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Research Article

Factors Affecting the Adoption of Wildfire Management Technology in Ghana

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Abstract

This study evaluates the factors that influence and limit the development of fire belts, a fire management technique used by Ghanaian farmers. We obtained primary data from three hundred farmers. Kendall's coefficient of concordance and the logit model were used. Awareness of fire belt creation as fire management technology was high, with a generally positive perception of fire belt creation. This methodology, however, was adopted by less than half of the farmers. Age, gender, marital status, type of crop grown by the farmer, access to community fire volunteers, FBO membership, awareness of technology, cost of technology, and ease of technology use are the factors that determine the incidence of adoption of fire belt creation. Major constraints in adoption include limited access to information, unavailability of assistance from GNFS, initial investment cost, illiteracy, unwillingness to adopt the technology, culture and traditions, time-consuming and difficulty in technology use and risk and uncertainty about the technological application. To improve the uptake of fire belt creation there is the need to form and strengthen community fire volunteers and group dynamics (FBOs) at the community level as it promises to promote fire belt creation as fire management technology and hence reduce wildfire risk in the communities.

Keywords

Biodiversity, Fire Volunteers, Ghana, Wildfire Risk, Transition Landscape

1. Introduction

Humans have used fire to manage natural resources for thousands of years [10, 35]. Fire has historically been employed as a management tool to regulate the composition and structure of vegetation, to hunt, and to recycle nutrients contained in dead and live biomass [10]. Nevertheless, inappropriate handling of fires frequently results in wildfires, which are uncontrolled fires that consume large areas of farmland and forest and have the potential to wipe out human life and biodiversity. Wildfire is undoubtedly one of the most significant and widespread natural disturbance agents worldwide, mostly devastating the environment and causing severe social, economic, and environmental consequences [16, 8, 19].

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Wildfires have significant negative effects on the environment, such as a decrease in biodiversity due to the loss of plants and animals, a decrease in soil fertility, an increase in erosion rate, and a decrease in infiltration. These factors can eventually result in a shortage of water for irrigation, livestock, fish, wildlife, and people.

Because a sizable section of Sub-Saharan Africa was formerly composed of a wide landscape of fire-prone tropical and subtropical savannas, the continent is known as the most fire-prone continent in the world [39, 34]. In Ghana, climate change has led to drier weather and higher temperatures, which has increased the risk of wildfires. The frequency, severity, and area burning at high intensity of wildfires are increasing [11, 1]. Large wildfires have become increasingly common and expensive in recent years due to a combination of factors, including expanding human settlements into vegetation prone to fire, which increases fuel loads [31].

Most wildfires in Ghana result from human activities, with negligence associated with leftover burning as the primary cause [8, 12]. Smallholder farmers' preparation of their farms has been blamed for the recent rise in wildfire incidents in the country. Indiscriminate bush burning continues to be practiced in most rural areas of Ghana [7, 4]. These actions have resulted in a sharp rise in the frequency of wildfires, which has severely damaged agricultural land, national parks, native forests, and commercial timber plantations. However, effective wildfire management technologies are crucial for minimizing wildfire risk among smallholder farmers and rural communities. One such technology is the creation of a fire belt during farmland preparation. A fire belt is a cleared area or strip of land that acts as a barrier to slow or stop the spread of a wildfire [32]. The creation of a fire belt during the burning of a farm involves removing vegetation and other combustible materials along the perimeter of the farm. This creates a gap in the fuel continuity, reducing the chances of the fire spreading beyond the designated area. Fire belts act as physical barriers that can help contain and control the spread of wildfires, protect property, enhance firefighter safety, facilitate fire suppression efforts, reduce fire intensity, and prevent spots [25, 32]. These benefits make fire belts an effective tool in mitigating wildfire risk and the associated impacts.

Ghanaian farmers are reluctant to use fire belt as a fire management technique during farmland preparation, despite its acknowledged advantages. According to the Ghana National Fire Service, which is in charge of promoting fire management technology in Ghana, farmers are not adopting these technologies at all. This might be the result of farmers holding differing opinions about the efficiency and long-term consequences of the technologies used to control fires. This study offers a source of data to direct institutions' and organizations' efforts, whose interventions aim to assist local communities in implementing strategies that lessen the likelihood of wildfires.

Owing to the paucity of empirical data regarding farmers' usage of fire belts as a fire management tool, the purpose of this study was to address the following queries: (A) What elements affect Ghanaian farmers' adoption of the creation of fire belts? (b) What limitations exist for the application of fire belt development as a technology for managing fires?

2. Materials and Methods

2.1. Conceptual Framework

This study is based on the presumption that farmers adopt fire belt creation as a management technology to help address wildfire risk in farming. While such a technology may reduce wildfire risk, its adoption could be hindered by many factors. However, as is well established in the literature and as shown in Figure 1, the adoption of fire belt creation as a fire management technology is influenced by several factors which may generally be grouped as demographic characteristics (age, gender, household size, years of formal education, marital status), farm-level characteristics (farm size, landscape, distance to farm, plantation crop), institutional characteristics (access to community fire volunteers, FBO membership, extension contact), and perception variables (awareness of technology, climate change, cost of technology, ease of technology usage). This implies that while some fire technologies could help reduce risk, a farmer may decide to forgo the adoption of such technologies if they fail to enhance their returns. It is generally assumed that a farmer will adopt a fire management technology if the benefits from the adoption of such a technology outweigh the cost.

