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Effects of Child Labor on Academic Outcomes: A Case Study of Child Labor among Junior High School Students in the Fishing Community of Elmina in the Central Region of Ghana

Moses Kwadzo*, James Kofi Annan

Department of Agricultural Economics and Extension, University of Cape Coast, Ghana
*Corresponding author: moses.kwadzo@ucc.edu.gh

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Abstract Several concerns have been raised about child labor use in the fishery sector of Ghana. While some have argued that child labor should be abolished because it endangers the lives of children, others maintain that the use of children in agricultural work promotes their socioeconomic development. This study sought to assess the nature of child labor in Ghana and examine its effects on the academic outcomes of students in junior high schools in the Elmina community in the Central Region in Ghana. A total of 242 students from two junior high schools in the Elmina fishing community completed questionnaires for the study. The questionnaire results were analyzed using descriptive statistics and independent-sample *t*-tests. The findings revealed that 104 of the 242 students were involved in various fishery activities, including sorting, selling, dressing, and smoking of fish. The students were found to be working 12.3 hours per week and 3.3 days per week on average. Contrary to expectations, the independent-sample *t*-tests showed no statistically significant difference in aggregate examination mean scores for students involved in and students not involved in fishery activities. This observation could be attributed to the fact that the majority of the students involved in fishery activities engaged mainly in fishery activities that can be described as child work rather than child labor. This study recommends that households engaged in fishing consider limiting their children to light and regular fishing activities if the need arises to engage them, to avoid distraction from their education.

Keywords: *child labor, child work, fishery activities, academic outcome*

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1. Introduction

Child labor is a complex phenomenon in developing countries. While some have argued that the use of children in agricultural work is part of their socioeconomic development, others are of the view that child labor cannot be a substitute for child work [1,2]. The UNICEF [3] convention tolerates child work but it does not promote child labor of all forms. The kind of child labor children engage in differs depending on the culture of a country or community and the socioeconomic conditions [4]. According to the International Labor Organization (ILO), child labor is work that deprives children of their childhood potential and dignity and that is harmful to their physical and mental development [5]. The ILO [6] reported that in 2016, ten percent of children (152 million) aged 5 to 17 around the world were involved in some form of labor and that 73 million were engaged in hazardous child labor. Approximately 70.9% worked in agriculture, 17.2% worked in services, and 11.9% worked in industry. For children aged 5-14 years involved in some form of labor, 32.0% did not attend school, and the other 68% divided their time between working and studying. Buonomo [7] and the ILO [5] observed that the agriculture, fishing, and artisanal mining sectors are the largest employers of child labor. Adeborna and Johnson [8] observed that child labor is most prevalent in the informal small- and medium-scale operations of capture fisheries, aquaculture and post-harvest fish activities. Small-scale fisheries provide over 90 percent of the 120 million livelihoods derived from fisheries and support more than 500 million people. In the fishery sector, children are engaged in activities such as harvesting and farming of fish in capture fishing and aquaculture [8].

Ghana is one of the countries with the world's largest proportions of working children. In Ghana, 21.8% of children 5-17 years old are engaged in child labor, and more than 14.2% are involved in hazardous forms of child

labor [9]. Child labor in Ghana is deep-rooted in the fishing industry, with the majority of child labor carried out in family enterprises and mostly within the family home, in the form of housework or as non-remunerated work [8]. Child labor has been found to compromise the health and personal development of children. Several studies have showed that children who engage in child labor do not perform well in school. Le and Homel [10] noted that children who engage in child labor do not perform well in school because it affects their concentration in class. It also leaves them with less time for schooling and for engaging in leisure activities [11].

In contrast, Afenyadu [4] and Heady [12] contended that not all child work is dangerous to children's mental well-being. Many families within the coastal fishing communities along the coast of Ghana encourage their children's involvement in their family fishery businesses as a sociocultural practice to preserve family business for the future and to ensure the survival of family members. Elmina is a major coastal fishing community in the Central Region of Ghana. The Elmina fishing harbor is the third largest fish landing site in Ghana and contributes approximately 15% of the country's total fish output [13]. Approximately 75% of the population of Elmina, including children, is involved in fishing and related fishing activities, such as processing and trading of fish, for their livelihood [13]. Although UNICEF's convention allows the use of child work, it discourages the use of child labor of all forms. While children within the Elmina fishing community engage in fishery activities, this kind of child labor can adversely affect the educational development of the children in Elmina. The authors raise the question: what is the nature of the fishery activities in which these children are engaged? This study sought to identity the nature of the child labor in Elmina and examine its effects on the academic outcomes for children in the junior high schools in the Elmina community in the Central Region of Ghana. It was hypothesized that there was no significant difference in academic outcomes between students who were involved and those who were not involved in fishery activities.

2. Literature Review

Child labor is a complex phenomenon that requires examination from social, economic, and cultural perspectives. The current study considered the theoretical orientation of child labor from an ecological systems perspective, which views the environment as being made of systems or factors (economic, social, and culture) that are interactive and interwoven in nature [14,15]. Economic factors are related to resources such as family income and the jobs and education of parents. Social factors are related to structural characteristics such family size and the availability of educational resources. Cultural factors are related to social values and norms regarding child labor.

2.1. Causes of Child Labor

From an economic perspective, variables that relate to child labor supply are household poverty status, family low income, parental unemployment, and other family economic shocks. According to Basu and Van [16], family poverty may be the primary reason for why children engage in labor. While there are laws prohibiting child labor, many children are compelled to work to help their families survive. Parental stress and a lack of parental social support may force children to work to support households in the absence of social assistance schemes [17]. A child's labor contribution could be used as an asset for smooth consumption for the family. Child labor serves as a shock absorber to ease the impact of possible parental job loss, failed harvests, and other shocks to the family's income stream.

Social factors that may provoke child participation in the labor market include illiteracy and ignorance of poor parents, household size, family type, and culture norms that emphasize the tradition of making children learn the family's entrepreneurial skills [18,19]. The educational status of the parents is an important social factor related to child labor. The more education parents (particularly the household's head) have, the less likely they are to let their children work. In general, single-parent families seems to be closely linked with a high prevalence of child labor. Some studies have also demonstrated a relationship between household size and the prevalence of child labor among poor families in developing countries. A culture of any society is shared and preserved from one generation to the next through a process of teaching and learning the various elements of the culture [18,19]. To preserve their culture and endeavor to overcome endemic poverty, fishing entrepreneurs often insist that at least one of their children familiarize themselves with the practice and management of their fishing business to be able to inherit their parents' assets and thereby take over and sustain the family business in future [8]. In doing so, child labor in fishing and fish processing become the sociocultural machinery by which the fishing culture is transferred from one generation to the next. In the Central Region of Ghana, many families within the coastal fishing communities of Gomoa-Fetteh, Nyanyano, Moree, Elmina, Apam, Winneba and Senya-Beraku are noted to encourage their children's involvement in their family business [8].

2.2. Impact of Child Labor

The ILO [5] (2014) reported that child labor is unfavorable and unsafe to children's health and denies them of a proper education. Studies show that children who do not work cope better in school than children who do. Children who combine work and school can experience negative psychosocial effects on their educational progress and performance [20,21,22]. Abdalla et al. [20] affirmed in various studies that child labor adversely affects the health of children, leading to severe health complications that adversely affect their education. A study conducted by Anumaka [23] involving 2,307 pupils who sat for the primary leaving examination in the Nebbi District of North-East Uganda found that many of the children who did not perform well were those who had engaged in labor activities. Rahman and Khanam [24] found that child work had a negative effect on learning attainment in the areas of arithmetic and reading in Ghana. In a study conducted by Al-Gamal et al. [25] in Jordan, children who were not engaged in any form of work were found to perform better in school than those who are engaged in work. Afenyadu [4] contended that not all

work is dangerous to children's mental development and that work improves their basic knowledge and skills. He noted that the damage that child labor may do depends on the intensity and nature of the work. Holgado et al. [26] argued that there is no simple linear association between child labor and academic performance and that multiple factors, including labor conditions, morning work schedules, and the number of hours worked per week, can negatively affect the academic performance of child laborers. Nevertheless, a study by Heady [12] on the effect of child labor on learning outcomes showed that in Ghana, child work, especially that carried out in the home, had a fairly small effect on children's school performance.

3. Methodology

3.1. Research Design and Study Area

This study employed a cross-sectional survey design and was conducted in Elmina (5°5'0"N 1°21'0"W), a major coastal fishing community in the Komenda–Edina–Eguafo–Abrem (KEEA) district in the Central Region of Ghana. Elmina, with a population of 32,819, serves as a center for several fishing-related and commercial activities. The Elmina fishing harbor is the third largest fish landing site in Ghana and contributes approximately 15% of the country's total fish output [13,27]. The harbor provides a landing site for all types of canoes and small semi-industrial boats that engage in traditional fisheries. A study by Amador et al. [28] indicated that there were 2,632 fishermen, 231 canoes, and some semi-industrial vessels involved in fishing operations in Elmina. Another study by KEEA [13,27] reported that approximately 75% of the population of Elmina is involved in fishing and fishing-related activities, such as processing and trading of fish. The landing harbor is reported to be always full of large crowds, including fishing crews, workers, and child laborers [13,27].

3.2. Population and Study Sample

Elmina was chosen for the study because of its economic importance in the fishery sector of the Central Region of Ghana, as well as the involvement of children in Elmina in fishery activities. The population of this study included all junior high school students in Elmina. Multi-stage sampling was used to select the sample for the study. First, simple random sampling was used to select two junior high schools out of six in the Elmina community. In the second stage, all students of the two schools were included in the study, based on the school's enrollment registers.

3.3. Instrument and Data Collection

The study questionnaire covered information on household demographics (the household head's education, employment/economic status, marital status, household size) and personal data of the students (age, sex, class, nature of child labor involvement, health conditions, and academic performance). The questionnaire was administered to students in the two junior high schools selected for the study, with the help of the teachers there. Data were collected from 242 students between July and August 2021. Data on the students' last term examination results were also extracted from the school's records. The data were analyzed using descriptive statistics and independent-sample *t*-tests.

4. Results

4.1. Demographic Characteristics of Respondents

Table 1 shows the descriptive statistics for students involved in and not involved in fishing activities and for the total of 242 students who participated in the study, 104 (43.0%) of whom were involved in fishery activities and 138 (57.0%) of whom were not. The mean ages of the working and non-working students were 7.79 and 6.64 years, respectively. Of the 242 students, 130 (53.70%) were males and 112 (46.30%) were females. With regard to statistics on the heads of the family, 59 (0.57%) of the 104 of the family heads of the students involved in fishery activities and 71 (0.51%) of the family heads of students not involved in fishery activities were found to be married. Approximately 57% of the family heads of the students involved in fishery activities and 62% of the family heads of students not involved in fishery activities were found to have a basic education (junior and senior high school). The majority (61%) of the families of the students involved in fishery worked within the traditional fishery sector and 34% did not. The household sizes of the students involved in and not involved in fishery activities are 7.79 and 6.54 members, respectively.

Table 1. Profile of Surveyed Students

Variables	Results for working students	Results for non working students	Total
Child labor force participation			
Working in fishery	-	-	104 (43.00)
Not working in fishery	-	-	138 (57.00)
Gender			
Male	59 (0.57)	71 (0.51)	130 (53.70)
Female	45 (0.43)	67 (0.49)	112 (46.30)
Age			
Mean (years)	16.076	15.86	
Household size			
Mean	7.79	6.64	
Marital status of head of family			
Married	54 (0.52)	71 (0.51)	125 (51.70)
Single	13 (0.13)	18 (0.13)	31 (12.80)
Divorced	20 (0.19)	23 (0.17)	43 (17.80)
Separated	17 (0.16)	26 (0.19)	43 (17.80)
Education level of head of family			
No formal education	29 (0.28)	27 (0.20)	56 (23.10)
Middle/junior high school	52 (0.50)	61 (0.44)	113 (46.70)
Senior high/vocational school	7 (0.07)	25 (0.18)	32 (13.20)
Tertiary	16 (0.15)	25 (0.18)	
Main occupational sector of head of family			
Formal sector	12 (0.12)	35 (0.25)	47 (19.40)
Fishery sector (local)	63 (0.61)	47 (0.34)	110(45.50)
Other job	26 (0.25)	49 (0.36)	75 (31.00)
No job	3 (0.03)	7 (0.05)	10 (04.10)

4.2. Fishery Activities Undertaken by Students

We examined the nature and types of the students' fishery activities. Table 2 shows the characteristics of fishery activities undertaken by children in the Elmina fishery community. Sixty-one (59.2%) of the students undertake fishery activities in family owned-enterprises, while the rest of the students work outside the family enterprise. Seventy (68%) of these students receive wages or token remuneration from their fishery work, and the rest, 33 (32%), receive no form of remuneration. On average, a working student was paid GHS 97 (19.4 US dollars) per month. Most of the students worked two day per week and four hours per week. However, the students' average working hours and days per week were 12.3 hours and 3.3 days, respectively.

Table 2. Nature of Students' Fishery Activities

	Frequency	Percentage
Location of work engagement		
Home/family work	61.00	59.2
Outside home	42.00	40.8
Remuneration		
Paid wage/token	70.00	68.00
No wage/token	33.00	32.00
Money received per month for working		
Mean (Ghana cedis)	97.5	
Work intensity (no. of days work per week)		
Mean	3.3	
Mode	2.0	
Work intensity (no. of hours work per week)		
Mean	12.3	
Mode	4.0	

4.3. Types of Fishery Activities Undertaken by Students during Child Labor

Table 3 shows the different types of fishery activities undertaken by children in the Elmina fishery community. We categorized the students' fishery activities as light, regular, or harmful work. Light and regular work are by their very nature safer and less stressful**.** Harmful work is work that by its nature or circumstances is likely to harm children's health or safety. As shown in Table 3, light work dominated the fishery activities in which children were engaged. Fifty percent of the working students were found to be engaged in light work, followed by 40.4% engaged in regular work. Only 9.6% of the students were engaged in harmful work.

