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Research Article

Modeling Pesticide Use Behavior Among Farmers in the Upper East Region of Ghana: An Empirical Application of the Theory of Planned Behavior

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Abstract: This study examined the pesticide use behavior of farmers along the White Volta Basin in the Upper East Region of Ghana, using the Theory of Planned Behavior (TPB) to explore the underlying factors. A multistage sampling procedure was used to select 300 food crop farmers, from whom data was collected and analyzed using the frequency, percentage, means, standard deviation and partial least squares structural equation modeling (PLS-SEM) techniques. The results revealed that attitude, subjective norm, and perceived behavioral control compositely accounted for approximately 29% of the variation in farmers' intention towards the safe use of pesticides, whereas intention and perceived behavioral control explained 38% of the variation in farmers' behavior towards safe pesticide use. Additionally, attitude and perceived behavioral control were found to significantly impact the intention and behavior of farmers towards safe pesticide use in the study area. Accordingly, it is recommended that stakeholders, including agricultural extension agents (AEAs), agricultural input retailers, the Environmental Protection Agency (EPA), and the Plant Protection and Regulatory Services Directorate (PPRSD), collaborate to develop training curricula aimed at improving the behavior of the farmers in the study area. The training regimes should incorporate extension training methods, for example, method and result demonstrations, which are known to improve the attitudes and behaviors of farmers.

Keywords**:** farmers, Ghana, PLS-SEM, safe pesticides use, Theory of Planned Behavior, Upper East Region

1. Introduction

Pests have been a major concern for agricultural production due to their threatening effects on productivity, farm income and the stability of the global food supply [1-4]. This concern has been exacerbated in recent years due to the rapidly growing world population, its reliance on agriculture for sustenance, and the need to minimize agricultural productivity and income losses due to pest attacks [5]. An important measure implemented by farmers to combat the devastating impact of pests on agricultural production and output growth has been the use of pesticides together with other agronomic practices [5, 6]. Although statistics show that Africa's pesticide usage is about 4% of the total world pesticide usage, the concern has been the pesticide use behavior of farmers in Africa [6-9]. Evidence shows that there

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is an increasing trend of inappropriate, unsafe and indiscriminate use of pesticides, coupled with the increasing use of unrecommended pesticides among farmers in Africa [7-9], raising serious food, health and environmental safety concerns.

In the Ghanaian context, the story is not different when it comes to the use of pesticides in combating the negative impact of pests on agricultural productivity. For instance, studies have shown that farmers have resorted to increased use of pesticides, with issues surrounding inappropriate application and disposal methods as well as the use of unapproved pesticides on their farms [5, 10, 11]. Although pesticides are considered effective in controlling pests of different kinds, their indiscriminate use has negative consequences on the environment, ecosystem, food safety, and human health [10, 12-14]. Concerns over the side effects of pesticides on non-target organisms have grown due to the fact that less than 1% of pesticides used for pest control reach the intended pests, while the rest pollute the environment by entering the soil, water, and air [14, 15]. The residue of pesticides often ends up in the food chain, causing destructive health issues for humans and other aquatic and non-aquatic life [4]. For instance, pesticide residual effects have been reported to account for significant cancerous diseases, food poisoning and other immune response suppression and chemical sensitivity in humans [16-18].

High health risks could also result from environmental contamination and the public's exposure to pesticide residue in the food chain [19]. The cumulative effect of pesticides in humans produces immune response suppression and chemical sensitivity at even low concentrations [16]. It has been reported that the negative effects of ingesting pesticides include exposing farmers to breast cancer, decreased sperm count, male sterility, etc. [17]. In another study, it was noted that pesticide poisoning and death incidents have been documented throughout the world, especially in undeveloped nations [18]. In the Upper East Region of Ghana, pesticide poisoning claimed the lives of 15 farmers [20]. Research has also shown that most farmers employ simple farm tools and equipment like knapsack sprayers, buckets, brushes, and brooms to apply pesticides because they lack the financial resources and economic incentives to purchase advanced farm machinery [11, 21, 22], exposing them to direct contact with pesticides and thereby contributing to the increasing incidence of pesticide poisoning. In addition, many farmers use pesticides without the proper personal protective equipment (PPE) like goggles, gloves, overall jackets, and Wellington boots, exposing them to a greater degree of pesticide poisoning with severe health and environmental repercussions [6].

Despite the negative effects of pesticides on human health and the environment, pesticides are being used more frequently in subsistence farming, though with some level of misapplication, especially on vegetable farms [19, 21, 23]. This is being encouraged by ongoing pesticide marketing campaigns by agricultural input enterprises [24, 25]. According to research, food crop producers in Ghana use pesticides at rates that range from 1.3 to 13 times higher than recommended levels [26]. In the riparian towns (especially in the Bawku Municipality, Bawku West and Binduri Districts) along the White Volta Basin in the Upper East Region, dry-season gardening is a significant source of income for the people [27]. It has been reported that farming activities in the area are semi-subsistence and consist of vegetable farms that are spread along the bank of the river [28]. Vegetable farming, on the other hand, is reported to be very high in pesticide usage [21]. There is a need to improve the behavior of farmers towards safe pesticide use in Ghana to reduce significant danger to the environment and human health. Farmers must also be trained and encouraged to adopt safer pesticide use methods and handling techniques. Many studies have been conducted on the use of pesticides by farmers in Ghana [5, 6, 10, 16, 29, 30]. Little is known, however, about the behavior of farmers towards safe pesticide use methods and handling techniques, especially among farmers working in the riparian communities of the White Volta Basin in the Upper East Region. The main objective of the study was to examine the behavior of farmers towards the safe use of pesticides in the area by adopting the Theory of Planned Behavior (TPB).