2.2. Study Area

Both quantitative and qualitative data were collected from the forest and transition landscapes of Ghana from June to August 2023. The forest and transition landscapes were purposely chosen for two reasons: firstly, both forest and transition landscapes have high levels of wildfire risk in Ghana; and secondly, Tropenbos Ghana, the private sector, the government, and development partners are undertaking various projects to enhance communities' preparedness in wildfire risk management, climate-smart practices, forest protection, and biodiversity conservation. Figure 2 shows the geography of the study site. Using a three-stage sample strategy, 300 farmers—150 from each landscape—were interviewed in a semi-structured survey format to gather data. Five districts were specifically chosen from each landscape for the initial stage. In the second phase, three communities were chosen at random from each district based on a list of high-fire risk communities that was obtained from the Ghana National Fire Service. In the third phase, ten farmers were selected at random from each community using a methodical random sample technique that was based on a community-level list of farmers. In addition, four Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) at the community level were conducted to confirm the data gathered. The FGDs provided qualitative information for understanding farmers' perspectives on adopting or not adopting fire belt creation as a fire management technology, and this information was considered while designing the survey instrument.

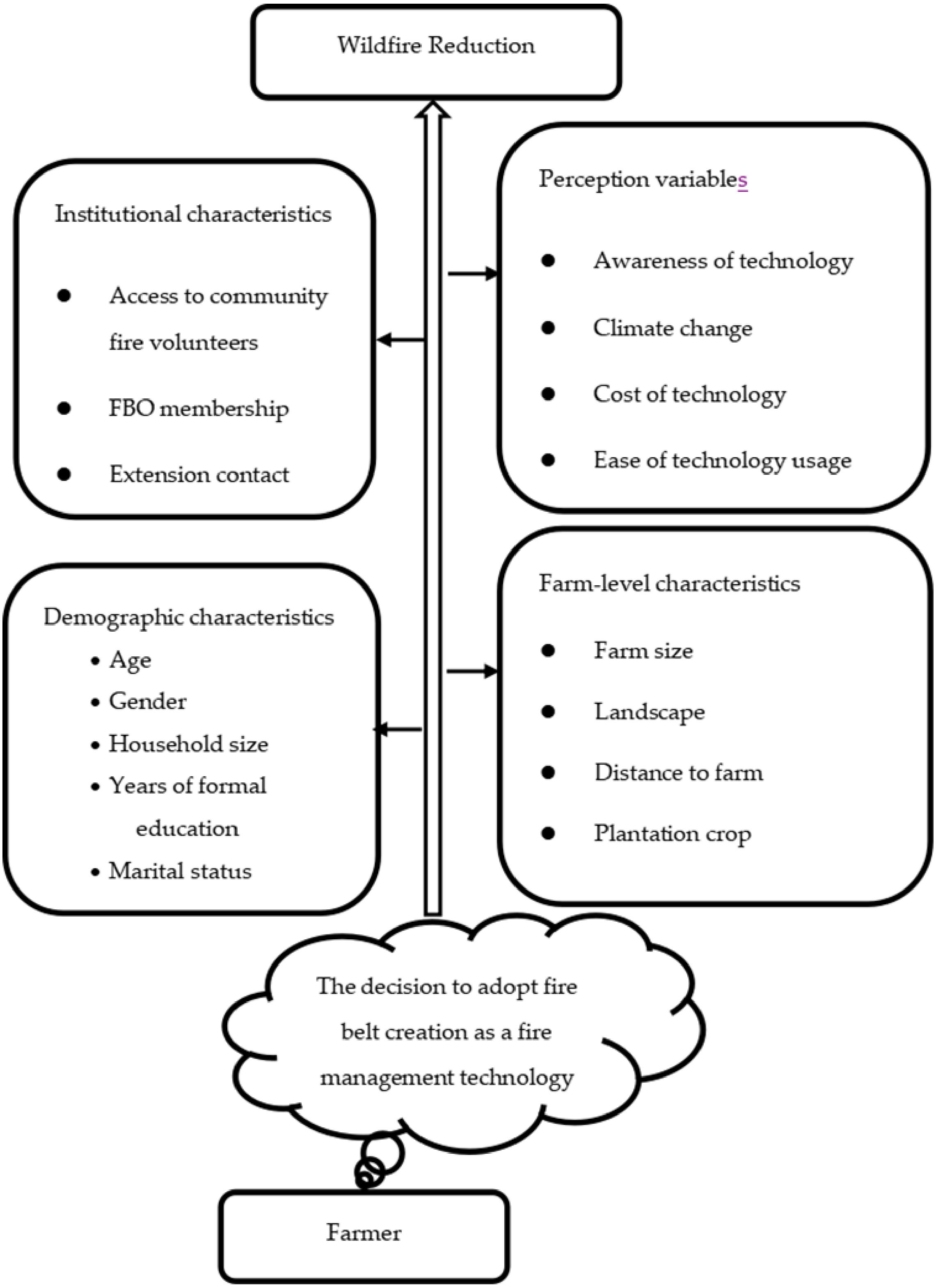

Figure 1. *Factors that influence the adoption of fire management technology.*

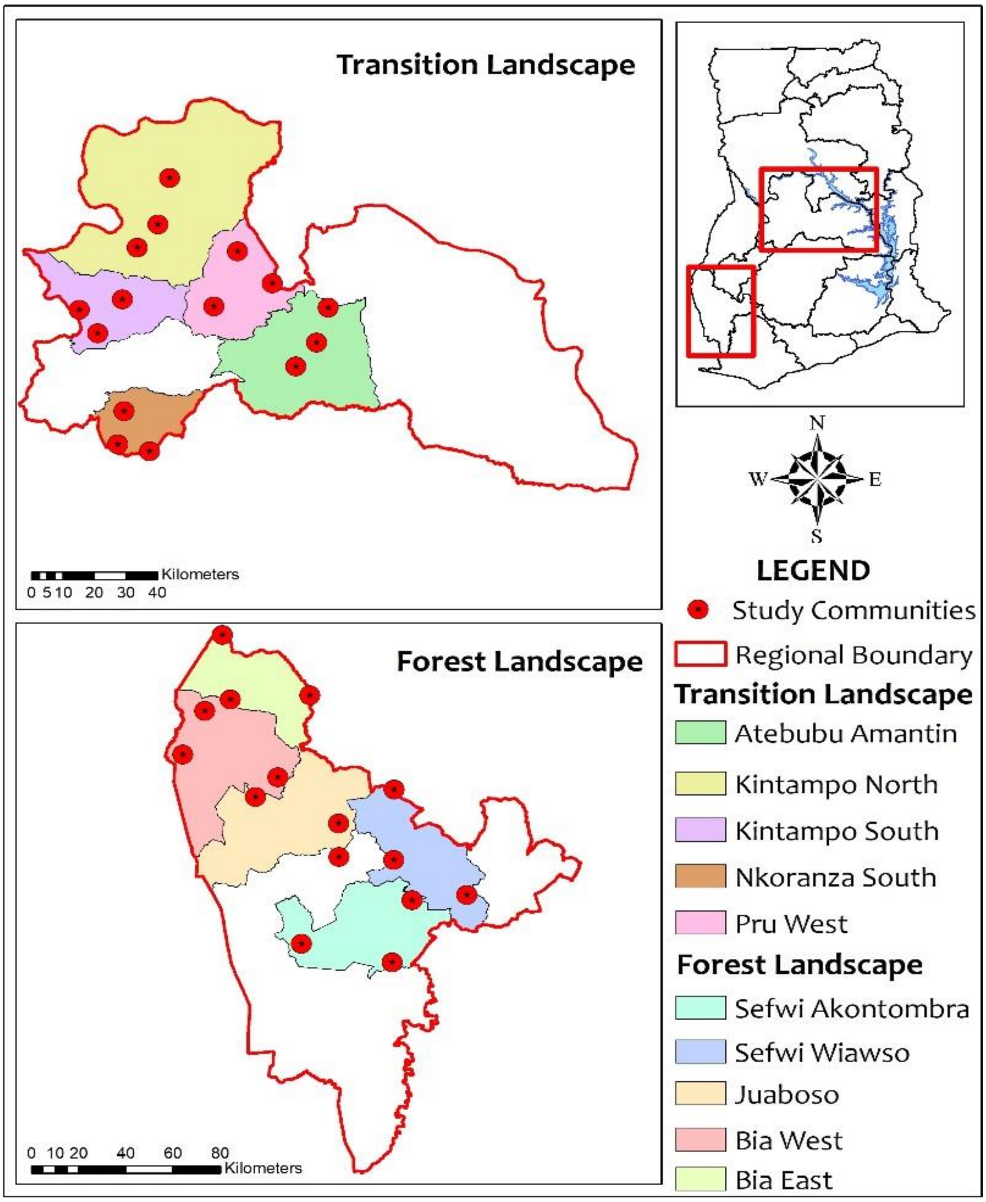

Figure 2. Map of the study area.