Table 3. Cross Tabulation of Types of Fishery Activities Engaged in by Children in Elmina

Fishery Activity	Type of Work	Frequency	Percentage
Selling fish	Light work	19	18.3
Sorting fish	Light work	33	31.7
Mending nets	Regular work	7	6.7
Dressing fish	Regular work	8	7.7
Dressing and smoking fish	Regular work	27	26,0
Fishing (in lagoon or on sea)	Harmful work	10	9.6
Total		104	100.0

4.4. Students' Age and Type of Fishery Activities

Age plays important role in determining the nature of the work in which children should be engaged. Under the ILO's conventions on child labor, light work is work that should be carried out by children between the ages of 13 and 14, regular work is work that should be carried out by children between the ages of 15 and 17, and harmful work is work that should be carried out by children aged 18 years or more. As shown in Table 4, 10 students that were involved in fishing in the lagoon or on the sea did not meet the age requirement, being less than 18 years old. In addition, one of those involved in the mending of nets was 12 years rather than the minimum of 13 years old as required for this type of regular work for children.

Table 4. Cross Tabulation of Types of Fishery Activities by Age

Fishery activity	Age Group (years)			
	12	13-14	15-17	18 & above
Selling fish		3	15	1
Sorting fish		9	22	1
Mending nets	**1**	2	2	1
Dressing fish		4	3	
Dressing & smoking fish		5	22	2
Fishing (lagoon or sea)	**1**	**2**	**7**	
Total	2	25	71	5

Age limits: Light work: 13–14; Regular work: 15–17; Hazardous: 18 years and above.

4.5. Effects of Working on Students' Health and Welfare

The respondents were also asked to indicate their perceptions regarding specific effects of child labor on their health and welfare, with response options ranging from strongly disagree (1) to strongly agree (5). As seen in Table 4, the mean score for work relating to students' tiredness was 2.78, implying that students were not sure if their engagement in fishing work makes them tired. The mean scores for having access to money for school and always having access to food were 3.67 and 3.28, respectively. These scores indicate that the working students agree that their fishery work helps to provide them with money and food.

4.6. Effects of Working on Students' Academic Outcomes

It is hypothesized that there was no significant difference in academic outcomes between students involved in and those not involved in fishery activities. The aggregate mean examination scores for the students involved in and students not involved in fishery activities were 54.71 and 50.90 respectively. The results actually show a slightly higher aggregate mean examination score for the students involved in the fishery business. An independent-sample *t*-test was conducted to compare the aggregate examination mean examinations scores for students involved in and not involved in the fishery activities in the Elmina community. The results revealed no statistically significant difference in aggregate mean

examination scores for students involved in fishery activities (M = 54.71, SD = 15.73) and students not involved in fishery activities (M = 50.90, SD = 15.07; *t* (240) = 1.915, p = 0.06, two-tailed). The magnitude of the differences in the means (mean difference = 3.82, 95% CI: -0.1104 to 7.75) was very small (eta squared = 0.007).

Table 5. Students' Perceptions of Effects of Working on Their Health and Welfare

Statement of work effects	Strongly disagree	Disagree	Not Sure	Agree	Strongly agree	Total	Mean score
Working makes me tired in school	33 (33)	19 (38)	9 (27)	24 (96)	19 (95)	289	2.78
I have access to money for school	21(21)	10 (20)	3 (9)	18 (72)	52 (260)	382	3.67
I always have access to food	28 (28)	10 (20)	3 (3)	25 (100)	38 (190)	341	3.28

Table 6. Statistical Test Results for Mean Examination Scores of Students Involved and Not Involved in Fishery Activities

Indicator variable	Levene's test for equality of variances		Two-tailed *t*-test for equality of means				
	F	Sig.	*t*	Sig	MD	95% Lower	C.I. Upper
Overall mean examination score	0.008	0.929	1.915	0.06	3.82	-0.1104	7.75

Note: P value = 0.00 (Sig. at 0.05 alpha level); MD = mean difference.

Table 7. Statistical Test Results for Mean Examination Scores for Girls and Boys Involved in Fishery Activities

Indicator variable	Levene's test for equality of variances		Student's two-tailed *t*-test for equality of means				
	F	Sig.	t	Sig.	MD	95% Lower	C.I. Upper
Overall mean examination score	0.373	0.542	0.924	0.358	2.87	-3.30	9.05

The second null hypothesis was that there was no significant difference in academic outcomes between boys and girls involved in fishery activities. An independent sample *t*-test was conducted to compare the aggregate examination mean scores for boys and girls involved in the fishery activities in the Elmina community (Table 7). The result show no statistically significant difference in scores for boys who were involved in fishery activities (M = 55.96, SD = 15.90) and girls involved in fishery activities (M = 53.08, SD = 15.53; *t* (102) = 0.877, p = 0.38, two-tailed). The magnitude of the differences in the means (mean difference = 2.75, 95% CI: -3.48 to 8.98) was very small (eta squared = 0.008).

5. Discussion

The problem of child labor in the agricultural sector in developing countries has received considerable attention in the economics literature. A particular concern is Ghana, which is one of the countries with the world's largest proportion of working children. Child labor in Ghana is common in the fishing industry, with the majority of children engaged in fishery activities being involved in family businesses. While researchers maintain that child labor should be abolished because it endangers children's lives and deprives them of their rights, others hold the view that child labor should be deliberated within the context in which it occurs, because some child work enables children to acquires basic resources, knowledge, and skills that can prove beneficial in later life [1,4]. The United Nations Children and Education Fund (UNICEF)'s conventions propose that child work and not child labor be used in agricultural work, as it assists in the social development of children [3]. These diverging views can pose a problem for policy enforcement with respect to child labor, and it is therefore necessary to reexamine children's work engagement and its effects on children. Many families in the coastal fishing communities in Ghana promote their children's participation in their family's fishery enterprises to preserve their business culture and the survival of family members. Although less attention is sometimes paid to this type of child labor, it can adversely affect the social and educational development of the child [1,4].

This study was conducted to examine the nature of child labor and its effects on children's academic outcomes in junior high schools in the Elmina community of the Central Region of Ghana. It was hypothesized that there was no significant difference in academic outcomes between students involved in and those not involved in fishery activities. A cross-sectional survey design was conducted, and a total of 242 students completed questionnaires containing information about their demographic characteristics, education, child labor activities, and their effects. The result of the study revealed that 104 of the 242 students were involved in various fishery. These students engaged in fishery activities for many reasons. The majority, 104 (43%), of the surveyed students were found to be involved in fishery work within the traditional fishery sector, with 61(59.2%) engaged in family business. The household sizes of the families of students involved in and students not involved in fishery activities were 7.79 and 6.54 members, respectively. As noted by Adeborna and Johnson [8], people living along the coast regard fishing as an integral aspect of their cultural identity and therefore ensure that their children learn fishing and fish processing. Children work to ensure the survival of their families and themselves. In addition, children in large families with low income are forced to engaged in work to help support their families.

It was hypothesized that there was no significant difference in academic outcome between students involved in and those not involved in fishery activities. The results of an independent-sample *t*-test showed no statistically significant difference in aggregate examination scores for students involved in fishery

activities (M = 54.71, SD = 15.73) and students not involved in fishery activities (M = 50.90, SD = 15.07; t (240) = 1.915, p = 0.06, two-tailed). The magnitude of the effect of differences in the means (mean difference = 3.82, 95% CI: -0.1104 to 7.75) was very small (eta squared = 0.007) (Table 5). This observation could be attributed to a number of factors, including the type and nature of their fishery work and its effects on their health and welfare. The analysis revealed that 104 of the 242 students were involved in various fishery activities, including sorting, selling, dressing, and smoking fish. On average, students were engaged in these activities 12.3 hours and 3.3 days per week. However, the majority of them worked 4 hours and 2 days per week. This confirms findings by Holgado et al. [26] that children working 1 or 2 hours per day may not interfere with schooling, may not make the child too tired to perform, and may even generate sufficient resources to enable the household to afford to send the child to school. According to ILO, "child labor" does not include all economic activity undertaken by children [3]. In the legal framework for child labor in the Children's Act (Act. 560, 1998) of Ghana, the minimum age for engaging a child in "light work" is 13 years, and that for regular work is 15 years. The minimum age for children engaged in harmful work is 18 years. Light work is work that is not likely to be harmful to children's health, development, and/or educational activities, while harmful work is work that poses a danger to the health and safety of children [8]. The respondents were also asked to indicate their perceptions regarding specific effects of child labor on their health and welfare. Generally, the students' perceptions regarding the effects of child labor on their health indicate that students were not sure (2.78 on a five-point Likert scale) whether their engagement in fishing work made them tired. With regard to their welfare, working students reportedly agreed (3.67 and 3.28 on five-point Likert scales) that their fishery work helped to provide them with money for school and food, respectively. These reflections could be attributed to half of the working students engaging in light fishing activities, such as sorting and selling of fish. Forty percent of the working students were involved in regular fishing activities, including mending nets and dressing and smoking of fish, which are light and regular fishing activities and therefore can be described as child work rather that child labor.

6. Conclusion

While several studies have shown that children who engage in work face challenges with respect to their academic performance, our study found no statistically significant difference in aggregate examination scores for students involved in and those not involved in fishery activities. Multiple factors, such as students' engagement in light work and working just a few hours and days per week, did not negatively affect their academic performance. Given that the students involvement in fishery activities in the Elmina community does not have any major negative impact on their academic performance, the authors recommend that fishing extension officers educate households in the fishing community to consider engaging their children in light and regular fishing activities if the need arises, to avoid disrupting their educational endeavors. Although this study provides a great insight into the effects of child labor on students' academic performance in a fishing community, it has a limitation that should be addressed in future research. The findings and conclusion of this study was based on data gathered on individual students' academic performance. Data on schools' performance were not collected and compared. Future studies should include comparison of schools' performance to gain a greater understanding of the effects of child labor on academic outcomes.

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Assessment of pesticide exposure risks among cocoa farmers in Western region of Ghana

Michael K. Miyittah[a], Boatemaa Ansah[a], Moses Kwadzo[b], Salifu Seidu-Larry[c] and Richard K. Kosivi[a]

[a]Department of Environmental Sciences, University of Cape Coast, Cape Coast, Ghana; [b]Department of Agricultural Economics and Extension, University of Cape Coast, Cape Coast, Ghana; [c]Department of Biochemistry, University of Cape Coast, Cape Coast, Ghana

ABSTRACT

A survey was conducted to investigate farmers' knowledge, attitudes towards pesticide use, storage/disposal, exposure risks and health symptoms in one of the eight cocoa growing regions in Ghana. A considerable proportion of the farmers (32%) used the bush as a storage facility for pesticides, 17% of the farmers stored chemicals in their living rooms, 3% of the farmers stored chemicals in their kitchen, 15% in their food storeroom, and 4% in the animal house. Personal protective equipment (PPE) use was positively associated with advice obtained from agrochemical shops (OR = 1.735, $p<0.01$) and extension services (OR = 1.643, $p<0.01$) as sources of information for PPE use. Female farmers (OR = 0.481, $p<0.01$) were less likely to use PPE. With respect to location, farmers in Suaman district were less likely to use PPE (OR = 0.56, $p<0.010$) compared with farmers in Wassa Amenfi. It is recommended that these factors should be considered for policy intervention. Reinforcement of appropriate pesticide storage and PPE education are necessary for securing safety in pesticide use.

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Smallholder; cocoa; pesticides; risk; exposure; PPE

1. Introduction

Cocoa is an international crop supplied by Ghana and Ivory Coast providing over 60% of the cocoa beans to the global chocolate industry (Wessel and Quist-Wessel 2015). The cocoa sector represents more than half (from 70 up to 100%) of the income for roughly 800,000 smallholder farmers families in Ghana, providing food, employment, tax revenue and foreign exchange earnings for Ghana (Anim-Kwapong and Frimpong 2004; Dormon et al. 2004). Despite the economic importance of cocoa, its production in Ghana is threatened by pests and diseases, a situation that reduced cocoa production, with adverse impact on the Ghanaian economy (Dormon et al. 2004). The low productivity phenomenon is aggravated by the climate change impacts. Läderach et al. (2013) predicted low productivity in spatially differentiated cocoa growing areas of Ghana and Ivory Coast. These predicted potential effects are already observed in Ghana, where higher productive region for cocoa shifted from Ashanti Region to Western Region (Ghana COCOBOD 2019).

In order to boost cocoa productivity, farmers adopted pesticide use to control pests and diseases, thus increasing yield and maintaining quality. However, the use of pesticides in agriculture, and for that matter the cocoa industry in Ghana, has raised serious concerns about the safety of pesticide residues in cocoa beans, soils and water, as well as factors causing potential exposure to humans (Adeogun and Agbongiarhuoyi 2006; Adejumo et al. 2014). In most developing countries like Ghana, these consequences have often been severe because farmers do not use approved pesticides and do not follow recommended application practices as stipulated by governmental agencies. Indeed, farmers often misuse, apply pesticides indiscriminately (Konradsen 2007; Damalas 2009; Hashemi et al. 2012; Antwi-Agyakwa et al. 2016) with disregard to safety measures and regulations on chemical use. A major global public health hazard about pesticides is causing death (Bertolote et al. 2006). In developing countries, many people die annually from pesticide effects through pesticide mishandling (Konradsen et al. 2003). An estimated number of 220,000 pesticide related deaths and 3 million poisoning cases were reported by WHO in 1990 (Jeyaratnam 1990; Khan and Damalas 2015). Based on the period it takes for toxicity symptoms to

CONTACT Michael K. Miyittah m-miyittah@ucc.edu.gh Department of Environmental Sciences, North Campus, University Avenue, Science Building, Cape Coast, Ghana.

manifest, pesticide health effect may be classified as being acute or chronic. A situation where symptoms are observed within a short period of pesticide exposure is termed acute toxicity, while long-term symptoms are reported as chronic toxicity (Damalas and Koutroubas 2016). Whatever the case, occupational health is a topical issue in developing countries and remains unaddressed (Nuwayhid 2004; Khan and Damalas 2015).