1.1 *Theoretical framework*

Many theories have been adopted to explain human behavior, and one of the most commonly used behavioral theories is the TPB by Ajzen [31]. The TPB is a flexible model that supports the degree of variance explained and supports application in other contexts, in contrast to other behavioral theories [32], and has been used to predict the intention and behavior of farmers towards pesticide use [33-35]. TPB is utilized in an attempt to clarify and understand the reasons why a farmer may act in a particular way towards safe pesticide use [36, 37]. TPB was useful in this study because it is an important socio-cognitive model for predicting an individual's intention and behavior [38-40]. The theory states that behavior is a result of behavioral intention, which is in turn influenced by the perceived behavioral control, subjective norms, and attitude towards that behavior [31, 41]. The most significant immediate antecedents of behavior are behavioral intentions, even though control over how the behavior is carried out must also be considered [42]. People's intentions are signs that they are prepared to carry out the behavior [39, 43]. An individual is more likely to engage in the behavior based on a stronger intention [32, 36]. On the other hand, three socio-psychological variables, including attitudes, subjective norms, and perceived behavioral control then determine intention [31, 37, 41].

As indicated by Ajzen, [31] attitude is characterized by a favorable or unfavorable assessment of engaging in a particular behavior. Thus, farmers are more likely to adopt safe pesticide usage if they believe that doing so will be helpful and advantageous to them and the environment, and result in fruitful outcomes. The term "subjective norm" refers to the amount of social pressure or expectations that a person feels from important reference people to engage in or refrain from a specific behavior [31, 39, 40]. People tend to follow arbitrary rules out of concern for social rejection [44]. Therefore, farmers' intentions to engage in safe pesticide usage should increase if they believe that people whose opinions they respect confirm it, as the validation of behavior usually serves as positive reinforcement [32, 36, 41]. Last but not least, perceived behavioral control refers to how easy or difficult a person perceives a specific behavior and can carry it out. This perception is linked to the existence of facilitating conditions, also known as situational restrictions [44]. This construct shows how much a person believes they have volitional control over the behavior in question [42, 45]. Farmers' intention to adhere to the safe use of pesticides should therefore grow as their perceived level of control over engaging in this behavior increases [32, 36, 41].

The TPB model is one of the most widely used models for predicting pro-safe environmental behavior. For instance, Meijer et al. [46] used the framework to predict tree-planting behavior and concluded that attitude was the most important predictor of intention. Maleksaeidi and Keshavarz [38] used it to predict farmers' intentions to conserve on-farm biodiversity and concluded that attitude and subjective norms were the most important predictors of farmers' intentions to conserve on-farm biodiversity in Iran. Moon et al. [47] also utilized the TPB to predict the behavior of university students purchasing green crops in Pakistan and revealed that attitude and subjective norms predicted intention. Previous studies have utilized the TPB model to predict the combined effect of attitude, subjective norm and perceived behavioral control on the intention of farmers and by extension behavior [33, 34, 41, 48-52]. In utilizing the TPB model, the study formulated the following hypothesis:

$H_0$1: Smallholder farmers' attitudes influence their intention to adopt the safe use of pesticides.
$H_0$2: Smallholder farmers' subjective norm influences their intention to adopt the safe use of pesticides.
$H_0$3: Smallholder farmers' perceptions of behavioral control affected their intention to adopt the safe use of pesticides.
$H_0$4: Smallholder farmers' intentions affect their behavior towards the safe use of pesticides.
$H_0$5: Smallholder farmers' perceptions of behavioral control affect their behavior towards the safe use of pesticides.
$H_0$6: Smallholder farmers' attitudes indirectly influence their behavior towards the safe use of pesticides.
$H_0$7: Smallholder farmers' subjective norms indirectly influence their behavior towards the safe use of pesticides.

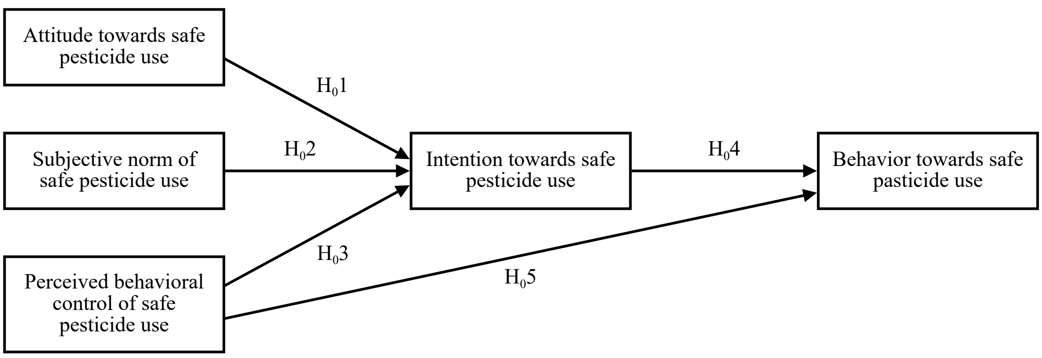

Figure 1. TPB Model of behavior of smallholder farmers towards safe pesticide use

2. Materials and methods

2.1 *Profile of the study area*

The study was carried out in three districts along the White Volta Basin in the Upper East Region. The Upper East Region, which is one of the 16 administrative regions in Ghana, is located in the northeastern part of the country [28]. The region is bordered by the Upper West Region to the west and the North East Region to the south, whereas it is bordered by Burkina Faso to the north and Togo to the east [53]. The study was specifically conducted in 12 communities in the Bawku Municipal (Beika, Mognori, Weit, and Yalugu), the Binduri District (Azum Sapeliga, Googo, Sakpari, and Sapeliga), and the Bawku West District (Gumbo, Kobori, Natinga, and Yarigu). The communities were selected because they are within a 5 to 10 km radius of the White Volta in the Upper East Region. A greater part of the land in the area is used for extensive cultivation and compound cropping (home gardening), which is located within a 3 to 10 km radius of the White Volta Basin [54]. The combined area of the three districts covers a total land area of 1,728 km^2 [55]. According to the 2021 Population and Housing Census [56], the population of the three districts stands at 340,326 people. The area is part of the Sudan Savannah agroecological zone with patches of short grasses, bushes and trees, where soil and moisture conditions allow the vegetation to flourish mainly along the White Volta Basin [53].