The forest landscape covers an area of around 22,391 square kilometers and is located between latitudes 6°18′0″ North and longitudes 2°48′0″ West. Meanwhile, the transition landscape is located between latitudes 7°45′ North and longitude 1°03′ West and covers 22,952 square kilometers. Table 1 provides the detailed hydrometeorological features of the research area.

Table 1. Hydrometeorological characteristics of the study area.

Characteristics	Forest Landscape	Transition Landscape
Mean temperature	25 to 30 degrees.	30 to 40 degrees.
Average humidity	Humidity is relatively high, at about 90% at night, falling to 75% during the day.	The relative humidity ranges from 90–95% in the rainy season to 75–80% in the dry season.
Average rainfall	Moderate to heavy rainfall pattern between 1200 mm and 1780 mm.	Average annual rainfall of 750 mm to 1050 mm (30 to 40 inches).
Topography	152.4 m to 660 m above sea level.	The land rises from an average height of 200 m in the

Characteristics	Forest Landscape	Transition Landscape
		southern and eastern parts to 700 m in the northern part.
Soil condition	The soils are mostly lateritic. They are subdivided into relatively fertile and less-acidic ochrosols (red, brown, and yellow-brown, relatively well-drained soils).	Three main soil types are found. They are the forest ochrosols in the south-western part, savannah ochrosols in the middle zone, and laterite ochrosols in the northern section.
Main occupation	Cocoa, rubber, and coconut and palm oil. There are many small- and large-scale gold mines.	Agriculture is a predominant economic activity (farming, fishing, and rearing of livestock).
Landscape type	Highest rainfall in Ghana, lush green hills, and fertile soils.	The vegetation consists predominantly of forest and fertile soils.