The Western Region (WR) produces about 450,000 metric tonnes (avg. of the last 10 years)of cocoa and is currently the leading producing area in Ghana (Ghana COCOBOD 2019). In general, farmers use pesticides extensively to control pests and diseases and maximize crop yields. Recently, Okoffo et al. (2016), and Paintsil (2017) studied pesticide application among cocoa farmers, but their studies were limited to one cocoa district within a region. In this study, we broadened the scope by focusing on three different cocoa districts because information regarding pesticide documentation and safety practices by cocoa farmers in the WR is limited. Unsafe pesticide practices can lead to predictable health impacts on farmers during pesticide application. This information is necessary for understanding the factors influencing farmers' behaviour, pesticides exposure levels of farmers and eventually, the mobility of pesticides in the environment. Information on pesticides application is important, so that policy interventions to reduce environmental risks and human health impacts can be developed. Also, such information is important for analytical and environmental scientists to gain insights into the socio-environmental factors driving pesticides in the environment. The objectives of this work were: i) to assess farmers' knowledge of pesticides use; ii) to evaluate farmers' attitudes in storage of pesticides and disposal practice after pesticides usage; and iii) to identify health risk from pesticide exposure.

2. Methods

2.1. Study area and sampling procedure

The study was conducted in the WR of Ghana with an approximate land cover of 23,921 km^2, constituting about 10% of Ghana's total surface land mass and 10% of its population. The WR is the leading producing area of cocoa since 1984 (Ghana COCOBOD 2019). The region receives the highest amount of precipitation nationwide and almost 75% of its vegetation interspersed with the high forest zone of Ghana (Figure 1).

For the purposes of assessing pesticides use among farmers, data were collected through a questionnaire in February 2018. The questionnaire covered demographic characteristics of the farmers, pesticide use practices, attitudes towards pesticide use, wearing of personal protective equipment (PPE) by cocoa farmers, and self-reported pesticide health symptoms of farmers during pesticide applications. The questionnaire was designed in English and then translated into the local language of the area in case that some farmers were uncertain of some technical terms. Farmers with prior knowledge in pesticide use application in the cocoa-growing communities were sampled within the districts.

Multi-stage sampling was used to select respondents for the study (Daniel 2012; Okoffo et al. 2016). One main advantage of multi-stage sampling is that it creates a more representative sample of the population than a single sampling technique and can reduce costs of large-scale survey research (Green et al. 2006). The multi-stage sampling in this study entailed four stages. In the first stage, the WR of Ghana was purposively selected due to the high production of cocoa in the region. In the second stage, Aowin, Suaman and Wassa Amenfi West districts known to be some of the major cocoa growing areas in the WR were randomly selected out of other cocoa-producing districts in the region. In the third stage, three major cocoa growing communities were randomly selected. In the final stage, 25 cocoa farmers were randomly selected from each of the three selected cocoa growing communities. Totally, 225 cocoa farmers were randomly sampled for the study. That is, three districts × three communities × 25 farmers = 225 farmers. In this study, the participants were informed that the data provided would contribute to the overall knowledge about the effects of pesticides on human health. In addition, participants were neither coerced nor financially induced to take part in the research.

2.2. Data analyses

Analysis was conducted using Statistical Package for the Social Sciences (SPSS) Version 21 (IBM, Chicago, IL, USA), STATA 13 (Stata Corp, College Station, TX, USA), and Microsoft Office Excel 2010 (Microsoft Corporation, Redmond, WA, USA). Descriptive statistics (frequencies and percentages), inferential statistics, analysis of variance (ANOVA), and Pearson correlation/chi-square tests were conducted on the data from the respondents to examine significant differences among the identified categorical groups. An alpha (α) level of 0.05 was used as the criterion for statistical significance. The relationship between response variable and explanatory variables was modelled using logistic regression.

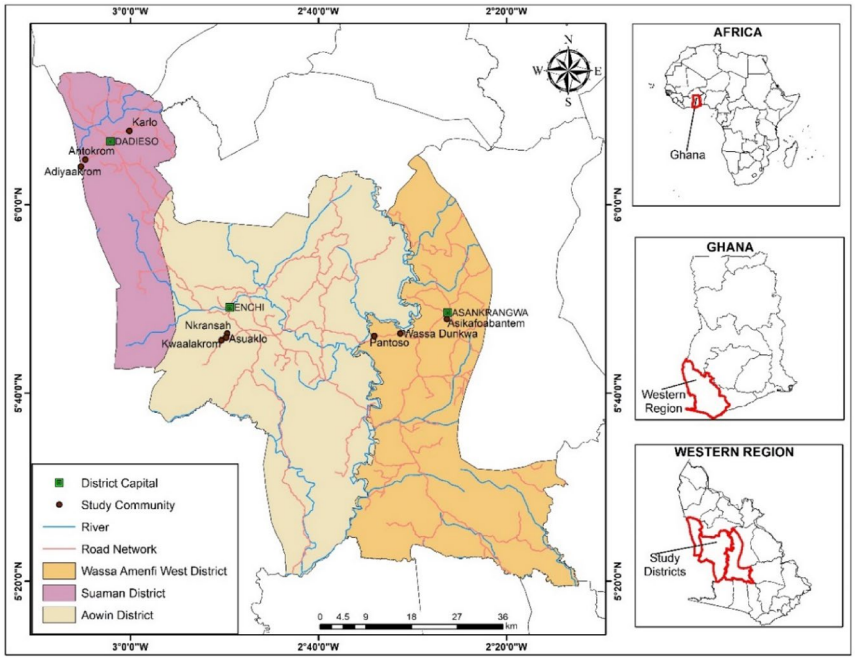

Figure 1. A map showing the study area.

Logistic regression has three common link functions, that is, the logit, the probit, and the complementary log-log. The logit and the probit are symmetric link functions, while the complementary log-log is applicable when the data come from multiple groups and are not symmetric in the 0–1 interval and increase slowly at small to moderate values, but increase sharply to 1. This response implies that we must not have the response curve of the participants showing 50% in the affirmative and the other 50% in the negative (Collett 2003; Armah et al. 2019). In this study, a complementary log-log regression model was fitted to binary outcomes data at the multivariate level. The complementary log-log transformation is expressed as:

$$\log\{-\log(1-p)\} = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \cdots\cdots + \beta_k X_k = Z. \quad (1)$$

where, β_o = the constant of the equation, $\beta_{1,2,3}$ = the coefficient of the explanatory variables 1, 2, 3 to be estimated; X_1……. X_k are sets of explanatory variables; *p* is the predicted probabilities; and log{-log(1-*p*)} is the link function.

$$-\log(1-p) = e(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots\cdots + \beta_k X_k). \quad (2)$$

As the probability increases, the transformation approaches infinity more slowly than either the probit or the logit. By using equations (1) and (2), the relationship between the response variable and the explanatory or predictor variable was modelled. The response variable is the use of PPE and the explanatory or predictor variables are the agrochemical shops, extension services availability, years of farmer's experience, age, education and the districts. The role of respondents using PPE or not in determining factors that influence famers' choice to use PPE during pesticide application was estimated using a complementary log-log model and reported as exponentiated coefficients or odds ratios (OR). An OR value of 1 means that the predictor does not affect odds of influencing farmers to use PPE during pesticide application, while OR > 1 means that the predictor is associated with higher odds of influencing farmers to use PPE during pesticide application. Finally, OR < 1 means that the predictor is associated with lower odds influencing farmers to use PPE during pesticide application. The study accounted for clustering of observations in units of communities and robust estimates of variance was used to correct for any statistical outliers in the estimation of standard errors. The study made use of 95% confidence interval (CI) and the level of statistical significance was set at 0.05. The main or key predictors used were agrochemical shop services, extension services and years of farmers' experience. Some compositional factors [(biosocial variables (age), socio-cultural variables (education)] and contextual factor (the districts where the study was conducted), which were known in the literature to influence farmer's choice to use PPE during pesticide application were controlled for in the models. Four models: main predictors, agrochemical shops/extension services availability (model 1), biosocial (model 2), socio-cultural (model 3), and contextual factors

(model 4) were run. Selection of reference groups for the independent variables in the models was based on theory and literature. "I do not get information about pesticide use from agrochemical shop" (No) was chosen as the reference group for the agrochemical shop services. The reference group for extension services was "I do not get information about pesticide application from extension services" (No). For farmers' years of experience, "I do not get information about pesticide use from farming years of experience" (No) was used as the reference group. Similarly, no formal education group was chosen as the reference group for education since this has direct influence on farmers' knowledge of dangers associated with pesticide use. The rest of the reference groups were "Male" for gender, and "Wassa Amenfi West" for district.

In addition, to validate the sample distribution, estimate the accuracy of a given parameter, and strengthen the stability of the statistical model, the bootstrap technique was used to provide support. The method takes a sample with replacement from the original sample and calculates the statistic of interest repeatedly (Islam and Begum 2018). In this study, the proxy sample population was 225 and large sample size of 2000 was estimated in bootstrapping.

2.3. Ethical statement

The study was approved by the Institute Review Board (IRB) of the University of Cape Coast. Agricultural extension officers of COCOBOD offered permissible access to cocoa farmers. Consent to collect and publish data was obtained from the participants. In addition, participants were not coerced through financial means to take part in this research. They were informed that the outcomes of the research would enhance their welfare in terms of pesticide usage.

3. Results

3.1. Farmers knowledge and understanding on pesticides

3.1.1. Socio-demographic description of the respondents

Table 1 presents the demographic background of the respondents from the selected districts.

The demographic data of the respondents include sex, age, educational level, family position, and economic activity. Out of 225 farmers, 154 males and 71 females were contacted in the study showing that the males dominated in cocoa farming. The majority of the study participants were males (68%), while the remaining (32%) were females. One third of the respondents (33%) had no formal education, 35% had only primary education and (32%) secondary education. The main economic activity for the sampling group was farming (95%). Most farmers surveyed were between the ages of 31 and 40 years old; however, farmers were within the economically active age range (18–65) (Table 1). Only 9% of the farmers were between 21 and 30 years old. It was observed that the farmers used different types of pesticides. In all, eleven types of pesticides were identified, and the most commonly used were the insecticides followed by the fungicides. About 46% of the

Table 1. Socio-demographic characteristics of the study population.

	N (%)	N(%)
Respondent characteristics	Male	Female
Sex	154 (68.44)	71 (31.56)
District		
Wassa Amenfi West	57 (76)	18 (24)
Aowin	44 (58.67)	31 (41.33)
Suaman	53 (70.67)	22 (29.33)
Age		
10 – 20	1 (50)	1 (50)
21 – 30	15 (75)	5 (25)
31 – 40	41 (62.12)	25 (37.88)
41 – 50	35 (68.63)	16 (31.37)
51 – 60	44 (74.50)	15 (25.42)
61 and above	18 (66.67)	9 (33.33)
Level of Education		
No formal	47 (63.50)	27 (36.50)
Primary	54 (68.40)	25 (31.60)
Secondary	53 (73.60)	19 (26.40)
Economic Activities		
Farming	147 (95.45)	7 (4.55)
Small business	67 (94.37)	4 (5.63)
	Mean	**Std. Err.**
Farm size (ha)	9.025	0.512

N = number of respondents in each category add up to 225; numbers in parenthesis indicate percentages; (ha) = hectares. Std. Err. = Standard error of the mean.

Table 2. Commonly used pesticides by the farmers.

Trade name	Active ingredient	WHO toxicity class
Insecticides		
Akate master	Bifenthrin (27 g/l)	II
Acati Power SL	Thiamethroxam (200 g/l)	II
Akate Star 3.5 EC	Bifenthrin (30 g/l)	II
Aceta Star 46 EC	Bifenthrin (30 g/l)	II
Confidor 200 OD	Thiamethroxam (240 g/l)	III
Miricon EC	Pyrethrin (12 g/l) + Deltamethrum (6 g/l)	II
Fungicides		
Champion WP	Copper Hydroxide (77%)	III
Ridomil Gold Plus 66WP	Cuprous oxide (60%) + Metaxyl – M (6%)	III
Nordox Super 75 wg	Cuprous oxide (86%)	III
Herbicides		
Aduodzi 757 SG	Glyphosate (757 g/l)	III
Tackle360 SL	Glyphosate (360 g/l)	IV

I = extremely hazardous; II = moderately hazardous; III = slightly hazardous IV = non-toxic; (WHO 2005).

pesticides were moderately/slightly hazardous according to WHO classification. In addition, about 8% of pesticide application fell into the non-toxic class (Table 2).

3.1.2. Farmers' knowledge of pesticide toxicity

An analysis of farmers' knowledge on the routes of entry of pesticides into the human body, on fruits such as cocoa and vegetables, and in the environment brought out the results shown in Table 3. There was a statistically significant difference between educational level of farmers and their knowledge of pesticide entering their bodies through inhalation (χ^2 = 10.28, $p < 0.05$), through the skin (χ^2 = 7.59, $p < 0.05$), and knowing whether pesticide residue is left on fruits and vegetables after the application of pesticides (χ^2 = 10.054, $p < 0.05$). However, the Chi-square (χ^2) of variables that were not significant (i.e. whether pesticides can cause negative effects, or pesticides residue can be left on air, soil, etc.) were positively associated with greater percentage of the farmers saying "yes" to the questions, indicating that knowledge is relevant and influential. In general, most farmers had good knowledge of the effects of pesticides on human health by explaining how their bodies react after the spraying of pesticides.

Table 3. Relationship between farmers' level of education and knowledge on pesticide toxicology.