The study was conducted along the White Volta Basin due to trends that have been observed, such as the harmful land and water quality degradation due to agricultural activities with their associated pesticide use due to the sharp rise in irrigation demand and the construction of several small dams and dug-outs in the river system's upstream areas [57]. Rain-fed agriculture in the White Volta Basin is becoming more unstable and unreliable as a result of climate change and the fluctuating precipitation that comes with it [27]. It has been observed that non-climatic factors including soil degradation, inadequate technology, poverty, and the decline in rainfall have led to a reduction in crop yield, which is forcing smallholder farmers to apply pesticides to protect their investments [11]. The risks of pesticides used by smallholder farmers may have a detrimental effect on food safety and water quality, with implications for human, animal and environmental sustainability [6]. This study sought to examine farmer behavior towards safe pesticide use along the White Volta Basin in the Upper East Region and its implication for sustainable farming and extension delivery in the area. Figure 2 shows the map of the study area within the regional and national contexts.

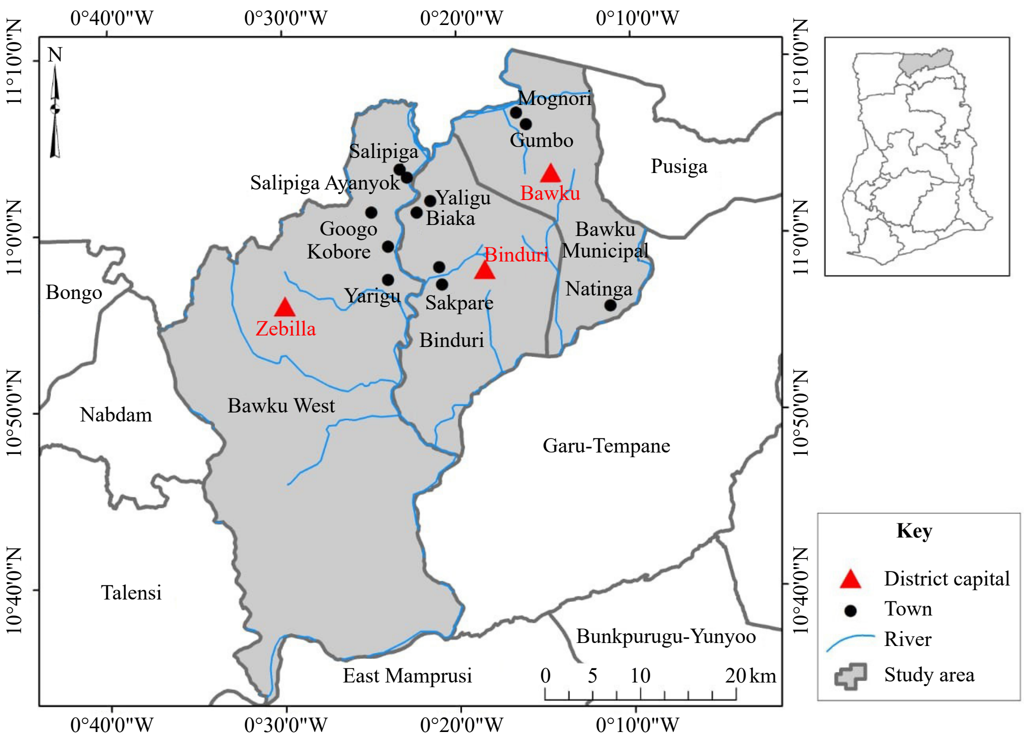

Figure 2. Map of the study area within the regional and national context

2.2 *Study population, sampling procedure, instrumentation, and data collection*

A descriptive cross-sectional survey design was utilized to sample 300 farmers from a population of 1,400 farmers in the three districts at one point in time to make inferences about their intention and behavior towards safe pesticide use along the White Volta Basin [58-60]. Using the Krejcie and Morgan [61] sample size determination table, an appropriate sample size of 300 farmers was estimated to be representative of the population of 1,400 farmers in the study area. Following that, a multi-stage sampling technique was adopted to select respondents for the study. First, three districts were randomly selected out of five within the catchment area of the White Volta Basin [62]. The second stage involved the selection of 12 communities (four from each district) within a 5 to 10 km radius of the river. The final stage involved the random selection of 25 farmers from each of the 12 communities as respondents of the study.

A structured interview schedule was used as the instrument of the study. The instrument for data collection was divided into three parts: information on farmer characteristics, pesticide handling and disposal methods, and behavior towards safe use of pesticides using the TPB model variables. The TPB model was used to measure the behavior of farmers towards safe pesticide use along the White Volta Basin in the Upper East Region of Ghana. The TPB construct items used for the survey were adapted from Bagheri et al. and Abadi [14, 63]. The constructs were reviewed, modified and aligned with the objectives and context of this present study. The TPB constructs were made up of five constructs and each had a different set of items (statements). Each of the constructs: attitude (six statements), behavior (three statements), intention (three statements), perceived behavioral control (three statements) and subjective norms (six statements) were measured on a seven-point Likert type scale of 1 = 'extremely disagree' to 7 = 'extremely agree', respectively. The individual scores (of each farmer) for each item were added up, and the average score was then determined. Following that, the mean values of all the items within each construct were used to compute the average score for each construct (attitudes, subjective norms, perceived behavioral control, intention, and behavior). The current study aimed to investigate how the various TPB constructs affected farmers' intentions and behavior towards safe pesticide use along the White Volta Basin in the Upper East Region of Ghana.

The instrument was pre-tested with 20 farmers in Pwalugu, a farming community along the White Volta Basin in the Talensi District in the Upper East Region, after which McDonald's omega was computed to estimate the internal consistency of the five TPB constructs using the International Business Machines Statistical Package for Social Sciences (IBM SPSS) version 26 [64]. From the results, the estimated McDonald's omega values for the constructs were found to be above 0.80, thereby justifying the reliability of the instrument for the actual data collection [65, 66]. The instrument for the final data collection was reviewed and amended based on the results of the internal consistency analysis [67]. Before data collection in the study area, permission was sought from the Departments of Agriculture in the three districts. The consent of the selected farmers was also sought before data collection [68]. Also, all farmers who declined to participate in the study were allowed to exit it. The instruments were administered to the 300 farmers in the 12 selected communities in the three districts of the Upper East Region with the help of three enumerators [69]. Data collection was carried out in April 2021, before the commencement of the planting season.