2.3. Data Analysis

Farmers' constraints and determinants of the adoption of fire belt creation as a fire management technology were assessed with Kendall's coefficient of concordance and the logit regression model, respectively. Collected data were analyzed using the statistical software STATA (version 18.0).

2.4. Assessing Constraints in Adopting Fire Belt Creation as a Fire Management Technology

The degree of agreement or concordance among respondents was further tested by ranking the drawbacks of employing fire belts as a fire management tool from most significant to least important using Kendall's coefficient of concordance. Using a five-point Likert scale, where +1 represents the most essential constraint and −1 represents the least important constraint, the respondents listed and rated the constraints they encounter when using fire belts for fire management. Kendall's coefficient of concordance (W) is given as follows:

$$W = \frac{n[\sum T^2 - (\sum T)^2/n]}{nm^2(n^2-1)} \quad (1)$$

Where m is the number of respondents; n is the number of constraints being ranked; and T is the sum of ranks for the constraints being ranked. First place goes to the constraint with the highest mean score, and last place goes to the constraint with the lowest mean score. When responders have a coefficient of concordance of exactly one, there is a maximum (100%) degree of agreement. On the other hand, when the coefficient is 0, there is the lowest level of agreement (0%).

2.5. Assessing the Determinants of Adopting Fire Belt Creation as a Fire Management Technology

To better understand the adoption decision of fire belt creation as a fire management technology, an econometric model was specified and estimated using the logit regression model. The logit regression model is used to investigate the determinants of the farmers' decisions on whether they adopt fire belt creation as a fire management technology or not. The decision may be influenced by an "asset bundle" comprised of socio-economic, farm-level, institutional, and perception variables.

In order to analyze binary responses, a logit model was employed, which enables one to look at how changes in any independent variable affect all of the outcome probabilities [22]. Reliability of the results to changes in the collection of explanatory variables included in the regression is often quite high. Consequently, there is a non-linear relationship between the discrete variable and a parameter. Let Y_i represent the binary answer of a farmer in the basic model. If the farmer chooses to accept fire belt development as a means of managing fire ($j = 1$), then $Y_i = 1$; otherwise, $Y_i = 0$. Assume that β, a vector of slope parameters, measures the slope, and x, a vector of explanatory variables, influences the farmer's adoption decision to adopt fire belt creation in managing fire. Thus, the probability of adopting the technology is then expressed as [22]:

$$P(Y_i = 1) = P_i = \frac{1}{1+exp^{-z}} \quad (2)$$

where

$$Z = \beta_0 + \beta_i X_i + \varepsilon_i$$

The logit transformation of the probability of the adoption of fire belt creation as a fire management technology, $P(Y_i = 1)$, can be represented as follows (following Gujarati, 2003):

$$L_i = \ln\left[\frac{P_i}{1-P_i}\right] = Z_i = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \varepsilon_i \quad (3)$$

where

$Y_i = (Adoption\ of\ fire\ belt\ creation)$ —Dichotomous dependent variable

$X_i = Vector\ of\ variables\ included\ in\ the\ logit\ model,$

$\beta_i = Parameters\ to\ be\ estimated$

$\varepsilon_i = error\ term\ of\ the\ model,$

$\exp(e) = base\ of\ natural\ logarithms$ (ln),

$L_i = Logit\ and\ \frac{P_i}{1-P_i} = Odd\ ratios.$

Here, the same explanatory variables (variables affecting the adoption of fire belt creation as a fire management technology) determined the dependent variable, so the logit model was used to gauge the factor affecting fire belt creation, using the functional form of the logit model expressed as:

$$Y_{ij}^* = \beta_0 + \beta_1 DC_{ij} + \beta_2 FC_{ij} + \beta_3 IC_{ij} + \beta_4 PV_{ij} + \vartheta_{ij}, (j = 1,2,3,4,5) \quad (4)$$

$Y_{ij} = \int if\ \ Y_{ij}^* > 0/0$ otherwise.

The empirical is therefore stated as:

Adopted "fire belt creation" = fire belt creation =

$$\beta_0 + \beta_1 age_1 + \beta_2 gender_2 + \beta_3 household\ size_3 + \beta_4 years\ in\ formal\ eductation_4 + \beta_5 marital\ status_5 + \beta_6 farm\ size_6 + \beta_7 landscape_7 + \beta_8 disctance\ to\ farm_8 + \beta_9 type\ of\ crop\ planted\ (plantation)_9$$

$$+\beta_{10} access\ to\ community\ fire\ volunteers_{10} + \beta_{11} FBO\ membership_{11} + \beta_{12} extension\ contact_{12} + \beta_{13} awareness\ of\ technology_{13} + \beta_{14} climate\ change_{14} + \beta_{15} cost\ of\ technology_{15} + \beta_{16} ease\ of\ technology\ usage\ _{16}$$

where $j = 1$ denotes fire belt creation as a fire management technology. In Equation (3) the assumption is that a rational ith farmer has a latent variable, Y_{ij}, which captures the unobserved preferences or demand associated with the ith choice of fire belt creation as a fire management technology (j = adoption fire belt creation, Yes = 1). Given the latent nature of Y_{ij}^*, the estimations are based on observable binary discrete variables Y_{ij}, which indicate whether or not a farmer undertook fire belt creation as a fire management technology at the farm level. β is a vector of slope parameters, DC is demographic characteristics (age, gender, household size, years of formal education, marital status), FC is farm-level characteristics (farm size, landscape, distance to farm, plantation crop), IC is institutional characteristics (access to community fire volunteers, FBO membership, extension contact), and PV is perception variables (awareness of technology, climate change, cost of technology, ease of technology usage) (refer to Table 2 for detailed descriptions of these variables).