Question asked	No formal education	Primary education	Secondary education	Inferential statistics
Can pesticides cause negative effects?				
No	17 (43.60)	13 (33.30)	9 (23.10)	X^2 = 2.8589, p = 0.239
Yes	57 (30.60)	66 (35.50)	63 (33.90)	
Do all pesticides have the same health effects?				
No	53 (33.30)	55 (34.60)	51 (32.10)	X^2 = 0.0753, p = 0.963
Yes	21 (31.80)	24 (36.40)	21 (31.80)	
Can pesticides be dangerous to use?				
No	10 (45.45)	8 (36.40)	4 (18.10)	X^2 = 2.6365, p = 0.268
Yes	64 (31.50)	71 (35.00)	68 (33.50)	
Can pesticides enter the body through inhalation?				
No	9 (75.00)	2 (16.70)	1 (8.30)	X^2 = 10.2818, p = 0.006*
Yes	65 (30.50)	77 (36.20)	71 (33.30)	
Can pesticides enter the body through skin?				
No	9 (75.00)	2 (16.70)	1 (8.30)	X^2 = 7.5390, p = 0.023*
Yes	65 (30.50)	77 (36.20)	71 (33.30)	
Can pesticide residue be left in the air?				
No	6 (46.20)	5 (38.50)	2 (15.30)	X^2 = 1.9726, p = 0.373
Yes	68 (32.10)	74 (34.90)	70 (33.00)	
Can pesticide residue be left in the soil?				
No	8 (26.70)	14 (46.70)	8 (26.70)	X^2 = 2.0316, p = 0.362
Yes	66 (33.80)	65 (33.40)	64 (32.80)	
Can pesticide residue be left in the fruit and vegetables?				
No	20(55.60)	9 (25.00)	7 (19.4)	X^2 = 10.0541, p = 0.007*
Yes	54 (28.60)	70 (37.00)	65 (34.40)	

N = number of respondents for each category is 225; Numbers in parenthesis indicate percentages; X^2= Pearson chi square; p = probability value; * = Significant result ($p < 0.05$)

3.1.3. Pesticide acquisition, reason for application, and knowledge of application

Table 4 shows pesticide acquisition, reason for application and knowledge of application using descriptive statistics. Farmers indicated agrochemical shops (27%), local governmental shops (41%), and extension officers (38%) as their main sources of purchasing pesticides. Part of the data (not shown) revealed the following brand names: Akate master, Confidor, Ridomil, and Nodox as the commonly used pesticides. All farmers consented to using motorized sprayers for insecticide application, while the knapsack sprayer was the preferred equipment for fungicide application. When farmers were asked why they use pesticides, 80% of the farmers identified the presence of pests as the driving factor for their decision to apply chemicals. When the respondents were asked where they buy the pesticides from, there was a plethora of sources and some of the sources were not regulated. Less than half of the respondents (41%) were buying pesticides from local governmental shops in villages, while the remaining were distributed among agrochemical shops in towns (27%), and other general shops (7%) while (38%) of the farmers obtained them from extension officers. Regarding timing of pesticides application, 30% followed the recommended calendar spraying schedules, no matter the observations in the field. Application strategies employed by the majority of the farmers involved the application of different chemicals individually (90%), but the remaining group (10%) indulged in the improper farming practice of mixing different chemicals to have rapid knockdown effects of pests. A greater part (88%) of the farmers did not read instruction on labels before using pesticides.

The majority of the farmers indicated that they obtained pesticide knowledge from extension officers (69%). Other farmers used their own experience (10%) or, they were taught by fellow farmers (18%).

3.2. Pesticides storage environment

3.2.1. Pesticides storage location and level of education

Figure 2 illustrates the result of storage of pesticides options explored by the farmers. Thirty-two percent (32%) of the farmers used the bush as their main storage facility for the pesticides they used.

Some respondents (17%) stored chemicals within their living rooms, whiles 7%, 3% and 4% of respondents stored them in agrochemical shop, kitchen and animal house respectively. The result of linking storage location to the levels of education is presented in Table 5.

There was a statistically significant association between farmers' pesticide storage location and their educational levels ($X^2 = 24.05$, $p < 0.05$). This means that farmers' knowledge of pesticide storage location is influenced by their level of education. Further, the usual and common way of disposing empty pesticide containers and remnants from spraying equipment was throwing them in the farm (Figure 3). Anecdotal evidence shows that empty pesticide containers and

Table 4. Pesticide application information by cocoa farmers.

Questions and predefined answers	Response N (%) Yes	Response N (%) No
Why do you use pesticides?		
To protect crops against insects and diseases	180 (80)	45 (20)
To make crops grow better	53 (23.56)	172 (76.44)
Because others use pesticides	5 (2.22)	220 (97.78)
Because I was advice to use it	10 (4.44)	215 (95.56)
Where do you get/buy the pesticides?		
Agrochemical shops in town	61 (27.11)	164 (72.89)
Local government shops in the village	93 (41.33)	132 (58.67)
Extension officers	85 (37.78)	140 (62.22)
General shops	15 (6.67)	210 (93.33)
Cooperative societies	0 (0.00)	225 (100)
Timing of pesticides application		
Presence of pests	144 (64)	81 (36)
Degree of pest infection	17 (7.56)	208 (92.44)
Date of planning	3 (1.33)	222 (98.67)
On the calendar spray schedules	67 (29.78)	158 (70.22)
Pesticide application strategy		
Mix more than one type of chemical	23 (10.22)	202 (89.78)
Depending on the instruction on the label	26 (11.56)	199 (88.44)
Sources of farmers' knowledge on pesticide application		
Agrochemical shops	11 (4.89)	214 (65.11)
Extension officers	156 (69.33)	69 (30.67)
Pesticides labels on packages	23 (10.22)	202 (89.78)
Fellow farmers	40 (17.78)	185 (82.22)
Own experience	23 (10.22)	202 (89.78)

N = number of respondents; Numbers in parenthesis indicate percentages. N (225).

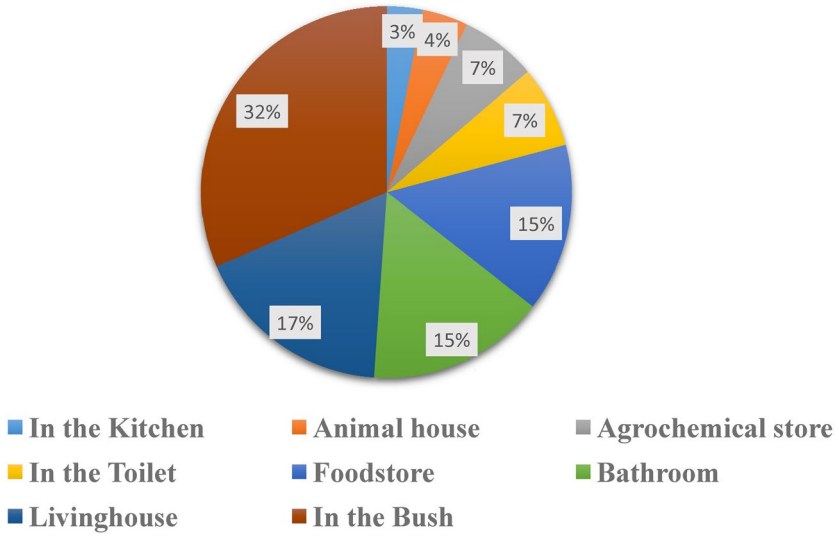

Figure 2. Pesticides storage location by cocoa farmers.

Table 5. Relationship between pesticides storage location and farmers level of education.

	Education			
Storage location	No formal	Primary	Secondary	Inferential statistics
Agrochemical store	4 (5.4)	5 (6.3)	6 (8.3)	X^2 = 24.05, p = 0.045* Cramer's V = 0.231
Animal houses	2 (2.7)	4 (5.1)	3 (4.2)	
In the food storeroom	8 (10.8)	13 (16.7)	12 (16.5)	
Living house	8 (10.8)	9 (11.4)	22 (30.6)	
In the kitchen	2 (2.7)	3 (3.8)	22 (30.6)	
In the bush	26 (32.9)	26 (32.9)	19 (26.4)	
In the toilet	6 (8.5)	5 (6.3)	5 (6.9)	
In the Bathroom	18 (24.3)	14 (17.7)	3 (4.2)	

X^2 = Pearson chi square; P = probability value; Cramer's V value (0–1) indicates how strong the values are associated with closeness to 1 which implies greater association. * = Significant result ($p < 0.05$); Numbers in parenthesis indicate percentages.

sachets were found disposed of indiscriminately on farms. Five of the respondents (2%) revealed that they put empty pesticide containers to other use once they were emptied of its content. Some farmers (8%) also mentioned digging holes on farm and burying containers as their preferred disposal method.

3.2.2. Farmers' response towards pesticide use

Farmers' opinion on the effectiveness of spraying was sought by expecting respondents to agree or disagree with certain statements. As shown in Table 6, 55% of the respondents strongly agreed to the statement that pesticide use was important to secure good crops. The majority of the respondents (98.7%) also admitted that knowledge was needed for the application of pesticides. The majority of the respondents agreed that precaution is necessary in the administration of chemicals (53% strongly agreed, 47% agreed). One third of the respondents (32%) disagreed that minimal health risks is associated with pesticide use, while the majority (68%) agreed. Further, 37.8% recognized and agreed that it is necessary to limit pesticides use. This might apparently be due to health symptoms that some of the respondents experienced during pesticide application.

3.3. Health and safety impacts due to pesticide application

3.3.1. The use of personal protective equipment (PPE)

Farmers were asked whether they use a single item, or multiple items of PPE. Multiple PPEs most often involve wearing two or more of the following: hats, gloves, goggles, respirator, protective boots, and coveralls. Farmers were asked whether they used full working gear of multiple PPEs for protection during spraying (Table 7). Fifty-five (55) farmers failed to use any safety equipment (zero PPE), while 68 of the farmers revealed they used the full working gear (six PPE items). Most of the farmers with zero PPE usage in the study were noted to be farmers who had no formal education. In addition, 102 of the farmers partially protected themselves before using chemicals on the farms (Table 7). Farmers with either primary or secondary level of education used all six PPEs items or some form of partial PPEs during spraying.

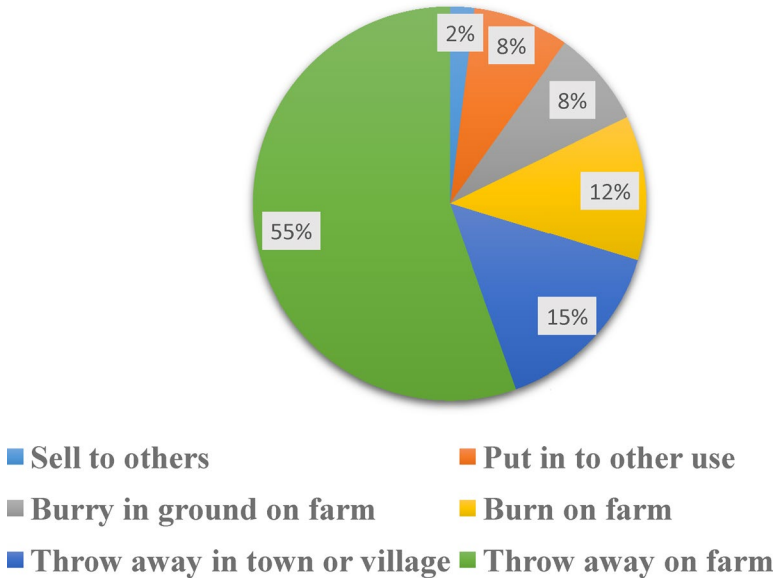

Figure 3. Disposal of empty pesticide containers.

Table 6. Attitudes towards Pesticide Use.

Farmers' perception on the effectiveness of spraying	Respondents N	%
Important to secure good crops		
Agree	101	44.89
Strongly Agree	124	55.11
Proper knowledge is necessary		
Strongly Disagree	1	0.44
Disagree	2	0.89
Agree	96	42.67
Strongly Agree	126	56.00
Precautions should be used		
Agree	106	47.11
Strongly Agree	119	52.89
Minimal Health Risks attached to pesticide use		
Strongly Disagree	1	0.44
Disagree	71	31.56
Agree	81	36.00
Strongly Agree	72	32.00
Limit pesticide use		
Strongly Disagree	16	7.11
Disagree	63	28.00
Agree	85	37.78
Strongly Agree	61	27.11

N = number of respondents; Numbers in parenthesis indicate percentages.

3.3.2. Common health symptoms associated with frequent pesticides usage

Table 8 shows common health symptoms self-reported and experienced by the farmers due to pesticide application. Data revealed that more than half of the respondents experienced symptoms of headache and burning eyes at 66% and 52% respectively. The remaining symptoms were skin rashes (32%), itching (48%), and chest pain (42%).

3.3.3. Factors influencing PPE use and logistic regression modelling

To investigate factors influencing PPE use, Cramer's V correlation was determined and presented in Table 9. The result showed a positive and negative correlation, with all the factors showing weak correlation <10%, with the exception of gender (30%). The weak correlation might suggest confounding factors influencing the variables, since the literature predicted otherwise. In Table 9 only gender and district of the farmers showed a statistically significant difference ($p < 0.01$), although the literature indicated several factors influencing PPE usage.

The data was modelled with the complementary log-log regression and was assessed with goodness of fit tests using Deviance, Pearson and Akaike Information Criterion (AIC). The goodness fit test showed Deviance to be 1.132, Pearson = 1.028, and AIC = 1.167. Since Deviance, Pearson and AIC values are almost similar to each other and with very

Table 7. Use of PPEs and educational background of the farmers during the application of pesticides.

Number of PPEs	No formal education (N)	Primary education (N)	Secondary education (N)	Total (N)
0	22	21	12	55
1	9	6	12	27
2	8	4	4	16
3	4	7	10	21
4	3	7	5	15
5	7	9	7	23
6	21	25	22	68
Total (N)	74	79	72	225

N = number of respondents; PPE = personal protective equipment.

Table 8. Common health symptoms associated with frequent pesticide usage.

Symptoms	Response N (%) YES
Have you experienced any of the following symptoms after chemical application?	
Headache	118(52.44)
Burning eyes	148(65.80)
Skin rash	73 (32.44)
Itching	109 (48.44)
Chest pain	95 (42.22)

N = number of farmers; Numbers in parenthesis indicate percentages.

Table 9. Correlation analysis of PPE use and source of pesticide knowledge with demographic variables.

Variables	Sign	Significance
Agrochemicals	(+)	ns
Extension services	(+)	ns
Farmers experiences	(-)	ns
Gender	(-)	s
Education	(+)	ns
Districts	(+)	s

Significant for coefficient: $p < 0.05$; s for significant and ns for non-significant; + and − signs indicate positive or negative correlation.

small values, it suggested that the model fit was considered satisfactory. The actual result of the complementary log-log regression modelling is presented in Table 10 showing the odds ratios, standard errors, *p*-values, and confidence intervals (CI) associated with the use of PPE, as well as compositional and contextual factors. Model 1 shows that agrochemical shops and extension services were statistically significant, indicating that farmers who depended on agrochemical shops (OR = 1.735, $p < 0.005$) as a source of information with regard to pesticide application were more likely to use PPE during pesticide application compared to their counterparts. Similarly, the probability that farmers who depended on the extension services (OR = 1.643, $p < 0.007$) as a source of knowledge with respect to pesticide application increased as compared to their counterparts. This situation could arise as farmers meet the extension officers and thus they receive educational information regarding the use of PPE in pesticide application. Surprisingly, farmers' years of experience in pesticide application was not statistically significant.