2.3 *Data processing and analysis*

The field data was coded into IBM SPSS for data processing and analysis. Frequencies, percentages, means, and standard deviations were used to analyze data on farmer and farm characteristics, farmers' main sources of pesticide information, pesticide disposal methods, and PPE used [70]. Furthermore, partial least squares structural equation modeling (PLS-SEM) was utilized for analyzing farmers' behavior towards safe pesticides following the TPB framework [71]. Smart Partial Least Squares (SmartPLS) version 3.9.9.0 by Ringle et al. [72] was applied to compute the TPB model. Preliminary assessment of the TPB model indicated that some items in the model had factor loading that was less than 0.70; hence, they were deleted from the model. Items 4, 5, and 6 of the TPB construct intention and perceived behavioral control, while items 1, 2, and 3 of behavior were deleted due to low factor loadings [73]. Tenenhaus et al.'s [74] global model fitness (GOF) index and Wetzels et al.'s [75] guidelines were utilized to compute the model fitness of the TPB model. The results of the GOF indices yielded a score of 0.52 (Table 1), indicating a large GOF sufficient to support the universal validity of the TPB model [74].

Table 1. Model fitness indices

TPB constructs	Average Variance Extracted (AVE)	R^2
Attitudes (ATT)	0.73	
Behavior (BEH)	0.93	0.38
Intention (INT)	0.92	0.28
Perceived behavioral control (PBC)	0.63	
Subjective norm (SN)	0.89	
Average scores	0.82	0.33
AVE * R^2	0.27	
GOF = Square root of AVE * R^2	0.52	

3. Results

3.1 *Farmer and farm characteristics*

Table 2 presents results on the farmer and farm characteristics of the respondents of the study. Male farmers dominated (96.0 %) the female farmers who participated in the study. The ages of the farmers ranged from 25 to 71 years, with a mean age of 44.2 years (standard deviation = 8.7 years). The age distribution shows that the majority (77.0%) of the farmers are aged between 31 and 50 years. It was observed that the farmers have considerable years of farming experience. For instance, more than half (56.3%) have accumulated 11 to 20 years of farming experience, with an average of 14.4 years (standard deviation = 6.2). Most of these highly experienced farmers have been using pesticides for 6 to 10 years. Their average number of years of experience with pesticides is 7.4 years (standard deviation = 2.7). The results further revealed that nine out of every ten farmers (97.0%) had no formal education, with a few (1.7% of them) having some form of formal education. All the farmers cultivate different crops, which are mainly vegetables. The five most important crops cultivated by the farmers are onion (85.3%), okra (52.7%), pepper (24.7%), tomatoes (12.3%), and green pepper (12.0%). The mean farm size cultivated by the farmers is 1.4 ha (standard deviation = 0.6 ha).

3.2 *Sources from which farmers acquire information on pesticides*

Table 3 presents the main sources from which the farmers access information on pesticide uses in the study area. The majority of the farmers indicated that their main sources of information on pesticides are agro-input dealers or retailers (88.7%) and agricultural extension agents (AEAs) (86.0 %), in the Departments of Agriculture of the Ministry of Food and Agriculture (MoFA) in their respective districts. Three out of every ten farmers (33.0%) access pesticide information from either their friends or from non-governmental organizations (NGOs).

Table 2. Farmer and farm characteristics

Variables	Frequency	Percentage (%)	Mean	Standard deviation
Sex				
Male	288	96.0		
Female	12	4.0		
Age (years)				
21 to 30	15	5.0	44.2	8.7
31 to 40	117	39.0		
41 to 50	114	38.0		
51 to 60	39	13.0		
61 and above	15	5.0		
Farming experience (years)				
1 to 10	113	37.0	14.4	6.2
11 to 20	169	56.3		
21 to 30	14	4.7		
31 to 40	4	1.3		
Pesticides use experience (years)				
1 to 5	55	18.3	7.4	2.7
6 to 10	235	78.3		
11 to 15	10	3.3		
Type of education				
No formal education	291	97.0		
Non-formal education	4	1.3		
Formal education	5	1.7		
Crops cultivated	*			
Onion	256	85.3		
Okra	158	52.7		
Pepper	74	24.7		
Tomatoes	37	12.3		
Green pepper	36	12.0		
Garden eggs	21	7.0		
Cabbage	20	6.7		
Total farm size cultivated (ha)				
Less than 1	69	23.0	1.4	0.6
1.0 to 2.0	204	68.0		
2.1 to 3.0	22	7.3		
3.1 to 4.0	5	1.7		

Note: * = Multiple responses

Table 3. Sources from which farmers acquire information on pesticides

Sources	Frequency*	Percentage (%)
Input dealers	266	88.7
MoFA/AEAs	258	86.0
Friends	51	17.0
NGOs	48	16.0
Other farmers	18	6.0

Note: * = Multiple responses

3.3 *Disposal methods for leftover pesticides adopted by the farmers*

The results of the disposal methods for leftover pesticides adopted by the farmers are presented in Table 4. Eight out of every ten farmers (83.0%) indicated that they had never received extensive training on safe pesticide use, despite the proximity of their farms to the riparian towns of the White Volta Basin in the Upper East Region. On the disposal of leftover pesticides, more than half of the farmers (53.3%) indicated that leftover pesticides are thrown away without any specific location in mind, while 40% keep them on their farms. An overwhelming nine out of every ten farmers (91.3%) indicated that they wash their knapsack sprayers with any available source of water. Almost all the farmers indicated that after rinsing the knapsack sprayer, the water is poured on the farm (97.3%). On the locations where farmers dispose of empty pesticide containers, a majority (70.7%) indicated that they throw away the empty containers, while the rest either leave the containers on the farm (20.7%) or burn them (8.7%).