Table 2. *Variables used in the logit regression model.*

Variable	Measurement	Expected Effect on Adoption
Response variable		
Adoption	1 if farmer has adopted "fire belt creation", 0 if farmer has not adopted	
Explanatory variables Demographic characteristics		
Age	Years	+/–
Gender	1 if male farmer, 0 if female farmer	+/–
Household size	Number	+
Formal education	Years of schooling	+
Marital status	1 if farmer is married, 0 if otherwise	+/–
Farm level characteristics		
Farm size	Hectares	+/–
Location	1 if transition landscape, 0 if otherwise	+/–
Distance to the farm	Kilometers (km)	–
Plantation crops farmer	1 if plantation crop farmer, 0 if otherwise	+

Variable	Measurement	Expected Effect on Adoption
Institutional characteristics		
Access to community fire volunteer	1 if access to community fire volunteer, 0 if otherwise	+
Extension contacts	1 if a farmer had extension contact in 2022, 0 if otherwise	+
FBO membership	1 if the farmer belongs to a Farmer-Based Organization (FBO), 0 if otherwise	+
Perception variables		
Awareness of technology	1 if aware of the technology, 0 if otherwise	+
Climate change	1 if climate changing, 0 if otherwise	+
Cost of technology	1 if technology is costly, 0 if otherwise	−
Ease of technology use	1 if ease of technology use, 0 if otherwise	+

3. Results

3.1. Descriptive Analysis of Variables

Characteristics of Farmers

Descriptive statistics of the sociodemographic factors of the farmers surveyed are shown in Table 3. Data was not separated according to landscape because there was no discernible difference between farmers in the forest and transition areas. Age, gender, farm size, landscape, FBO organization, awareness of technology, cost of technology, climate change, and ease of use of technology are among the characteristics of adopters and non-adopters of "fire belt creation" that show statistically significant differences, according to the table's t-test results. Based on the pooled data, 35% of farmers interviewed had adopted ‘fire belt creation” as a fire management technology during land preparation. However, the rate of adoption was lower (30%) in the transition landscape compared to the forest landscape, where about 40% of respondents had adopted the technology. More than half (76%) of the farmers in the pooled sample were males, and the majority (65%) of the adopters were males. Traditionally and culturally, the burning of farms as part of land preparation is a male-dominated activity [36]. From the pooled data the average age of farmers was 42 years, indicating that farming in Ghana is dominated by farmers of advanced ages. The average number of years of formal education is equal for both adopters and non-adopters (7 years). An average farmer in the pooled sample completed seven years of formal education, implying that farmers in Ghana have a low level of education in general. Only 24% of the farmers had access to community fire volunteers during the 2022/2023 farming season. More than 61% of farmers who have adopted fire belt creation in fire management belong to FBOs, compared with only 51% for non-adopters. Usually, the adoption of new technologies involves cost; about 47% of the farmers consider the cost of technology. About 78% of the respondents are aware of changing climatic conditions in the communities. A greater percentage of adopters (82%) were aware of fire belt creation as a fire management technology during land preparation, compared with non-adopters (67%). This indicates that farmers in Ghana are highly aware of the establishment of fire belts as a fire management technique. According to Table 3’s findings, farmers were further informed via other farmers (81%), the Ghana National Fire Service (GNFS) (82%), radio and television (88%), and extension education (91%). Even with such widespread knowledge, less than half (35%) of Ghanaians had used "fire belt creation" as a fire management technique.

Table 3. *Description of farmer characteristics.*

Variables	Adopters (N = 105)			Non-Adopters (N = 195)			*t*-Test	Pooled (N = 300)		
	N	Mean	Std. Dev	N	Mean	Std. Dev		N	Mean	Std. Dev
Age	105	43.48	15.10	195	41.08	15.50	−1.29	300	41.92	15.38

Variables	Adopters (N = 105)			Non-Adopters (N = 195)			*t*-Test	Pooled (N = 300)		
	N	Mean	Std. Dev	N	Mean	Std. Dev		N	Mean	Std. Dev
Gender	105	0.76	0.42	195	0.59	0.49	−3.02 ***	300	0.65	0.48
Household size	105	6.65	3.34	186	6.22	3.34	−1.07	291	6.38	3.34
Years of formal education	105	7.70	4.16	195	6.59	4.16	−2.01 **	300	7.0	4.53
Marital status	105	0.49	0.50	195	0.36	0.48	−2.21 **	300	0.41	0.49
Farm size	105	3.23	2.18	195	3.24	1.75	0.069	300	3.24	1.90
Landscape	105	0.34	0.48	195	0.34	0.50	1.65 *	300	0.41	0.49
Distance to the farm	105	2.75	1.67	195	2.22	1.74	−2.53 **	300	2.41	1.72
Plantation crop farmer	105	0.48	0.50	195	0.36	0.48	−1.89 **	300	0.40	0.49
Access to community fire volunteer	105	0.19	0.39	195	0.26	0.44	1.47	300	0.24	0.42
Extension contacts	105	0.76	0.86	195	0.43	0.50	−4.19 ***	300	0.43	0.51
FBO membership	105	0.61	0.49	195	0.51	0.50	−1.61	300	0.55	0.49
Aware of defensible space creation	105	0.82	0.38	195	0.67	0.47	−2.83 ***	300	0.72	0.45
Cost of technology	105	0.55	0.49	195	0.42	0.49	−2.19 **	300	0.47	0.50
Climate change	105	0.75	0.43	195	0.79	0.40	0.74	300	0.78	0.41
Ease of technology usage	105	0.90	0.29	195	0.75	0.42	−3.10	300	0.81	0.39
Aware through radio and TV	105	0.93	0.25	195	0.85	0.36	−2.20 **	300	0.88	0.32
Awareness through GNFS	105	0.92	0.25	195	0.77	0.42	−3.40 ***	300	0.82	0.38
Awareness through extension officers	105	0.92	0.27	195	0.89	0.30	−0.747	300	0.91	0.29
Awareness through other farmers	105	0.89	0.32	195	0.78	0.79	−1.31	300	0.81	0.67