The result for model 2, where biosocial factors were controlled for, showed that farmers who relied on agrochemical shops (OR = 1.773, $p < 0.005$) and extension services (OR = 1.507, $p < 0.032$) as a source of information about pesticide application were more likely to use PPE than those who responded negatively. Gender ($p < 0.000$) also influenced PPE use during pesticide application. It was also revealed that female farmers were 48.1% less likely to use PPE during pesticide application compared to male farmers. This response may be because although female farmers may be owners of the farm, they may consult their male counterparts to do the spraying and may utilize PPE during pesticide application. When the socio-cultural factors (e.g. education) was controlled for in model 3, agrochemical shops (OR = 1.777, $p < 0.004$) and extension services (OR = 1.497, $p < 0.036$) continued to predict the use of PPE. However, the probability of PPE use during pesticide spraying was higher for farmers who depended on agrochemical shops for information about of pesticide application compared to their counterparts. Farmers who depended on extension services on the other hand were 100% likely to use PPE than their counterparts. Interestingly, there was no significant relationship between educational levels and the use of PPE during pesticide application.

In model 4, contextual factors influencing famers' choice to use PPE were considered by controlling districts from which the respondents were drawn.

Table 10. Multivariate complementary log-log regression model predicting PPEs usage during pesticide application.

	Source of pesticide knowledge (Model 1)				*Bio-social factors (Model 2)*				*Socio-cultural factors (Model 3)*				*Contextual factors (Model 4)*			
Predictors	OR	SE	*p*	95% CI	OR	SE	*p*	95% CI	OR	SE	*p*	95%CI	OR	SE	*p*	95%CI
Agrochemicals shops (Ref: No)																
Yes	1.735	0.343	**0.005**	1.178–2.554	1.773	0.358	**0.005**	1.192–2.636	1.777	0.357	**0.004**	1.200–2.633	1.646	0.334	**0.014**	1.106–2.452
Extension services (Ref: No)																
Yes	1.643	0.303	**0.007**	1.144–2.359	1.507	0.287	**0.032**	1.037–2.189	1.497	0.288	**0.036**	1.027–2.183	1.374	0.268	0.104	0.937–2.015
Farmers' experiences (Ref: No)																
Yes	0.752	0.752	0.362	0.408–1.388	0.833	0.259	0.557	0.452–1.533	0.838	0.260	0.569	0.456–1.539	0.837	0.262	0.57	0.453–1.546
Gender (Ref: Male)																
Female					0.481	0.097	**0.000**	0.325–0.713	0.483	0.097	**0.000**	0.325–0.716	0.466	0.094	**0.000**	0.313–0.693
Education (Ref: No formal education)																
Primary education									1.010	0.217	0.961	0.663–1.540	1.095	0.240	0.679	0.713–1.681
Secondary education									1.065	0.229	0.770	0.699–1.624	1.090	0.238	0.692	0.711–1.672
Districts (Ref: Wassa Amenfi West)																
Aowin													0.882	0.187	0.553	0.581–1.337
Suaman													0.568	0.125	0.010	0.368–0.875

OR-odds ratio; SE-standard error; *p*-probability value; CI-confidence intervals.

Observations under farmers' experience were not statistically significant for models 1 to 3, while the extension services variable, which was statistically significant in models 1 and 2 ceased to be significant in model 4, when the contextual factor was added. In addition, agrochemical shop was significant under models 1 to 4. Farmers who depended on agrochemical shop services (OR = 1.646, $p < 0.014$) for information about pesticide application were still more likely to use PPE compared to their counterparts. The result also showed that female farmers (OR = 0.466, $p < 0.000$) were still less likely to use PPE during pesticide application than the male farmers. Concerning districts, only Suaman district showed relationship with PPE use. Farmers in Suaman (OR = 0.568, $p < 0.010$) were less likely to use PPE compared to Wassa Amenfi West district. It is obvious from the results that agrochemical shop services and extension services influence farmers' choice to use PPE during pesticide application.

3.3.4. Bootstrapping model statistics

In order to validate the model statistics and avoid doubts of sample distribution, bootstrapping was used to measure the accuracy of the logistic regression model (multivariate complementary log-log) parameter estimates. Table 11 shows the result of the bootstrapping used. The bootstrap method attempted to estimate the sampling distribution empirically with the given sample size of 225 and estimate the parameters on large scale of 2000 sample size. There were no differences between the OR, SE, and CI for logistic complementary log-log regression model in Tables 10 and 11. In addition, the *p*-values were identical as predicted by both the logistic regression and the bootstrap method. The implication of the result is that the sample size distribution and parameter estimates are accurate and correctly predicted by the complementary log-log model.

4. Discussion

4.1. Demographic characteristics of farmers

This study investigated smallholder cocoa farmers' knowledge of pesticide use, their attitudes towards storage of pesticides, and evaluated their exposure to health symptoms. The study revealed that the common reason for using pesticides was to protect cocoa plants from insects, pests and diseases. This finding is in line with Khan and Damalas (2015), who reported that in order to control pests and prevent loss of crop yields in their crops, farmers use synthetic pesticides extensively. The present study also showed that the dominant gender involved in cocoa farming in the study area is the male. The large male to female ratio in this study is in line with the findings of Bosompem et al. (2012), Boateng et al. (2014), Antwi-Agyakwa et al. (2016), Zhu (2015), and Tijani (2006). The educational background of respondents showed that a good number of farmers had received basic and secondary level education while the majority of the farmers did not have further studies beyond the secondary school level. Nonetheless, the proportion of illiterates was equally low. This case is similar to Paintsil (2017) and Zhu (2015) findings, where farmers had the view that a high level of education is not necessary for carrying out farming. A study from Nigeria (Oluwole and Cheke 2009) also confirmed this trend with a similar finding where the majority of farmers surveyed had no formal education. Hence, it can be deduced that the inability of a farmer to undertake a good agricultural practice is because of poor educational background in rural Africa. The results further show that three-fourths of the respondents had either no or just primary level of education. Thus, farmer's level of education may be a contributing factor to their inability to read the labels on the chemical containers and in understanding the hazardous nature of pesticides chemistry. In a related study, about 94% of the farmers stated that pesticide labels were difficult to read and understand which was attributed to low educational levels, poor literacy skills and difficulty in following the language used in the wording of the label (Damalas et al. 2006). The cocoa sector has been the mainstay of the Ghanaian economy since 1957 (Vigneri and Kolavalli 2018). Surprisingly, however, it is pathetic to note that this cash crop for Ghana is not attracting those with tertiary level education. It is no wonder, the cocoa farming production is still in the hands of smallholder farmers. Ghana Statistical Service (2013) data indicated that Ghana's agricultural sector is dominated by 90% smallholder farmers with less than 2 hectares of land. These farmers still use traditional production methods and farm inputs. The current global state of agricultural practice is driven mainly by science and technology, but without adequate level of education, applying science and technology to transform agriculture to a knowledge-based enterprise may become quite problematic. Recently, Kwadzo (2015) examined smallholder cocoa farmers in Mpohor-Wassa East district, Ghana and found that 73% of the farmers had shifted from cocoa to rubber cultivation. The result buttressed the fact that investment outcomes of cocoa have a significant effect on their enterprise-shift behaviour and

Table 11. Bootstrap results generated after 2000 samples to validate parameters of multivariate complementary log-log regression model predicting PPEs usage during pesticide application.

	Source of pesticide knowledge (Model 1)				*Bio-social factors (Model 2)*				*Socio-cultural factors (Model 3)*				*Contextual factors (Model 4)*			
Predictors	OR	SE	*p*	95%CI	OR	SE	*p*	95%CI	OR	SE	*p*	95%CI	OR	SE	*p*	95%CI
Agrochemicals shops (Ref: No)																
Yes	1.735	0.365	0.009	1.149–2.619	1.773	0.387	0.009	1.156–2.718	1.777	0.370	0.006	1.182–2.673	1.646	0.334	0.014	1.106–2.452
Extension services (Ref: No)																
Yes	1.643	0.317	0.010	1.125–2.399	1.507	0.290	0.033	1.033–2.198	1.497	0.299	0.043	1.012–2.215	1.374	0.268	0.104	0.937–2.015
Farmers' experiences (Ref: No)																
Yes	0.752	0.250	0.392	0.392–1.443	0.833	0.284	0.591	0.427–1.623	0.838	0.290	0.610	0.425–1.653	0.837	0.262	0.570	0.453–1.546
Gender (Ref: Male)																
Female					0.481	0.103	0.001	0.316–0.734	0.483	0.103	0.001	0.318–0.732	0.466	0.094	0.000	0.313–0.693
Education (Ref: No formal education)																
Primary education									1.010	0.227	0.963	0.651–1.569	1.095	0.240	0.679	0.713–1.681
Secondary education									1.065	0.246	0.785	0.677–1.676	1.090	0.238	0.692	0.711–1.672
Districts (Ref: Wassa Amenfi West)																
Aowin													0.882	0.187	0.553	0.581–1.337
Suaman													0.568	0.125	0.010	0.368–0.875

OR-odds ratio; SE-standard error; *p*-probability value; CI-confidence intervals.

decisions. If this trend is drifted to other districts and regions, it may not auger well for the sustainability of the cocoa sector.

4.2. Relationship between farmers' level of education and knowledge of pesticide toxicity

In general, most farmers had good knowledge of the effects of pesticides on human health as they indicated how their bodies react after the spraying of pesticides. It was also discovered that farmers' knowledge in health effects of pesticides was influenced by their educational background. According to Bagheri et al. (2018), well-educated farmers had more safe behaviours than less-educated farmers. Similarly, well-educated farmers were more likely to pay a high premium for safe pesticides (Khan and Damalas 2015). Thus, training and education positively influence environmentally sound behaviour in pest management (Damalas and Khan 2017). Interventions such as education and training of farmers which enhance safety behaviour should be intensified to minimize pesticides exposure among farmers, (Damalas and Koutroubas 2017). It is clear that having a clear insight regarding farmers' level of knowledge and farmers' practices on safe use of pesticides is necessary to augment the current scenario for a new policy change (education). The policy change should involve the farmers, the extension agents, the agrochemical retailers, and regulatory agencies. This new policy change is needed to protect the public health. Contrary to expectations, although, the majority of the farmers in this study were aware of the harmful effects of pesticides, this did not significantly change their practices or attitudes towards safe pesticides use. This finding is consistent with that of Sharifzadeh et al. (2019) and showing that even though good knowledge about pesticide safety is imperative for farmers, this alone is not enough to encourage them to indulge in safety behaviours. Perhaps cultural and social driving forces are strong determinants limiting behavioural change necessary to evoke a collective safety responsibility (Feola and Binder 2010).

4.3. Relationship between pesticides storage location and farmers level of education

The present study also highlighted some unsafe practices regarding storage of pesticides, i.e. in the kitchen, living room and in the food storerooms. Thus, it was clearly shown that farmers were lacking knowledge regarding appropriate places for storing pesticides. Storing pesticides in the living rooms, kitchen, and food storerooms increases the potential for pesticide exposure risks. The majority of the farmers kept chemicals in their farmlands. However, a good number of them kept chemicals within the living room, kitchen, in the food storeroom, and in the animal house. An additional fascinating situation in these rural communities setting was the storage of chemicals in the toilet and bathroom. A very small proportion of the farmers (7%) kept pesticides in the agrochemical stores. This finding is similar to that of Paintsil (2017) because the selected study area is in the same region but in different districts. Oluwole and Cheke (2009) also gave similar support to this assertion with data from rice farmers, while Zhu (2015) recognized a similar trend in vegetable farmers within the cocoa growing belts. Additionally, Bagheri et al. (2018) found out that about 60% of the farmers in Iran stored their pesticides in stalls and warehouses, while about 40% threw empty pesticide containers at the orchard and in the canal. On the other hand, Tijani (2006) uncovered a different pattern, that is, the majority of the farmers were storing pesticides in designated stores and a minority was keeping them in their bedrooms. The attitudinal behaviour exhibited by the farmers in understanding the hazardous nature of pesticides storage location is linked to the educational levels of the farmers. Based on these findings, farmers need to be trained on proper and safe storage of pesticides. Damalas and Koutroubas (2017) have shown that training of farmers was associated with increased levels of knowledge of pesticides and beliefs of pesticides hazard control, which was accompanied by high safety attitude in farmers resulting in lower occupational pesticide exposure. Undoubtedly, farmers who undertake educational programs experience fewer poisoning symptoms by pesticides (Bagheri et al. 2018). Apart from education, farmers can also be motivated to store and dispose of pesticides in a safe manner through the constitution of credit bonuses at the purchase of pesticides. For example, part of the money paid for the pesticide by the farmers can be given back to them when they return the pesticide containers to the manufacturers, retailers or packaging companies (Bagheri et al. 2018).

It was also found that the most prominent containers and sachet disposal strategies currently employed were throwing in the field, village landfills, burning on farm and burying in a hole (Figure 3). This trend is coherent with data reported by Tijani (2006), Oluwole and Cheke (2009) and Paintsil (2017). Previous studies in Ethiopia and Greece found dumping empty pesticide containers by fields, near, or into irrigation streams and canals and

burning them in open fire are well-known practices of pesticide container disposal methods that farmers are often involved in, coupled with using them for storage of fuel, water and food (Damalas et al. 2008; Haylamicheal and Dalvie 2009). It was also observed that some farmers practice rinsing the empty containers by discharging the water into nearby uncultivated lands, throw away empty containers into rivers, lakes or irrigation canals or bury them in the ground. However, it is interesting and alarming to note that some farmers also put the empty containers to other use for storing household items such as salts, palm oil, flour and other products meant for consumption. In addition, the majority of the respondents were found even washing their pesticide containers in rivers, streams or irrigation canals. Similar behaviour and attitudes were observed by Jallow et al. (2017) among farm workers in Kuwait, showing that the practice cut-across various cultural backgrounds. Thus, again this study demonstrated poor knowledge of cocoa farmers about pesticides and their transport in the environment. These poor handling and disposal practices can have devastating effects on soil, water contamination, and the overall impacts on public health. This is because such unsafe practices can release pesticide residues and contaminate the environment (Damalas and Eleftherohorinos 2011, Miyittah et al. 2020).