Table 4. Pesticide disposal methods adopted by the farmers

Sources	Frequency	Percentage (%)
Participation in extension training on safe pesticide use		
Yes	51	17.0
No	249	83.0
Disposal of leftover pesticides		
Throw away	160	53.3
Kept on the farm	120	40.0
Stored in a warehouse	20	6.7
Total	300	100.0
Location of the washing knapsack sprayer		
At home	3	1.0
Available water sources on the farm	23	7.7
Is any water source available to me	274	91.3
Location for disposing of wastewater after rinsing sprayers		
Pour it by the riverside	8	2.7
Pour it on the farm	292	97.3
Location for disposing of empty pesticide containers		
I throw away	212	70.7
I leave it on the farm	62	20.7
Burns it	26	8.6

3.4 *Personal protective equipment used by farmers*

As shown in Table 5, the results of the PPE used by the farmers indicate that they are well protected when spraying pesticides. The results show that almost all the farmers apply pesticides with a pair of trousers (99.0%), long-sleeve shirts (96.3%), hand gloves (94.3%), head hat (93.3%) and Wellington boots (93.3%). The majority of the farmers also use nose masks or respirators (85.7%), overall clothes (82.3%), and goggles (78.0%).

Table 5. PPE used by farmers

PPE	Frequency*	Percentage (%)
Pair of trousers	297	99.0
Long-sleeved shirt	289	96.3
Hand gloves	283	94.3
Head hat	280	93.3
Wellington boots	280	93.3
Nose mask or respirators	257	85.7
Overalls clothes	247	82.3
Goggles	234	78.0

Note: * = Multiple responses

3.5 *Factors influencing the behavior of farmers towards safe pesticide use*

To understand farmers' pesticide use behavior within a safe protocol context, the study employed the TPB framework and modeled under PLS-SEM. Table 6 presents the results of the means and factor loadings for the constructs and indicator variables from the PLS-SEM model. The PLS-SEM evaluated the direct and indirect relationships between five key constructs from the TPB framework (that is, attitude, subjective norm, perceived behavioral control, intention and behavior towards safe use of pesticides). The results showed that of the five TPB constructs that were modeled in the PLS-SEM, behavior towards the safe use of pesticides scored the highest mean, while perceived behavioral control scored the lowest mean. Generally, the farmers 'agreed' that they have positive behavior toward safe pesticide use (mean = 5.30). The farmers agreed that they would use high-quality pesticides to reduce the frequency of spraying at the riverside and spray low-danger pesticides as recommended by pesticide retailers. TPB construct's subjective norms had the second-highest mean score (mean = 4.74). The farmers 'agreed' that family, friends, pesticide retailers and AEAs agents positively influence their decisions concerning safe pesticide use in the study area. Also, the farmers 'agreed' that they have good intentions towards safe pesticide use alongside the White Volta Basin in the Upper East Region (mean = 4.64). This is shown in the intention to learn and implement plans that reduce pesticide use along the White Volta Basin. The farmers are also willing to use pesticides efficaciously in the next three planting seasons.

Furthermore, the farmers had a 'moderately high' attitude towards safe pesticide use, with a mean score of 4.49. The farmers acknowledge that pouring unused pesticide solutions into the farm contaminates the soil and water bodies, which may be harmful to human health. Additionally, farmers believe that to minimize the harmful effect of pesticides on human health, pesticides should be optimally utilized. The TPB construct's perceived behavioral control had the lowest rank mean score among the farmers (mean = 3.96). The farmers 'moderately agreed' that they can purchase and use pesticides if they want to and have enough skills to use pesticides on their farms. The results imply that the farmers 'moderately agreed' that they have the intrinsic ability to control the way pesticides are used on their farms.

Table 6. Means, standard deviations and factor loadings of TPB model constructs

Variables/Items	Mean	Standard deviation	Loadings
Attitudes (ATT) construct	4.49	1.59	
Pouring unused pesticide solution onto the farm is harmful to human health	4.71	2.16	0.82
To reduce the harmful effect of pesticides on human health, they should be optimally used	4.71	2.16	0.82
Pesticide solutions released into the environment contaminate soil and water	4.55	1.65	0.87
To decrease the number of sprayings, high-quality pesticides should be affordable	4.45	1.67	0.88
Pouring unused pesticide solution onto the farm is harmful to animal health	4.27	1.69	0.86
Pesticides should be used effectively since production is not possible without them	4.24	1.80	0.86
Behavior (BEH) construct	5.30	1.88	
I use high-quality pesticides to reduce the frequency of spraying along the river	5.48	1.93	0.95
I spray the quantity of pesticide as recommended by pesticides retailers	5.27	1.93	0.97
I use low-danger pesticides along the river	5.13	2.08	0.97
Intention (INT) construct	4.64	2.04	
I intend to implement plans that reduce pesticide use along the river	4.66	2.04	0.95
I am willing to use pesticides on my farm efficaciously in the next three years	4.64	2.19	0.96
I intend to learn the efficacious ways of pesticide use along the river	4.61	2.13	0.97
Perceived behavioral control (PBC) construct	3.96	1.67	
I can use pesticides properly if I want to	4.11	2.09	0.81
I have enough skills to use pesticides	3.98	2.11	0.85
I can afford to buy high-quality pesticides	3.78	2.11	0.71
Subjective Norm (SN) construct	4.74	1.85	
My relatives advise against leaving pesticide waste on the farm	4.79	1.97	0.95
My family prevents me from buying pesticides more than recommended	4.77	1.98	0.96
Pesticide retailers prohibit mixing new and old pesticide solutions	4.75	1.99	0.94
My friends advise against leaving pesticide waste on the farm	4.72	1.91	0.94
AEAs prevent us from overspraying crops	4.70	2.00	0.95
Pesticide retailers advise me to return unused pesticides to them	4.69	1.91	0.94

Note: 1 = extremely low; 2 = very low; 3 = low; 4 = moderately high; 5 = high; 6 = very high; and 7 = extremely high

3.6 *Assessment of the measurement model*

The results of the evaluation of the measurement model of the TPB model as used in the PLS-SEM are shown in Table 7. The reliability and validity of the model were evaluated as part of the measurement model [71]. Factor loadings, Cronbach's alpha (rho_A), and composite reliability were utilized to estimate the reliability of the constructs. The factor loadings of the individual items used to measure the construct all recorded values greater than 0.70 [76]. Results of factor loadings are presented in Table 6. Cronbach's alpha and composite reliability all recorded values greater than the threshold of 0.70, demonstrating that TPB model constructs had both indicator reliability and internal consistency, respectively [77, 78]. Adopting the average variance extracted (AVE) indices, the convergent validity of the model was examined. The AVE values of all the constructs were greater than 0.50, therefore the constructs used in the model were deemed to have been validly measured [79].