Notes: N denotes number of observations; Std. dev. denotes standard deviation. Values in parentheses are t statistics. ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

3.2. Constraints Associated with the Adoption of Fire Belt Creation as a Fire Management Technology

Farmers who use fire belts as fire management technologies indicated the constraints they face in adopting fire belt creation (Table 4). The table shows that limited access to information, unavailability of assistance from the GNFS, initial investment costs, illiteracy, unwillingness to adopt, culture and traditions, ease of use, and risks and uncertainties about the technology's application were reported as important constraining factors. Fire belt creation, like all other fire management technologies, needs to be understood by these farmers. Concerns about the ease of use and effectiveness of wildfire management technologies may discourage their adoption [24]. Likewise, farmers may have limited knowledge or understanding of the benefits and potential of wildfire management technologies [20]. Cost implications and financial constraints can be great barriers that can hinder wildfire management technologies [20]. The absence of sufficient incentives or regulatory frameworks to promote the adoption of wildfire management technologies can hinder their implementation [23]. The lack of access to appropriate tools and resources for implementing wildfire management technologies can impede their adoption [20]. The complexity of wildfire management technologies and their compatibility with existing systems and processes can pose challenges to their adoption [37]. Uncertainty about the benefits and outcomes of adopting wildfire management technologies can deter their adoption [27]. According to Kendall's coefficient of concordance, farmers' agreement on how to order the limitations was only 12.3%. These limitations align with earlier research. According to earlier research, farmers who score highly on the inhibitor dimension of technology readiness are more likely to stick to their comfort zones and be reluctant to explore new technologies, which reduces the possibility that they will embrace the technology [33]. High adoption costs and a lack of perceived technology benefits were among the challenges [17].

Table 4. Constraints farmers face in using fire belt creation as a fire management technology.

Constraint	Level of Agreement (%)						
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean Rank	Position
Limited access to information	18.33	12.33	63.00	3.33	3.00	4.87	2nd
Unavailability of assistance from GNFS	22.00	11.00	58.67	3.67	4.67	4.68	3rd
Initial investment costs	63.67	5.67	27.33	3.33	0	4.52	5th
Illiteracy	8.00	19.00	32.33	6.00	34.67	5.82	1st
Unwillingness to adopt the technology	20.33	17.33	22.00	35.50	4.5	3.07	8th
Culture and traditions	37.00	12.67	31.67	4.33	14.33	4.33	6th
Ease of use	20.67	11.33	66.67	1.00	0.33	4.62	4th
Risks and uncertainties about technology application	43.33	11.00	25.33	4.67	15.67	4.10	7th
Test statistics							
Number of observations	300						
Kendell's coefficient of concordance	0.123						
Chi-square	258.378						
Degree of freedom	7						
Asymptotic significance	0.000						

3.3. Determinants of Adoption of Fire Belt Creation as a Fire Management Technology by Farmers

The logit model estimates for the factors affecting the adoption of 'fire belt creation' as a fire management technology are shown in Table 5. The mean variance inflation factor (VIF) of 1.314 shows no multicollinearity among explanatory variables (Table A1 in the appendix). Also, from the Breusch–Pagan/Cook–Weisberg test for heteroscedasticity (Section S1 in the supplementary material), the chi-squared 4.96** is significant, leading to the rejection of the null hypothesis of constant variance. Due to the presence of heteroscedasticity, the robust standard error was used in the model estimation. The Pseudo R-squared shows that the explanatory variables explain 19.51% of the variations in adoption.

Age: age has a positive and significant effect on technology adoption. The mean age of the surveyed farmers was 42 years, which is far below the national average age of 55 years for a farmer in Ghana as documented by the Ministry of Food and Agriculture in 2015. The marginal effects show that older farmers are better placed (2.2% more likely) to adopt improved fire belt creation as a fire management technology. This can be attributed to high agility and enthusiasm to experiment with technologies like fire belt creation. This means that the likelihood of taking up fire belt creation as a fire management technology is higher among older farmers. It is believed that older farmers are more knowledgeable and experienced than younger farmers and can assess technological information more accurately [28]. This result confirms a prior expectation for this study and agrees with studies by [21, 11], which indicate that older farmers adopt technology more easily than younger farmers who are risk-loving.