4.4. Pesticide application information by cocoa farmers

The present study also indicated that most farmers obtained pesticides from local governmental shops as their main source. Anecdotal evidence supported by this reality is that most of these agrochemical retailers themselves need more education on pesticide use and handling. Moreover, if pesticide retailers are well informed they can help by providing accurate source of information regarding environmental and human health impacts of pesticides to farmers who cannot read instructions or labels on the containers. There is, therefore, a need to train and equip pesticides retailers regarding dissemination of agricultural information, since they can play a critical role as a primary information and knowledge source for the farmer. Lekei et al. (2014) reported the impact of retailers as technical advisors on farmers and other end users as a key contributing factor in occupational exposure to pesticides. Additionally, 69% of the respondents obtained information for pesticides from agricultural extension officers. This observation is in line with results obtained by Tijani (2006) and Zhu (2015). However, others prefer to use their own experience or get information from their fellow farmers. There is nothing wrong if the farmer gets information from their peers. However, the difficulty occurs when the said information is not accurate and the source of information cannot be verified by the farmers themselves. The unverified information can be further distorted along the communication channels and such distortion can contribute to propagation of inaccurate information regarding pesticides use among cocoa farmers. Agricultural extension officers in general act as conduits between the Ministry of Food and Agriculture and farmers, or farm workers. Extension aims primarily at improving the knowledge of farmers for rural development. Thus, agricultural extension plays a critical component of technology transfer (Bonye et al. 2012). In general, extension officer-to-farmer ratio in Ghana is about 1:3000. However, the COCOBOD as an agency in charge of cocoa have reduced the ratio gap by having extension services specialized for cocoa affairs.

This gap reduction in extension officer-to-farm ratio may be the reason why 69% of the respondents reported that they obtained information about pesticides through extension officers. A considerable number of the respondents (90%) reported mixing more than one pesticide type and applying to cocoa farms as one of the pesticide application strategy. This practice has further demonstrated that the farmers lack knowledge application doses and the impact it may have on the toxicity of insect pests and on the development of resistance of the insects with respect to the said pesticides, as reported elsewhere (Damalas and Khan 2017). It has been reported that over 600 species of pests have developed some level of resistance to pesticides (Gill and Garg 2014). Therefore, new policy and updated training is urgently required to educate the retailers, extension agents, farm workers and farmers regarding pesticides resistance and the implications it may have on the cocoa sector. There should be a documentation of all pesticides sold and a link of the respective serial numbers on containers with the farmer through the retailer. The farmer should have a pesticide book with a documentation where the pesticides was bought and with the documented location of the retailer. At the end of the pesticide application, a mechanism should be put in place to retrieve all the empty containers. By this approach, the empty containers would no longer be used as alternative storage containers with its concomitant health implications. The present study further showed that most farmers had good knowledge of the effects of pesticides on human health and the environment. Most farmers were positive that

pesticide could enter the body via mouth (92%), inhalation (94%), and skin (93%). The majority was also aware that residues of pesticides can be deposited on fruits and vegetables and they can contaminate soils and groundwater.

4.5. Common health symptoms associated with frequent pesticide usage

It was also observed that 66% of the farmers experienced health symptoms such as headaches, burning eyes, skin rashes, itching and chest pain. This may be attributed to the heavy use of pesticides for pest management and the non-use of PPE or the use of inappropriate PPE during the various stages of pesticide usage. Similarly, Atreya (2007), on the other hand found that pesticide operators reported greater signs and symptoms of pesticides exposure such as skin irritations, stomach poisoning, and eye irritations than other farm workers. Similar effect was observed in another study conducted by Neghab et al. (2014) with 268 male farmers in Iran. The result showed that 68% of the participants reported to their general health practitioners, suffering from burning and skin irritations, burning eyes, headaches, vertigo, nausea and vomiting during spraying. Damalas and Koutroubas (2016) found that accurate usage of appropriate PPE in all stages of pesticide handling coupled with less use of pesticides could reduce farmers' exposure to pesticides. Toxicity symptoms of pesticide may be categorized as mild (skin irritation) and severe (headache, nausea and dizziness) (Damalas and Koutroubas 2016).

4.6. Personal protective equipment (PPE) use by the farmers

About fifty-five farmers failed to wear any personal safety equipment (zero PPE), while 68 of the farmers revealed they used the full working gear (six PPE items). Most of the farmers who used zero PPE in the study were noted to be farmers who had no formal education. In addition, 102 of the farmers partially protected themselves before using chemicals on the farms. Farmers with either primary or secondary level of education used all six PPE items or some form of partial PPE items during spraying. Knowledge, attitudes, and practices (KAP) surveys by Ntow et al. (2006) showed that only 32% of the farmers were wearing full PPE. In addition, measuring the relative toxicity of pesticides used in controlling pest in Akumadan, Ghana, showed that 58% of the farmers did not use any PPE, while only 29% used some form of PPE. Furthermore, high illiteracy rates contribute to farmers' difficulty in understanding and following instructions and safety advice on pesticide use.

In Brazil, knowledge was not found to influence pesticide application practices because the majority of the farmers admitted receiving information, training and claimed reading labels, adhering to instructions and warnings, but did not take adequate protective measures (Waichman et al. 2007). The level of knowledge and perception of risk were not enough to influence farmers' self-protective behaviour (Remoundou et al. 2014). It was also reported that farmers were exposed to agrochemicals because of non-use of PPE cover cloths during spraying and leakages from knapsack sprayers. In addition, spraying during windy conditions can cause incidental drifting of the chemicals to unapproved routes. The study also revealed a positive correlation between education, agrochemical services, extension services, and location of farmers with farmers' PPE use. However, farmers' years of experience and gender showed a negative correlation with farmers' PPE use. In addition, the modelling showed that factors such as agrochemical shops, extension services availability as sources of information with respect to pesticide application had positive significant influence on PPE usage. This finding is in line with the observation of Okoffo et al. (2016) that the probability of a farmer wearing PPE increases with the availability of agrochemical shops. This behaviour may be attributed to the fact that agrochemical shop retailers can serve as a conduit in educating the farmers on the dangers in application of pesticides without the use of PPE. Even when the model was controlled for biosocial, socio-cultural, and contextual factors, these parameter estimates were still significant, except for extension services in contextual factor modelling. These services should be used as a medium to educate farmers on the importance of PPE use by providing training and capacity building for extension officers and agrochemical retailers. Previous research has shown that farmers who perceived usefulness of PPE, such as effectiveness, safety, and ease of use were more willing to use PPE in the future (Sharifzadeh et al. 2017). The implication is that proximity of farmers to extension officers and location were crucial in PPE usage. In addition, the sources of information about pesticide application should be supported by governmental interventions regarding pesticide educational activities to encourage the famers to use PPE. Surprisingly, however, farmers' years of experience in pesticide use was not translated into PPE usage. The parameter estimate for farmers' years of experience was similar under biosocial,

socio-cultural, and contextual factors. The prevailing socio-cultural conditions can serve as confounding factors (Feola and Binder 2010) such that the educational information received maybe masked after massive education regarding pesticide application. The implication is that sociological conditions underpinning the socio-cultural factors hampering the use of PPE must be investigated to shed more light on the situation regarding acceptability of PPE use in the study area. However, other studies have indicated that farmers' experience with adverse health effects of pesticides significantly influence their safety behaviour and the use of PPE (Feola and Binder 2010; Hashemi et al. 2012; Damalas and Abdollahzadeh 2016; Sharifzadeh et al. 2018, 2019). Thus, the more farmers experience threats and health risks by pesticides, the more they are likely to show safety behaviours (Abdollahzadeh et al. 2015; Damalas and Abdollahzadeh 2016). The inability of the female farmers to use PPE could also be linked to what some of them said during the field survey about the discomfort they go through any time they put on PPE. This phenomenon is worrisome because when female farmers are exposed to pesticides, they can indirectly expose their breast-feeding babies (Lorenz et al. 2012). A study on the analysis of pesticide contamination of farmers in Ghana revealed the presence of residues of organo-chlorine pesticides, including dichlorodiphenyltrichloroethane (DDT), in the breast milk and blood of female farmers (Ntow et al. 2008). The sociological condition might also be the reason why females are less likely to use PPE compared with their male counterparts. Our preliminary interpretation is that women would be more exposed to health risk of pesticide than men. This may be attributed to the fact that female smallholder farmers have limited access to training programs regarding pesticide safety, and hence, they follow just few pesticide safety behaviours when handling pesticides (Naidoo et al. 2010; Damalas et al. 2019). In order to enhance pesticide safety awareness among female farmers, gender-sensitive safety programs should be organized (Wang et al. 2017; Damalas et al. 2019). In this study, about 30% of women were engaged in cocoa farming and therefore, further research is needed in this direction, since pesticide hazards have several debilitating and consequential effects on women as child-life support givers. Educational levels have been observed as having no influence on the use of PPE under socio-cultural and contextual factors. On the contrary, other researchers proposed that educational programs enhance sustainable PPE use among pesticide applicators and smallholder farmers (Sharifzadeh et al. 2019). This means that there is a significant positive effect on PPE use and education, and thus, the educational status of the farmers strongly determines their PPE usage (Al Zadjali et al. 2015; Blanco-Munoz and Lacasana 2011; Sharifzadeh et al. 2019). Educational impacts on individuals occurred in multiple layers with interacting context (Rappaport and Smith 2010; Armah et al. 2019). Moreover, each of these contexts is a domain of social relations and each factor in each domain interacts. Thus, there is a difference between education as a context and education as a process because these two elements have different types of implication on environmental health and can affect pesticide use. This understanding is in line with Feola and Binder (2010) who indicated that socio-cultural factors are usually masked by educational factors; hence, there is a need to disaggregate the various elements and their interacting effects. Under the contextual factor, the location of the district towards the use of PPE is a case in point. For example, farmers in Suaman district were less likely to use PPE compared with those in Wassa Amenfi West. Thus, the sociological mindset occurring in a particular district bounded by language and culture may contribute towards the use of PPE. Elements within the culture and the language that is leading to the influence of PPE use must be studied. Perhaps, more access to extension services within the district may be the contributing factor in using PPE as noted by Danso-Abbeam et al. (2018) who reported agricultural extension plays a critical role in improving the knowledge base of the farmer and in the transfer of technology. The use of PPE is a type of skill that influences productivity and the farmer must have it and understand why it is important. This is because the health of smallholder farmers who has been the backbone of Ghana's economy for decades is at a risk, and there is the need to protect the human health and the environment in order to sustain the cocoa industry in a sustainable manner. One limitation of this study is that it was based on self-reported data that depends heavily on the sincerity of the participants, which is subject to some extent of biases (Weinstein and Klein 1996; Jallow et al. 2017). Self-reported studies may include some inaccurate data such as respondents trying to be politically correct or report socially desirable behaviours. A second limitation could be the inability to link directly health symptoms with pesticide exposure. It could be that other factors may be

responsible for the health symptoms (Jallow et al. 2017). Despite these limitations, the study provided a window of insight into pesticide use, knowledge, and safety practices among smallholder cocoa farmers and it could assist in major policy change to protect public health and the environment. Policy changes are necessary to ensure the overall cocoa beans health for global exports and for the chocolate industry sustainability.

5. Conclusions

The drive to earn foreign exchange through increase cocoa productivity is huge, and so is pesticide usage. In this study, we investigated potential exposure factors that are likely to cause harm to human health and the environment among cocoa farmers. We found that farmer's method of storing, disposing, and washing of empty pesticides containers after use were inappropriate and potentially detrimental to human health and the environment. Farmers' level of education had a strong association with the toxicological routes of entry of pesticides into the human body. Common and frequent health symptoms experienced by the farmers were, headache, burning eyes, skin rashes, itching and chest pain. These health symptoms were likely due to inappropriate and inadequate use of PPE. It was also found that farmers' level of knowledge acquired on the dangers of pesticides was not translated into actual use of PPE. Several factors likely influenced the usage of PPE among farmers. Through modellng, factors affecting the use of PPE were agrochemicals shops, extension services, and farmers' district location. The obvious implication is that these factors must be brought into the equation for policy interventions that could minimize farmers' exposure to pesticides as well as health impacts of pesticide use in cocoa farming.

Author contributions

M.K.M conceptualization, study design, methodology, drafting and review. B.A: coordination of the pesticide analysis, software programming, drafting.
M.K software programing, method validation, interpretation of results, review and editing of this article. S.S.L method validation, review and editing of the article and R.K.K software programming, review and editing of the article. All authors M.K.M., M.K., B.A., S.S.L., and R.K.K. revised the manuscript critically for important intellectual content and approved of the version to be published.

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Disclaimer

The authors declare that the findings and conclusions in this article are those of the authors and do not represent the views of the organisations of affiliation or agencies.

Disclosure statement

No potential conflict of interest was reported by the authors.

Ethics consent and permissions

All participants agreed to participate in the research study, and they were free to participate without duress and coercion.

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ORCID

Michael K. Miyittah http://orcid.org/0000-0002-2033-7108

Data availability statement

The authors confirm that the majority of the data supporting the findings of this study are available within this article.

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Toward the Achievement of Household Food Security: Effects of Freezing and Drying on the Sensory Attributes of Okra

Moses Kwadzo[1,*], Rebecca Owusu[1], Fatimah Abubakari Von[1], Edward Decker[2], James Kofi Annan[1]

[1]Department of Agricultural Economics and Extension, University of Cape Coast, Ghana
[2]Council for Scientific and Industrial Research, Accra, Ghana
*Corresponding author: moses.kwadzo@ucc.edu.gh

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Abstract Preservation of highly perishable farm produce at household level is very essential in promoting food security. In this paper, we examine the effects of freezing and drying on the sensory attributes of okra. Fresh-frozen, blanched-and-frozen, and sun-dried okra samples were preserved for eight weeks. Portions of the preserved okra samples (treatments) and fresh okra (control) were cooked in equal quantities of lightly salted water. A preference test was then conducted using a panel of 20 judges. Paired sample t-tests between the treatments and the control showed that the blanched and frozen okra was the preferred preserved sample type, with sensory attributes closest to those of fresh okra. Given that consumers are more likely to accept preserved vegetables that retain most of their sensory qualities, it is recommended that blanched and freezing are employed to preserve fresh okra at the household level.