Table 7. Construct reliability and validity

Constructs	CA	rho_A	CR	AVE
Attitude towards safe pesticide use	0.93	0.94	0.94	0.73
Behavior towards safe pesticide use	0.96	0.97	0.97	0.93
Intention towards safe pesticide use	0.96	0.96	0.97	0.92
Perceived behavioral control towards safe pesticide use	0.71	0.73	0.83	0.63
Subjective norms towards safe pesticide use	0.98	0.98	0.98	0.89

Note: CA = Cronbach's alpha; CR = composite reliability; and AVE = average variance extracted

The second index assessed under the measurement model is the discriminant validity of the TPB model. The discriminant validity of the TPB model of safe pesticide use beside the White Volta Basin was estimated using the Fornell-Larcker criteria and the heterotrait-monotrait (HTMT) ratio. Table 8 shows the results of the Fornell-Larcker criteria for assessing discriminant validity. The criteria indicate that the square root of the AVE scores should be greater than and above the inter-construct correlations of the variables in the model [80]. The results showed that the squared root of the AVE of the five constructs was all greater than and above the inter-construct correlation of the other variables in each column. The results indicate that the model achieved discriminant validity based on the Fornell-Larcker criteria [71].

Table 8. Fornell-Larcker criteria for assessing discriminant validity

Variables	ATT	BEH	INT	PBC	SN
ATT	0.85				
BEH	0.79	0.96			
INT	0.52	0.60	0.96		
PBC	0.36	0.33	0.30	0.79	
SN	0.62	0.64	0.39	0.33	0.95

The second index of discriminant validity of the TPB model was examined using the HTMT ratio [81]. The HTMT ratio values of the TPB model were all over and above the 0.85 recommended threshold for assessing discriminant validity based on the HTMT ratio (Table 9). The results indicate that the model achieved discriminant validity; hence, all the TPB model constructs are uniquely distinct from each other [82].

Table 9. HTMT ratio for assessing discriminant validity

Variables	ATT	BEH	INT	PBC	SN
ATT					
BEH	0.83				
INT	0.54	0.62			
PBC	0.44	0.40	0.35		
SN	0.66	0.66	0.40	0.42	

3.7 *Evaluation of the structural model*

Table 10 presents the coefficient of determination (R^2), Stone-Geisser's (Q^2) value, the f^2 effect and the variance inflation factor (VIF). To ascertain whether the structural model does not violate model assumptions, a multi-collinearity test was performed for the latent independent variables in the structural or inner model using VIF [71]. The latent dependent variable behavior had two latent independent variables (intention and perceived behavioral control), whereas intention as a latent dependent variable had three latent independent variables (attitudes, subjective norms and perceived behavioral control). The VIF scores presented in Table 10 show that all values are below the recommended value of three, indicating that no collinearity issues emerged and hence the results of the structural model can be evaluated [82]. The structural model's explanatory power was evaluated using R^2 values of behavior and intention. The R^2 values of behavior (0.38) and intention (0.29) were considered weak [83]. The findings indicate that farmers' intentions and behaviors regarding the safe use of pesticides close to the White Volta Basin's banks in the Upper East Region are weak. The results indicate that attitudes, subjective norm and perceived behavioral control compositely accounted for 29% of the variation in the intention of the farmers to adopt safe pesticide use, while intention and perceived behavioral control also accounted for 38% of the variance in the behavior of the farmers towards safe pesticide use.

Using Cohen's [84] effect size criteria, the f^2 effects of attitudes, perceived behavioral control and subjective norm on intention and perceived behavioral control and intention on behavior were evaluated (see Table 10). The results show that attitude and perceived behavioral control had a 'medium' and 'small' effect on intention towards safe pesticide use, respectively. On the contrary, subjective norms had 'no effect' on intentions toward safe pesticide use. Also, intention and perceived behavioral control had a 'large' and 'small' effect, respectively, on the behavior of the farmers towards safe pesticide use. Furthermore, adopting the blindfolding technique with a specific omission distance , the Q^2 value was utilized to examine the strength of the predictive accuracy of the intentions and behaviors of the farmers concerning safe pesticide use [85, 86]. The results of the Q^2 values as presented in Table 10 indicate that farmers' intentions (Q^2 = 0.26) and behaviors (Q^2 = 0.34) regarding safe use of pesticides had 'medium' predictive relevance, signifying that the TPB model had a good analytical impact, thereby confirming the precision of the data used in the path model valuation [87].

Table 10. Coefficient of determination, predictive sample technique (Q^2), f^2 effect size and VIF

Dependent variables	R^2	Adjusted R^2	Q^2	Relationships	f^2	Decision	VIF
BEH	0.38	0.37	0.34	INT→BEH	0.44	Large	1.10
				PBC→BEH	0.04	Small	1.10
INT	0.29	0.28	0.26	ATT→INT	0.15	Medium	1.68
				PBC→INT	0.02	Small	1.17
				SN→INT	0.01	No effect	1.64

3.8 *Assessing the hypothesized and direct relationships from the path coefficients*

To estimate the significance of the relationships in the TPB model, the bootstrapping technique with a sample of 10,000 at a 95% confidence interval was executed with SmartPLS [72]. Table 11 presents the results of the beta coefficients, T statistics, and confidence intervals of the variables in the TPB model. The results of the beta coefficients show that attitude (0.42) and perceived behavioral control (0.12) had a strong positive effect on the intention of the farmers towards adopting safe pesticide use. Subjective norms (0.09), on the other hand, did not affect farmers' intentions to adopt safe pesticide use. Further analysis of the beta coefficient values showed that intention (0.55) and perceived behavioral control (0.17) had a good positive effect on the behavior of the farmers about safe pesticide use near the White Volta Basin's banks. Also, attitude (0.23) had a positive indirect effect on behavior, while subjective norms had no indirect effect (0.05) on farmers' behavior towards safe pesticide use.

