (Mume and Kemal, 2014). Compared to the Ashanti region, farmers in the Central region are 0.149 less likely to harvest rainwater for maize production (Table 2).

Community infrastructure

None of the variables under community infrastructure show a significant influence on farmers' decision to harvest rainwater for maize production (Table 2). This result shows that community infrastructure such as access to tarred roads and electricity do not influence farmers' decision to adopt rainwater harvesting.

Institutional factors

The result shows that farmers with limited access to agricultural extension services are associated with a 0.237 lower probability of harvesting rainwater for maize production (Table 2). Agricultural extension services educate farmers on how to cope with climate change and they are likely to encourage farmers to harvest rainwater to irrigate their crops. Extension services in other studies increased the likelihood of adopting rainwater harvesting in other African countries (Mume and Kemal, 2014; Mangisoni et al., 2019).

Perception of climatic factors

Interestingly, farmers with the perception that there are changes in rainfall time and those with the perception that the rainfall amount has decreased are associated with 0.233 and 0.183 lower probability to harvest rainwater for maize production, respectively (Table 2). The reason is that farmers who are aware of climate change, especially in terms of the timing and amount of rainfall, may not rely on unpredictable rainfall patterns as an adaptation strategy, but resort to other strategies (Bessah et al., 2020, 2021b). On the other hand, farmers with access to weather information are 0.183 more likely to harvest rainwater to irrigate their maize crop (Table 2). Access to weather information can help farmers identify the timing of rainfall so that they can adequately prepare for rainwater harvesting to irrigate their crops. Our finding corroborates with Partey et al. (2018) who found that climate information services promoted the adoption of climate-smart agriculture in West Africa.

Conclusion and policy implications

This study provides insights and further evidence on how socioeconomic, institutional, community infrastructure, and perception of climatic factors influence maize farmers' decision to harvest rainwater for crop irrigation in Ghana. The result shows that the adoption of rainwater harvesting is low among maize farmers in Ghana. Moreover, socioeconomic, institutional, and perception of climatic factors account for the variations in farmers' decisions to adopt rainwater harvesting. In particular, socioeconomic factors, gender, primary education, farm size, and experience in maize farming show a significant positive correlation with the adoption of rainwater harvesting while lack of labor and age show a significant negative correlation. For the institutional factor, only limited access to extension services shows a significant negative association with the adoption of rainwater harvesting. Under climatic factors, the study shows that the perception of changes in rainfall time and decreases in rainfall amount are significantly negatively correlated with the adoption of rainwater harvesting while access to weather information shows a significant positive correlation.

The study concludes that rainwater harvesting could be promoted as an adaptation strategy to climate change by formulating climate policies that consider contextual factors such as socioeconomic, institutional, and perception of climatic factors. In particular, national policies on climate change adaptation should bridge the gap between the Ministry of Food and Agriculture and the Ghana Meteorological Agency to make climate information promptly available for farm-level decision-making. Furthermore, gender inclusiveness in policies on rainwater harvesting could increase the adoption rate as well as increase the reach of agriculture extension in the nation. Access to knowledge on climate change impacts could empower local farmers to pursue better adaptation strategies. The limitation of this paper is that it does not explicitly analyze the impacts of rainwater harvesting on maize yields, food security status, and resilience, although this correlation has been observed in several SSA countries, especially in drylands. Further research is required into this aspect. We also recommend further studies on the potential impacts of climate change on other major crops in Ghana, according to different scenarios and adaptation strategies.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, upon request.

Ethics statement

Ethics review and approval/written informed consent was not required as per local legislation and institutional requirements.

Author contributions

ED: conceptualization, methodology, data analysis, and writing-original draft preparation. EB: conceptualization, methodology, data curation and analysis, and writing-original draft preparation. AR, OT, OO, AS, and SAg: supervision, writing-reviewing, and editing. SAm: data curation, writing-reviewing, and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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