Keywords: *food security, sensory attributes, okra, consumer preferences, acceptability*

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1. Introduction

According to the Swiss Agency for Development and Cooperation (SDC) [1], food security and nutrition are major global challenges. Although the proportion of undernourished people in developing nations has decreased by almost half since 1990 (from 23.3 percent in 1990-92 to 12.9 percent in 2014-16), almost 800 million people worldwide still suffer from hunger and are unable to consume enough food for a healthy life [1,2]. In addition, 2 billion people suffer from micronutrient deficiencies. Currently, only 3 million people escape chronic undernourishment annually, whereas 60 million people would need to do so annually to meet the target of 800 million people by 2030 to achieve a world without hunger [1]. According to the 2002 World Food Summit, food security exists when all people have access at all times to safe, sufficient, and nutritious food to meet their dietary needs and food preferences for an active and healthy life [3]. Considering the global food supply and the population growth rate, it has been estimated that food production will need to increase by 70% to feed the world's population in 2050 [4,5]. Considering the many challenges facing agricultural food production in developing countries, it will be difficult to meet this target by 2050 [4,6,7].

Food loss and waste have been reported to account for a third of food produced for human utilization worldwide [8,9]. According to Ridolfi et al. [9], research funded by the Food and Agriculture Organization of the United Nations (FAO) on postharvest loss has shown that approximately a third (1.3 billion metric tons) of food produced for human consumption is lost worldwide annually. The study indicated that sub-Saharan African countries recorded relatively high proportions of food loss and waste compared to other low-income countries. Disproportionally greater losses during production, postharvest handling, and storage occur for food crops, vegetables, roots, and tubers. Food is lost when edible food mass decreases at any stage of the food supply chain. Food loss and waste must be reduced to improve food security [5,10].

The Economist Intelligence Unit [11] rates countries' food security using a food security index (on a 0–100% scale) based on three dimensions— food availability, affordability, and safety. In 2014, Ghana's food security score was 43%, which corresponded to a moderate degree of food security. In many developing countries such as Ghana, fresh vegetables are grown mostly by smallholder farmers. Seasonal production of fresh vegetables makes

them abundant during the rainy season and scarce in other seasons [12,13,14]. Ridolfi et al. [14] and the Affognon et al. [7] have estimated that Ghana loses approximately 20–50% of its fruits, vegetables, roots, and tubers annually. In Ghana, vegetables, fruits, and nuts account for approximately 10% of total food output and 23% of household consumption expenditures. This disparity in the percentages of food production output and household expenditures on fruit and vegetable in Ghana suggests that these food categories are important in the Ghanaian diet and that their adequate provision is a concern to both producers and consumers in Ghana [15,16]. Data on food preservation at the household level in Ghana show that households process large proportions of cereal and tuber into flour and dough and process nuts into paste and oil for storage. However, fruits and vegetables typically receive less processing attention from households [16,17]. A study conducted by the International Centre of Insect Physiology and Ecology (ICIPE) on major crops loss in Ghana during postharvest handling and storage indicated that okra suffers the largest loss percentage (30.0%), followed by tomatoes (28.8.%), yams (12.8%), mangos (8.7%), and maize (6.2%) [10]. Okra is sold in almost every market in Africa and is one of the most commonly consumed vegetables in Ghana [18]. Immature green okra and leaves are mainly cooked as vegetables. Dried okra is ground into powder, preserved, and used in stews and soups**.** Fresh okra consists primarily of water (85%), fat (0.5%), protein (4%), and carbohydrate (5.4%). Okra has a high quantity of folate, which is a vital nutrient for healthy prenatal brain growth and development [19].

Okra is one of the major vegetable crops cultivated by smallholder farmers in Ghana, with an estimated annual production output of approximately 1,548–4,507 metric tons [16,20]. Okra has a short shelf life, as the fresh pods deteriorate rapidly under ambient conditions. Okra is harvested and sold fresh in almost all markets in Ghana. Nevertheless, okra is prone to aging and fibrosis after harvest because of its high initial moisture content (88–90% wet matter) [18,20]. During the main production season, large amounts of fresh okra deteriorate. This situation often compels producers to sell their harvested okra pods at less than 50 percent of the expected price, and retailers sometimes throw away unsold okra pods at the end of the market day to avoid incurring extra costs for transporting unsellable produce back home [10]. Okra is usually found in dehydrated form during the dry season, when it is scarce and expensive [18].

Postharvest preservation makes local foods available and less costly even during off-seasons. Small-scale food preservation practices can ensure the presence of various vitamins and minerals in daily diets. Therefore, research on small-scale preservation of highly perishable foods at the household level to prevent loss is timely. Although okra may be preserved in small quantities by individuals or households by freezing and drying techniques, the author has not seen a comparative analysis of the effects of freezing and drying on the sensory attributes of okra. The use of unsuitable preservation techniques may adversely affect the sensory qualities of stored vegetables, and consumers are more likely to accept preserved vegetables that retain most of their sensory attributes [21,22]. The main objective of this study was to examine the effects of freezing and drying on the sensory attributes of okra. The hypothesis tested was that there were no significant differences in the sensory attributes of fresh and preserved okra samples.

Food preservation is a group of methods for treating food to stop or greatly slow spoilage caused by microorganisms [23,24]. These methods involve taking actions to maintain the desired properties of foods for longer periods. Consumers' demand for healthier and more convenient foods has been found to affect how food is preserved [22]. Food preservation extends seasonal availability and ensures longer shelf lives. Additionally, food preservation retains food quality in terms of color, aroma, flavor, and texture. However, the quality of preserved food may be diminished in terms of its sensory attributes, depending on the preservation method employed. Ineffective preservation may result in loss of quality ranging from minor changes, such as color loss, to severe changes that result in the food becoming unfit for consumption. Food preservation methods are categorized as heat treatment, chemical application, drying, and freezing methods [25,26].

Heat treatment involves exposing food to high temperatures, which is an effective way of preserving food because most harmful pathogens are killed at temperatures close to the boiling point of water [25,26]. Blanching is a form of heat treatment that involves brief exposure to hot water or steam (for a few minutes) to inactivate enzymes. Blanching is not a primary food preservation method but rather a pretreatment method carried out before a primary preservation method. Blanching helps stabilize the color and protects food's flavor and texture, especially green vegetables. Overblanching of fruits and vegetables can cause excessive softening and loss of flavor and color. Blanching vegetables prior to freezing or drying reduces bacterial load and helps to preserve sensory attributes such as color, aroma, taste, and texture [23,24].

Drying is one of the oldest methods of food preservation. Drying preserves food by reducing water activity sufficiently to prevent or greatly delay microbial growth. Microorganisms need moisture to grow and reproduce. Food preservation by drying decreases the water content of the food below a certain critical value and thereby depresses microorganisms' growth. Eliminating water from food makes it unavailable to bacterial cells and prevents their multiplication [23,24]. A low water content slows the rates of respiration, enzymatic action, and overall deterioration that make food products susceptible to decay. Many fruits and vegetables contain considerable amounts of water that make them susceptible to spoilage by microorganisms. Drying fruits and vegetables lower their water activity to levels that inhibit their spoilage during long-term storage. While drying is a good method of food preservation, some horticultural produce may lose some vitamins and/or develop unpleasant tastes after drying. For example, drying can decrease the contents of fat-soluble vitamins such as vitamin B (carotene) by as much as 25 percent, and vitamin C is very sensitive to light and oxygen [25,26]. Enzymes in foods can be inactivated by temperature and moisture changes. Microorganisms require free water for biochemical reactions. When water is removed from food, it becomes unavailable to microbial cells.

Food can be preserved by freezing because microorganisms do not multiply below -18°C (0°F), and biochemical reactions are increasingly suppressed as temperatures fall below 0°C [24]. Freezing eliminates the presence of liquid water as the essential medium for microbial action. However, freezing can adversely affect the sensory quality of food, particularly texture. Freezing causes the formation of ice crystals in foods, resulting in profound effects on food texture, taste, and aroma. Fruit and vegetables with high moisture contents do not freeze well because their cellulose structures tend to be broken down by freezing, making the fruits and vegetables undesirably soft upon thawing. Blanching prior to another method of food preservation allows many vegetables to retain their natural color, flavor, and texture [25,26]. The use of domestic freezers to store vegetables in smaller quantities by individuals or households can be an effective way to promote food security.

2. Materials and Methods

2.1. Sample Preparation

Fresh okra pods were purchased from a local market in Cape Coast. The selected okra samples were washed with tap water and drained to remove foreign materials. The stems and tapered tips of the cleaned pods were cut off to form cylindrical shapes approximately 50 mm long. Each trimmed pod was then cut into pieces approximately 10 mm long. The cut okra pieces were divided into three portions. Charcoal ash was sprinkled on one portion of the cut pieces of fresh okra, and the pieces were then sun-dried in a simple rectangular household basin covered with plastic netting to protect them from flies. Charcoal ash has been reported to prevent fungus from spoiling dried okra. The sun-drying was carried out for seven days until the pieces reached the desired moisture content. The sun-dried okra pieces were placed in moisture-resistant polythene bags and then stored on a shelf. One of the remaining two portions of cut okra pieces was blanched in very hot water for approximately 2 min. The blanched okra pieces and the remaining unblanched okra pieces were preserved in a domestic deep freezer for eight weeks.

2.2. Measures and Data Collection

The three preserved okra samples (fresh-frozen, blanched-and-frozen, and sun-dried) represented three preservation treatments compared to a control (fresh okra). The three preserved okra samples and a control sample were cooked in equal amounts of lightly salted water for approximately 9 min. An evaluation sheet based on 9-point hedonic scales was used by the judges to evaluate the treated and control samples. Nine-point hedonic scales are widely used in consumer research to assess various aspects of food acceptability. Each scale ranges from a value of 1, denoting extreme dislike, to a value of 9, denoting extremely high liking. A mean preference score of 7 or higher on a 9-point scale is usually suggestive of a highly acceptable sensory quality.

Such scales allow researchers to compute the mean values of responses and compare the mean values using parametric statistical tests, such as analysis of variance and t-tests [27]. Students and staff members from the School of Agriculture at the University of Cape Coast were invited to participate in the evaluation. This is a self-sponsored study and the researchers were not required by any agency to receive ethical approval for the study. Nevertheless, all the respondents agreed to participate in the research study and they were free to participate with or without any justification. The consent to publish individual data in any form was obtained from the study participants. Twenty judges who reported using okra in their diets on a regular basis were provided with prior skill training on sensory evaluation of food. Each of the judges was provided with tissue paper, spoons for tasting, and a palate cleanser (sparkling water) between tastes to avoid the transfer of sensory qualities. Pieces of each of the cooked okra samples (fresh, fresh-frozen, blanched-and-frozen, and sun-dried) were placed on plates labeled A, B, C, and D. The judges were asked to rate their preferences and acceptability of the four okra samples in terms of color, aroma, taste, and texture, using a 9-point hedonic scale for each attribute, as well as a 9-point hedonic scale for overall acceptability.

2.3. Statistical Analysis

It was hypothesized that there are no significant differences in the sensory attributes of fresh okra and the three preserved okra samples. To test the hypothesis, paired-sample t-tests were performed, and eta squared values were computed to assess the magnitude of any significant effects detected. Paired-sample t-tests are suitable for evaluating two related observations per subject and determining whether a significant difference exists in the means of two treatments with respect to normally distributed variables [28]. The statistical significance (p-value) of a test reflects whether a significant effect exists, but it does not reveal the size of the effect. Eta squared is an appropriate effect size statistic. For example, values of 0.2, 05, and 0.8 for eta squared are considered to reflect small, moderate, and large effect sizes, respectively. By determining both p values and ta squared values, a researcher is well-positioned to know whether and how much a treatment affects a dependent variable [28,29].

3. Results and Discussion

Sensory attributes greatly influence consumers' food preferences [30,31]. However, inappropriate food preservation methods can adversely affect the quality of sensory attributes. Identifying and utilizing appropriate preservation methods that optimally retain the sensory attributes of vegetables is therefore important [24,25,26]. The statistical results of the effects of freezing and drying on the sensory attributes of preserved okra are discussed below.

3.1. Evaluation of Color of Fresh Versus Preserved Okra Samples

The paired-sample t-test results shown in Table 1 indicate a statistically significant difference between the color of the fresh okra sample (control) (M = 7.90, SD = 1.62) and the color of the fresh-frozen okra sample

(M = 5.30, SD = 1.34) ($t_{(20)}$ = 7.41, p < 0.00). The magnitude of the effect of freezing on the color of the fresh-frozen okra sample was moderate **(**eta sq =.59). Similarly, there was a significant difference between the color of the fresh okra sample (control) (M = 7.90, SD = 1.62) and the color of the dried okra sample (M = 4.15, SD = 1.90) ($t_{(20)}$ = 7.55, p < 0.00), and the magnitude of the effect of drying on the color of the sun-dried okra sample was also moderate (eta sq. = .60). There was no significant difference detected between the color of the fresh okra sample (control) (M = 7.90, SD = 1.62) and the color of the blanched-and-frozen okra sample (M = 7.00, SD = 1.52) ($t_{(20)}$ = 1.96, p < 0.06), and the magnitude of the effect of blanching and freezing on the color of the blanched-and-frozen okra sample was small **(**eta sq. = .06). Color is an essential aspect of the human sensory experience of food. Natural bright colors give the sensory impression of high-quality, healthy, nutritious food, whereas colorlessness gives an impression of poor food quality [32]. A given vegetable is known to have a specific color when fresh and ripe. The outer cell walls of edible fresh okra pods are normally green in color. The blanched-and-frozen okra sample therefore emerged as the most preferred preserved okra sample with respect to color. This can be explained by the fact that blanching and freezing cause little physical or chemical change to okra and therefore help it to retain a green color similar to that of fresh okra.