A review of the statistical significance at a 95% confidence interval showed that the results of the *t*-values from bootstrapping techniques showed that four out of the five relationships assumed statistical significance. The results show that the relationships between attitude and intention (ATT → INT, t = 6.59) and perceived behavioral control (PBC → INT, t = 2.04) are statistically significant. On the contrary, the relationship between subjective norm (SN → INT, t = 1.31) and intention is not significant. Additional examination of the beta coefficient shows that the relationship between intention and behavior (INT → BEH, t = 13.82) and perceived behavioral control and behavior (PBC → BEH) are statistically significant. The results suggest that the TPB model supported hypotheses $H_0$1, $H_0$3, $H_0$4, and $H_0$5, but not $H_0$2. Furthermore, of the three driver variables, attitude (ATT → BEH, t = 5.22) had the strongest significant total effect on the behavior of the farmers regarding safe pesticide use in the study area. The subjective norm (SN → BEH, t = 1.29), however, is not significant. It is therefore important for agricultural stakeholders to focus on improving attitudes and perceptions of behavioral control, which significantly impact farmers' intentions and behaviors regarding safe pesticide use along the banks of the White Volta Basin in the Upper East Region. Figure 3 provides the output of the PLS-SEM from SmartPLS analytical software.

Table 11. Path coefficients and direct relationships

Hypothesis	Relationships	Beta	Standard error	T statistics	P values	2.50%	97.50%	Decision
$H_0$1	ATT → INT	0.42***	0.064	6.59	0.00	0.29	0.54	Supported
$H_0$2	SN → INT	0.09	0.068	1.31	0.19	-0.04	0.23	N/A
$H_0$3	PBC → INT	0.12**	0.059	2.04	0.04	0.00	0.23	Supported
$H_0$4	INT → BEH	0.55***	0.04	13.82	0.00	0.46	0.62	Supported
$H_0$5	PBC → BEH	0.17**	0.051	3.29	0.00	0.08	0.28	Supported
$H_0$6	ATT → BEH	0.23***	0.044	5.22	0.00	0.15	0.31	Supported
$H_0$7	SN → BEH	0.05	0.04	1.30	0.20	-0.02	0.13	N/A

Note: ** stands for p = 0.01; and *** stands for p = 0.001

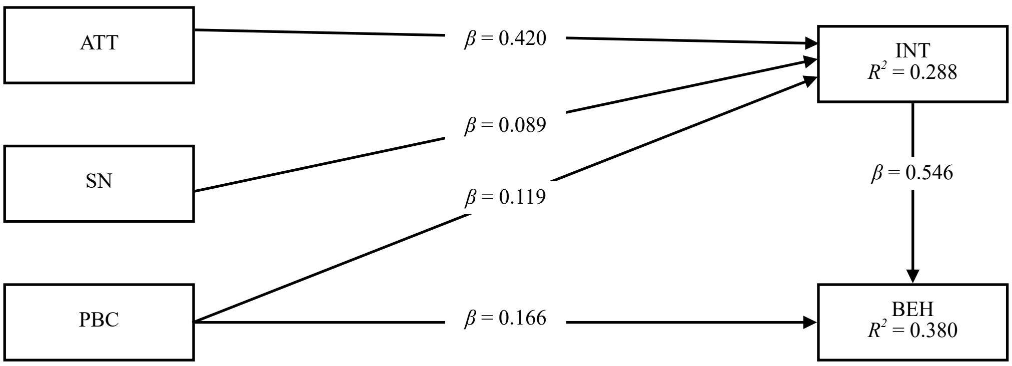

Figure 3. TPB framework showing relationships in PLS-SEM

4. Discussion

This paper examined the behavior of farmers towards the safe use of pesticides in relation to their main sources of pesticide information, pesticide handling and application protocol by farmers close to the banks of the White Volta Basin in the Upper East Region of Ghana. Indiscriminate use of pesticides by farmers has been reported to be one of the causes of environmental pollution and its concomitant effects on the ecosystem, food safety and human health [13, 14]. Significant volumes of pesticide residues have been found in soils, water bodies and the air [15, 34], resulting in the release of carcinogenic substances and leading to disease conditions and the deaths of farmers and the larger population [20, 21]. The situation requires a change in the behavior of farmers towards safe pesticide use, especially as farmers are reported to be applying pesticides at a rate of 1.3 to 13 times more than the recommended volumes [26]. The need to train farmers on safe pesticide use has become apparent. Little is however known about the intention and behavior of the farmers towards the adoption of safe pesticide use, especially those working along the White Volta Basin. This study provides a novel insight into the behavior of farmers regarding the safe use of pesticides along the White Volta Basin and its implications for sustainable farming and agricultural extension delivery in the area. The study adopted the TPB by Ajzen [31] as the theoretical framework. TPB has been used to empirically predict the intention and behavior of farmers in many different agricultural activities [14, 33, 34, 40, 47, 52, 63, 88].

The results show that the TPB provided an empirical explanation of the behavior of farmers regarding the safe use of pesticides near the banks of the White Volta Basin. The three drivers of farmers' intention - that is, attitude, subjective norm and perceived behavioral control - combinedly predicted approximately 29% of the variation in intention, whereas intention and perceived behavioral control explained 38% of the variation in behavior towards safe pesticide use. Attitude toward the safe use of pesticides and perceived behavioral control were the two significant predictors of intention toward safe pesticide use. The results imply that when the farmers develop positive attitudes towards safe pesticide use and master control over their behavior, it positively influences their intention to adopt safe pesticide use. Attitudes had a positive and significant effect on intention, indicating that improvements in attitudes towards safe pesticide use will result in positive intentions towards safe pesticide use. The result is consistent with prior studies, which found a positive effect of attitude on intention [14, 41, 47, 52].