Gender: Farmers' likelihood of implementing fire belt formation as a fire management technology is positively and significantly impacted by gender ($p < 0.005$). In comparison to households headed by women, there is an 80% chance that a male will embrace fire belt development as a fire management device. According to the marginal effects, male farmers are more likely than female farmers to use fire belt development as a fire management technology, with a 14.6% higher likelihood. Compared to female farmers, male farmers are more likely to have access to agricultural information such as methods for managing fires. For instance, men are more likely to benefit from agricultural extension education than women because of women's household chores, which prevent them from attending certain meetings. Female farmers, as such, may lack relevant fire management information or obtain outdated information. Since information/awareness is key in fire management technology adoption, this gives male farmers an edge in adopting fire belt creation as a fire management technology. [38] examined the influence of gender on technology adoption and discovered no statistically significant correlation between gender and the likelihood of adoption in Ghana.

Plantation crop farmer: the type of crops grown (plantation) is a significant explanatory variable in this study. The presence of plantation crops positively influences farmers' decisions to adopt fire belt creation as a fire management technology. For each one-unit increase of plantation farmers, the probability of adopting fire belt creation in fire management increases by 13.6% and 74.20%, respectively, keeping other variables constant. In this case, plantation crops are considered an asset for the farmers and play a very important role by serving as a source of income. Therefore, having a plantation can strengthen farmers' adaptive capacity for fire belt creation in fire management. Consequently, as the number of plantation farmers increases, the farmers will look for adaptation measures that safeguard their assets against wildfire risk. This study agrees with findings by [30] who found out that farmers who practice high-value plantation crop diversification may have a higher likelihood of adopting wildfire technology as they seek to protect their diverse crop portfolio. The study also corroborates the findings of Izaba et al. (2023) [26] and Anuja, A. R. et al. [9], who indicated that farmers growing high-value crops may be more motivated to adopt technology to protect their investments and ensure crop productivity.

Access to community fire volunteers: access to community fire volunteers is critical to the adoption of improved fire management technologies by farmers. The probability of adopting fire belt creation as a fire management technology increases by 88.9% for farmers who have access to community fire volunteers, keeping other variables constant. The marginal effects revealed that farmers' access to community fire volunteers increases the likelihood of adopting fire belt creation as a fire management technology by 16.2%. This is expected because information flow to farmers via contact with the community fire volunteers facilitates technology adoption due to established trust relations between the two parties. Community fire volunteers are familiar with the terrain, weather patterns, and specific fire risks in their area. Findings from this study agree with [15], who found that localized knowledge allows farmers to respond effectively to fire incidents, making informed decisions about fire management strategies.

FBO membership: The adoption of fire belt development as a fire management tool by farmers is positively and statistically significantly impacted by membership in a Farmer-Based Organization (FBO). Holding all other things equal, farmers who are members of FBOs have a 68.2% higher likelihood of using fire belt formation as a fire management tool than their non-affiliated peers. According to the marginal effects, farmers are 12.5% more likely to use fire belt formation as a fire management technology for every unit increase in FBO membership. This study's conclusion is consistent with that of [6], who discovered that farmers in FBOs have a higher propensity to exchange ideas and gain knowledge from one another over time, hence promoting the adoption of agricultural innovations. Farmers within an organization are more likely to have access to initiatives that increase capacity, hear about colleagues' successes, and learn about obstacles from other farmers who have dealt with wildfires. These will probably facilitate group members' adoption of new technologies, including the development of fire belts as a fire management tool. The strength and composition of farmers' social networks can influence their adoption of wildfire management technologies. Farmers who are part of networks that promote and support the adoption of these technologies may be more likely to adopt them [18].

Awareness of technology: farmers' awareness of the technology influenced its adoption. The positive coefficient of 67.8% indicated that farmers are more likely to adopt fire belt creation as a fire management technology when they are already aware of the technology. The marginal effect indicates that farmers' awareness of fire belt creation as a fire management technology increasing by one unit increases the adoption of the technology by 34.5% when other factors are held constant. This study agrees with [2], who concluded that awareness could bridge the gap between technology adoption and non-adoption. Also, a study by [29] found that a lack of awareness and information were significant barriers to the adoption of improved maize varieties among farmers in Zambia. This implies that only technologies that farmers are aware of or have heard about will be adopted by them. Information accessibility lowers ambiguity about a technology's performance, which—over time—may cause an individual's opinion to shift from being solely subjective to being objective. When the general public has little experience with a particular technology, more information tends to make people less inclined to adopt it. This is likely because more knowledge reveals an even greater information vacuum, which increases the risks or benefits involved in such technology [13, 29, 16]. It is therefore important to ensure that information is reliable, consistent, and accurate.

Cost of technology: the cost of technology had a significant and negative effect on the adoption of fire belt creation as a fire management technology, at 1%. The marginal effect indicated that a one-unit increase in the cost of technology decreases the probability of farmers adopting fire belt creation as a fire management technology by 22.6%, keeping other variables constant. The study agrees with [5] who found that the adoption of an improved technology decreased with the cost of adoption. The study further affirms an assertion by [3] that the likelihood that farmers will adopt a high-cost technology is low, irrespective of the level of gains associated with adopting such technology. This is because most smallholder farmers may not be well-placed to invest such an amount in fire management technology, and this may reduce the rate of adoption.

The adoption of fire belt creation as a fire management technology was significantly and favorably correlated with ease of use of technology. When all other factors are held constant, the marginal effect shows that a one-unit increase in technological ease of use increases the probability of adopting fire belt formation as a fire management technology by 21.6%. The results of this study support research by [14] Caffaro et al., 2020) which discovered that farmers' propensity to adopt technology is positively influenced by its perceived ease of use. Technologies that farmers believe to be simple to use and apply are more likely to be adopted by them. Furthermore, a technology's intricacy and difficulty may serve as impediments to its adoption, particularly for farmers with limited resources. Technologies that require less labor, time, skills, and resources are more likely to be adopted [14].