Additionally, perceived behavioral control had a positive and significant impact on intention, indicating that as farmers' perceived control over their behavior towards safe pesticide use increases, it will positively impact their intention to adopt safe pesticide use. Previous studies also reported a positive impact of perceived behavioral control on intention [39, 40, 52, 88, 89]. Subjective norms indicate that farmers perceived external forces such as AEAs, family members and pesticide retailers as influencing their decisions; however, these external forces did not significantly influence their intention towards safe pesticide use. The results imply that the intention of the farmers to adopt safe pesticide use is not significantly influenced by immediate family, relatives, friends, pesticide retailers and AEAs. The result is not surprising since most of the farmers have not received any training on safe pesticide use from extension agents, who are the mandated state agents responsible for training farmers on good agricultural practices, including safe pesticide use. The results are similar to the findings of Rezaei et al. [52] and Shirahada and Zhang [41], which found a non-significant effect of subjective norm on intention.

The results showed that intention and perceived behavioral control were important determinants of farmers' actual behavior towards safe pesticide use. The results indicate that as farmers' intentions and perceived control over their behavior towards safe pesticide use improve, their behavior significantly improves. The results are consistent with the findings of Carfora et al. [88], Pouladi et al. [48], and Wang et al. [90], which concluded that both intention and perceived behavioral control significantly influenced the actual behavior of farmers. The results however contradict the findings of Bagheri et al. [14] which found the effect of perceived behavioral control on actual behavior to be significant but intention as not significant. The results of this study confirm the assertion that intention is the strongest predictor of actual behavior [31, 39, 42]. It is worth noting that of all the drivers utilized in the TPB model, attitude had the largest total effect on actual behavior.

The main sources of information on pesticide use for farmers are agro-input retailers and AEAs. The results mirror previous studies, which also reported that farmers access pesticide information from input retailers [6, 11] and extension agents [91, 92]. Even though the majority of the farmers indicated that input retailers and AEAs extension agents are their main sources of information on pesticide use, eight out of ten indicated that they have never participated in any extension training on safe pesticide use. The lack of training is manifest in unsafe pesticide disposal practices such as the wrongful disposal of pesticide leftovers, and pesticide containers, poor choice of location for rinsing of knapsack sprayers, and how wastewater is discarded after rinsing the sprayers. The majority of farmers (90%) dispose of pesticide leftovers and empty containers without any specific location in mind, while spraying machines are washed near any available water supply.

Bagheri et al. [14] posited that calculating the quantities of pesticides required to spray the targeted field, using the calculated quantity only, and applying the pesticides with a properly calibrated sprayer are the easiest strategies used to avoid issues with residual spray solution disposal. On the other hand, reusing leftover spray solution poses a risk because it employs a solution that becomes less potent over time and therefore less effective the next time it is applied.

Previous research has shown that despite knapsack sprayers getting washed after each use, pesticide residues still linger on their exterior surfaces, which could be a significant source of exposure for the operators [11]. Most of the farmers in this present study demonstrated unsafe pesticide use practices, especially in the way they dispose of the empty pesticide containers and wastewater after rinsing sprayers, which are a real cause for concern for the farmers, humans, animals, and underground water systems [26]. Bagheri et al. [14] suggested that surface and underground water could become contaminated by improper treatment of rinse water; therefore, any extra pesticide solution from the rinses should be applied to a labeled field for proper cleaning of sprayers. Bagheri et al. [14] further noted that the impact of agricultural water pollution on water quality has increased not just in industrialized countries but also in many developing countries, resulting from improper pesticide use practices and the management of pesticide waste. Hence, the need for urgent attention and mitigation [39].

The results also show that most of the farmers apply pesticides while wearing appropriate PPE, such as a pair of trousers, long-sleeve shirts, hand gloves, hats or caps, and Wellington boots. Additionally, nose masks or respirators, overalls, and goggles are also used. The findings are in line with those of previous studies, which reported that most farmers use PPE during spraying activities [30, 52]. The results are indicative that the farmers always protect themselves from the effects of pesticides during pesticide application. This finding, however, contradicts the assertion of Demi and Sicchia [6] that most farmers in Ghana do not use PPEs.

One of the strengths of this paper is that primary data was collected from farmers who farm within a 5 to 10 km radius of the White Volta in the Upper East Region of Ghana. The study provides some useful information and understanding into the conduct of farmers regarding safe pesticide use in farms along the banks of the White Volta Basin in the Upper East Region of Ghana. The understanding of the critical nature of the results would help the Departments of Agriculture in the three districts to collaborate and implement tailor-made agricultural extension delivery programs to improve the behavior of farmers in the area and improve sustainable farming in the area. The random selection of participants and the use of PLS-SEM strengthen the validity and robustness of our results and increase the generalizability of our findings. A limitation of this study is that the scope did not cover the environmental effect, farmers' health, and pesticide residual effect on the river as a result of the pesticide use behavior of farmers in the area. Future research should focus on the environmental effect, farmers' health, and pesticides residual effects on the river.

5. Conclusions and implications for extension of delivery

The present study sought to examine the intention and behavior of farmers towards safe pesticide use along the White Volta Basin of the Upper East Region of Ghana. 300 farmers who farm within a 5 to 10 km radius of the river were randomly selected and surveyed. The results demonstrate that attitudes and perceived behavioral control are the two variables significantly impacting the intention and behavior of farmers towards safe pesticide use in the study area. Also, agricultural input retailers and extension agents are the main sources from which farmers access information on pesticides in the study area. Most of the farmers have not received any training on safe pesticide use and disposal of containers and residue, which constitute a great threat to underground water systems, crops, animals and human health with associated implications for sustainable farming in the area. Our findings emphasize the need for policymakers to promulgate policies for extensive training of farmers on the safe use of pesticides. Therefore, stakeholders, including AEAs, agricultural input retailers, the Environmental Protection Agency (EPA), and the Plant Protection and Regulatory Services Directorate (PPRSD), should collaborate to develop training curricula for farmers aimed at improving their behavior as they work along the banks of the White Volta Basin. The training regimes should incorporate some extension training methods, such as method and result demonstrations, which are known to improve the attitudes and behaviors of farmers.

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Data availability

The data that support the findings of this study are openly available in the Mendeley Data and Digital Commons Data at http://doi.org/10.17632/wx4tv3h2fx.1

Conflict of interest

The authors declare no conflict of interest for this study.

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