Table 5. Logit estimates of the factors influencing the adoption of fire belt creation.

Variable	Coefficient	Std. Err	*p*-Value
Age (years)	0.022	0.010 **	0.034
Gender (= male)	0.796	0.324 **	0.014
Household size (number)	0.019	0.042	0.637
Years of formal education (years)	0.043	0.032	0.188
Marital status (1 = married)	0.698	0.317 **	0.027
Farm size (hectares)	0.011	0.072	0.884
Landscape type (1 = transition landscape)	−0.323	0.297	0.278
Distance to farm (kilometers)	0.020	0.102	0.840
Type of crops planted (1 = plantation farm)	0.742	0.344 **	0.031
Access to community fire volunteer (1 = yes)	0.889	0.344 **	0.011
FBO membership (1 = yes)	0.682	0.324 **	0.036
Extension contacts (1 = yes)	−0.359	0.313	0.251
Climate change (1 = yes)	0.519	0.325	0.110
Awareness of technology (1 = yes)	0.678	0.345 *	0.050
Cost of technology (1 = yes)	−1.235	0.435 ***	0.005
Ease of technology usage (1 = yes)	1.177	0.502 **	0.019
Constant	−3.621	0.862	0
Number of observations	300		
Wald chi-squared (16)	64.264		
Probability chi-squared	0.0000		
Pseudo R-squared	0.1714		
Chi-square	64.246		
Akaike crit. (AIC)	344.67		
Bayesian crit. (BIC)	406.82		
Log pseudo likelihood	−155.336		

Note: Response variable for the selection model (adoption) is yes or no; values in parentheses are t statistics. ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

Table 6. *Marginal effects of logit estimates (delta method).*

Variable	dy/dx	Std. Err.	z-Value
Age	0.0040	0.002 **	0.030
Gender	0.146	0.057 **	0.011
Household size	0.0036	0.0078	0.637
Years of formal education	0.008	0.0060	0.184
Marital status	0.128	0.056 **	0.023
Farm size	0.0019	0.013	0.884
Landscape type	−0.059	0.054	0.274
Distance to farm	0.0038	0.019	0.840
Type of crops planted (Plantation)	0.136	0.061 **	0.027
Access to community fire volunteer	0.162	0.062 ***	0.008
FBO membership	0.125	0.058 **	0.031
Extension contacts	−0.066	0.057	0.248
Climate change	0.095	0.059	0.105
Awareness of technology	0.124	0.062 **	0.044
Cost of technology	−0.226	0.75 ***	0.003
Ease of technology usage	0.216	0.089 **	0.015

***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

4. Conclusions

Effective wildfire management strategies are crucial for minimizing wildfire risk. One such strategy is the creation of a fire belt as a fire management technology during land preparation. It is unknown, meanwhile, how widely this technology is being used by farmers and what motivates them to do so, particularly at the farm and family levels. With an emphasis on the development of fire belts as a fire management technique, this study examined the primary forces behind Ghana's acceptance of new technology. The study made use of a sample of 300 replies gathered from a household survey that was recently carried out in Ghana and covered the forest and transition environments. Using the logit model, the following statistically significant variables were found to have an impact on farmers' adoption of fire belts as a fire management technology: age, gender, the type of crop they grow, availability of volunteer community firefighters, FBO membership, technology awareness, cost, and ease of use. The likelihood of adopting this fire management technology is the greatest with ease of technology use. Factors such as household size, level of education, extension contact, climate change, and distance to farm were found to be statistically insignificant in driving farmers' decisions to adopt fire belt creation as a fire management technology. Many parties involved in the agricultural and forest ecosystem, such as NGOs, the forestry commission, extension agents, farmers, district assemblies, the commercial sector, legislators, and the government, can benefit from the study's conclusions. The formation and reinforcement of community fire volunteers and group dynamics (FBOs) at the local level has the potential to encourage the establishment of fire belts as a fire control technique, hence lowering the danger of wildfires. It is necessary to pursue policy efforts that raise public awareness of the technology and simplify and lower the cost of its use. Complementary methods that can promote the adoption of fire belt formation technology among Ghanaian farmers include the effective targeting of high-risk regions for fires and the supply of fire belt creation logistics. Future research could look at other fire management technologies in Ghana, as well as expand the scope of the study to the savanna landscape.

Abbreviations

FBO	Farmer Based Organization
NGO	Non-Governmental Organization
KII	Key Informant Interview
GNFS	Ghana National Fire Service
IAWF	International Association of Wildland Fire
NFPA	National Fire Protection Association

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Conflicts of Interest

The authors declare no conflict of interest

Appendix

Table A1. *Variance inflation factor.*

	VIF	1/VIF
Cost of technology	1.675	.597
Ease of use	1.658	.603
Extension contact	1.57	.637
Climate Change	1.535	.651
Distance to farm	1.501	.666
Type of crop planted	1.397	.716
Awareness of technology	1.372	.729
Marital Status	1.229	.814
FBO Organization	1.214	.824
Age	1.208	.828
Year of schooling	1.176	.851
Gender	1.165	.858
Landscape	1.133	.883
Access to CFV	1.114	.898
Total Farm Ha	1.099	.91
Household size	1.06	.943
Mean VIF	1.319	.

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