3.2. Evaluation of Aroma of Fresh Versus Preserved Okra Samples

Aroma and taste are major components of flavor. Aroma is the fragrance or odor of food. Vegetables contain volatile aromatic compounds in their intact tissues that give them characteristic aromas [31]. Sometimes, these compounds undergo changes following processing and preservation [8,9] (Spence, 2015; Srivastava & Kumar, 2017). The paired-sample t-test results showed that there was no significant difference between the aroma of the fresh okra sample (M = 7.45, SD = 1.30) and the aroma of the blanched-and-frozen okra sample (M = 6.66, SD = 2.41) ($t_{(20)}$ = 1.68, p < 0.11). The magnitude of the effect of blanching and freezing on the aroma of the blanched-and-frozen okra sample was small (eta sq.= .07).

According to Ramaswamy [24] (2021), blanching tends to preserve the flavor of food, especially green vegetables. There was a statistically significant difference between the aroma of the fresh okra sample (control) (M = 7.45, SD = 1.30) and the fresh-frozen okra sample (M = 5.35, SD = 1.60) ($t_{(20)}$ = 5.30, p < 0.00), and the size of the effect was near to moderate (eta sq.= .43). There was also a statistically significant difference between the aroma of the fresh okra sample (control) (M = 7.45, SD = 1.30) and the aroma of the dried fresh okra sample (M = 4.10, SD = 1.21) ($t_{(20)}$ = 11.45, p < 0.00), and the effect size was large (eta sq.= .78). The judges' ratings of the aromas of the fresh-frozen and sun-dried samples as being quite different from the aroma of the fresh okra sample can be attributed to the undesirable effects of freezing and sun-drying on the two preserved samples [25,26].

3.3. Evaluation of Taste of Fresh Versus Preserved Okra Samples

The paired-sample t-test results shown in Table 3 indicate a statistically significant difference between the taste of the fresh okra sample (M = 7.30, SD = 1.56) and the taste of the fresh-frozen okra sample (M = 5.80, SD = 1.70) ($t_{(20)}$ = 3.94, p < 0.00). There was also a statistically significant difference between the taste of the fresh okra sample and the taste of the sun-dried okra sample (M =3.70, SD = 1.34) ($t_{(20)}$ = 9.31, p < 0.00). The **e**ta squared values (.28 and .70**)** indicate small effect size in taste for the fresh-frozen and moderate effect size in taste for the sundried okra samples, respectively. The results showed that there was no significant difference between the taste of the fresh okra sample (M = 7.30, SD = 1.56) and the taste of the blanched-and-frozen okra sample (M = 7.02, SD = 1.87) ($t_{(20)}$ = 1.32, p < 0.20). Food taste components (sweet, sour, bitter, salty, umami, and fat) arise from chemical compounds associated with specific macronutrients in foods [30]. However, these chemical compounds can be diminished or lost by some preservation methods [25,26]. Blanching and freezing might have contributed to the retention of macronutrients in the blanched-and-frozen okra sample, making its taste comparable to that of the fresh okra sample. It could be concluded that freezing (without blanching) or drying might have adversely affected the taste of the other two treated samples, resulting in diminished desirable taste sensation compounds or the development of unpleasant taste sensation chemicals [24,25].

Table 1. Comparison of Color of Fresh Versus Preserved Okra Samples

Okra Sample	Fresh Okra		Preserved Okra		t-Test			95% CI	
	Mean	SD	Mean	SD	Score	p	Eta sq.	Lower	Upper
Fresh versus Fresh-frozen	7.90	1.62	5.30	1.34	7.41	0.00	.59	1.87	3.33
Fresh versus Blanched-and-frozen	7.90	1.62	7.00	1.52	1.96	0.06	.06	-0.06	1.86
Fresh versus Dried	7.90	1.62	4.15	1.90	7.55	0.00	0.60	2.71	4.79

Table 2. Comparison of Aroma of Fresh Versus Preserved Okra Samples

Okra Sample	Fresh Okra		Preserved Okra		t-Test			95% CI	
	Mean	SD	Mean	SD	Score	p	Eta sq.	Lower	Upper
Fresh versus Fresh-frozen	7.45	1.30	5.35	1.60	5.30	0.00	.43	1.30	2.93
Fresh versus Blanched-and-frozen	7.45	1.30	6.65	2.41	1.67	0.11	.07	-0.20	1.80
Fresh versus Dried	7.45	1.30	4.10	1.21	11.45	0.00	.78	2.74	3.96

Table 3. Comparison of Taste of Fresh Versus Preserved Okra Samples

Okra Sample	Fresh Okra		Preserved Okra		t-Test			95% CI	
	Mean	SD	Mean	SD	Score	p	Eta sq.	Lower	Upper
Fresh versus Fresh-frozen	7.30	1.56	5.80	1.70	3.94	0.00	.28	0.70	2.30
Fresh versus Blanched-and-frozen	7.30	1.56	7.02	1.87	1.32	0.20	.04	-0.16	0.72
Fresh versus Dried	7.30	1.56	3.70	1.34	9.31	0.00	.70	2.79	4.40

3.4. Evaluation of Texture of Fresh Versus Preserved Okra Samples

Food texture is a physical property arising from the structural constituents of food and is often sensed by touch. Consumers have specific expectations for given food textures [33]**.** Consumer perceptions of diminished food texture are closely related to the disintegration and decomposition of food. Undesirable textures can turn consumers off [33]. The paired-sample t-test results shown in Table 4 indicate that the blanched-and-frozen okra sample had the most acceptable texture (gelatinous) of the preserved sample, with no significant difference in mean value (M = 7.20, SD = 1.51) from the fresh okra sample (control) (M = 7.75, SD = 1.37) ($t_{(20)}$ = 1.99, p < 0.06) as reflected by the small effect of blanching and freezing on the texture (eta sq.= .09. In contrast, there was a statistically significant difference in texture between the fresh okra sample (control) (M = 7.75, SD = 1.37) and the fresh-frozen okra sample (M = 5.95, SD = 1.15) ($t_{(20)}$ = 4.49, p < 0.00), with a small effect size (eta sq. = .35). Similarly, the judges' assessment of the texture of the fresh okra sample (control) (M = 7.75, SD = 1.37) was significantly different from that of the dried okra sample (M = 3.9, SD = .97) ($t_{(20)}$ = 12,08, p < 0.00), and the effect size was large (eta sq. = .90). This finding could be explained by the fact that vegetables such as okra with high moisture contents do not freeze well because their cellulose tends to be broken down by enzymes, which makes the vegetables soft. Freezing causes the formation of ice crystals within food structures, with resulting profound effects on texture. Blanching prior to freezing helps the okra retain its texture [25,26].

3.5. Evaluation of Overall Acceptability of Fresh Versus Preserved Okra Samples

A consumer's preference for and opinion of the acceptability of a given vegetable depends on a combination of sensory attributes (color, aroma, taste, and texture) [30]. The paired-sample t-test results in Table 5 show statistically significant differences between the judges' overall acceptability ratings of the fresh okra (control) (M = 8.00, SD = 1.17) and those of the fresh-frozen okra (M = 5.70, SD = 1.26) ($t_{(20)}$ = 7.07, p < 0.00. The magnitude of the effect of freezing on the overall acceptability of the fresh-frozen okra sample was moderate (eta sq. = .57**).** There was also a statistically significant difference between the overall acceptability of the fresh okra (control) (M =8.00, SD = 1.17) and the dried okra (M = 4.25, SD = 1.29) ($t_{(20)}$ = 10.81, p < 0.00) with a large effect size (eta sq.= .75**).** However, there was no significant difference between the overall acceptability of the fresh okra (control) (M =8.00, SD = 1.17) and that of the blanched-and-frozen okra (M = 7.55, SD = 1.32) ($t_{(20)}$ = 1.44, p < 0.00), as also reflected by the small effect of blanching and freezing on the overall acceptability (eta sq.= .05). The blanched-and-frozen okra sample emerged as the overall preferred preserved sample, with sensory attributes closest to those of fresh okra. The fresh-frozen okra was less preferred than the blanched-and-frozen okra because freezing vegetables without blanching results in the formation of ice crystals that adversely affect sensory attributes. The sun-dried okra sample was the least preferred because sun-drying caused changes in and some loss of micronutrients, resulting in a darkly colored product with less desirable sensory attributes. This finding is consistent with those of previous studies that have shown that consumers typically do not like sun-dried okra [10].

Table 4. Comparison of Texture of Fresh Versus Preserved Okra Samples

Okra Sample	Fresh Okra		Preserved Okra		t-Test			95% CI	
	Mean	SD	Mean	SD	Score	p	Eta sq.	Lower	Upper
Fresh versus Fresh-frozen	7.75	1.37	5.95	1.15	4.49	0.00	.35	0.96	2.64
Fresh versus Blanched-and-frozen	7.75	1.37	7.20	1.51	1.99	0.06	.09	-.03	1.13
Fresh versus Dried	7.75	1.37	3.90	0.97	12.08	0.00	.80	3.18	4.52

Table 5. Comparison of Overall Acceptability of Fresh Versus Preserved Okra Samples

Okra Sample	Fresh Okra		Preserved Okra		t-Test			95% CI	
	Mean	SD	Mean	SD	Score	p	Eta sq.	Lower	Upper
Fresh versus Fresh-frozen	8.00	1.17	5.70	1.26	7.07	0.00	.57	1.62	2.98
Fresh versus Blanched-and-frozen	8.00	1.17	7.55	1.32	1.44	0.17	.05	-0.20	1.10
Fresh versus Dried	8.00	1.17	4.25	1.29	10.81	0.00	.75	3.02	4.48

4. Conclusion

Small-scale preservation of fruits and vegetables such as okra preservation at the household level is vital to achieving food security as food wastage prevents households from obtaining the required diets. The findings of this study indicated that blanched frozen okra sample is non significantly different from the fresh okra sample in terms of sensory attributes and overall acceptability. It is recommended that blanched-freezing is employed to preserve fresh okra at the household level as these preservation techniques retain most of the sensory attributes of the fresh okra. This study has improved our understanding of what kind of preserved okra product consumers would prefer and consume.

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Pollution and climate change impacts on livelihood outcomes of lagoon fishermen in Central Region, Ghana

Moses Kwadzo [a,*], Michael K. Miyittah [b,*], Delali B.K. Dovie [c,*], Richard K. Kosivi [d], Rebecca Owusu [a]

[a] Department of Agricultural Economics and Extension, University of Cape Coast, Ghana
[b] Department of Environmental Sciences, University of Cape Coast, Ghana
[c] Regional Institute for Population Studies, University of Ghana, Legon, Ghana
[d] Moree Senior High Technical School, Cape Coast, Ghana

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ABSTRACT

Although the concurrent impacts of pollution and climate change on livelihoods of fishermen are well established, the mechanics within the livelihoods are less known. To understand the mechanics, this paper evaluates the responses of fishermen on the impact of pollution and climate change on livelihoods, using field surveys of 124 fishermen. The result indicated that plastic and domestic wastes are the major lagoon pollutants identified by the respondents. Also, almost all the respondents noted that climate change and lagoon pollution impact negatively on the lagoon which subsequently affect their fishing activities. The fishermen reported difficulty in meeting basic livelihood essentials including feeding their family, paying of their children school expenses, paying of hospital and utility bills. The analysis of logistic model indicated that the likelihood of fishermen landing a high volume of fish catch was statistically significantly influenced by the number of days of fishing in a week, lagoon water temperature, other jobs and formal education. Considering the fact that the main factors impacting on fishing activities are extrinsic without controls of the fishermen, there is need for policy makers within the Cape Coast Metropolis to address drainage systems that feed pollutants into the lagoon.

1. Introduction

The most productive ecosystems in the world are coastal lagoons. They support essential fisheries and also maintain intensive and extensive aquaculture exploitations. Lagoons are highly productive due to their relative shallowness, isolation and protection from the sea, and presence of boundaries with a formidable physical and ecological gradient (Perez-Ruzafa and Marcos, 2012). Ghana has a marine coastline of nearly 550 km and a total continental shelf area of about 24,000 km^2 that support a marine fishing industry (Armah and Amlalo, 1998a, 1998b). There are over 90 coastal lagoons along the coastline of Ghana contributing to the overall productivity of coastal waters by supporting a diversity of habitats, including salt marshes, sea grasses, and mangroves (Aggrey-Fynn et al., 2011; Bertness, 2007)). These habitats are essential for many fish and shellfish species (Bertness, 2007). Lagoons also provide employment opportunities for the surrounding communities. Most indigenous dwellers along lagoons are engaged in fishery and farming activities. The Food and Agriculture Organization (FAO) in 2016 reported that water bodies including rivers, lagoons and lakes form the basis of a strong inland fisheries industry that covers about 10% of Ghana's land surface (FAO, 2016). The total captured fisheries production from the marine and inland (freshwater) sectors and coastal lagoons in Ghana was about 29,8000 tons in 2013 of which 24% (900.00 tons) come from inland fisheries. The fishery sector of Ghana provides full-time employment for 10% of the country's population, and 80% of fishermen are employed in the small-scale fishery sector (Nunoo and Asiedu, 2013a, 2013b). According to Belhabib et al. (2015), the small-scale fishery sector contributes 3% to the GDP and generates a revenue of $341 million annually (Belhabib et al., 2015).

Although fishing plays a major role in the sustainable livelihoods and poverty reduction of several households and communities in Ghana, the sector has been recording decreasing productivity over the past couple of years (GSS, 2019). This may be attributed to improper management of coastal lagoons which has led to the degradation of its habitat and food

* Corresponding authors.
E-mail addresses: moses.kwadzo@ucc.edu.gh (M. Kwadzo), m-miyittah@ucc.edu.gh (M.K. Miyittah), dbdovie@ug.edu.gh (D.B.K. Dovie), rebecca.owusu@ucc.edu.gh (R. Owusu).

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supply. This is evidenced from the decreasing contribution of fisheries to the national GDP. The Ghana Statistical Service (GSS) recent estimates for the fishery sector showed a GDP growth rate of −6.8% in 2018 from a growth rate of −1.4% in 2017 (GSS, 2019). The fishing sector contribution to the national GDP also decreased from 1.2% in 2017 to 1.0% in 2018 (GSS, 2019). Persistent decline in fishery sector productivity in Ghana results in diminishing economic returns to fishermen. This situation accounts for poverty among small-scale fisheries worldwide especially in developing countries including Ghana (Bene and Friend, 2011). Over the last decades, the decline in the global volume of fish catch by small scale fishermen has been dramatic. According to FAO (2014), global marine fishery catches increased fairly steadily to 86 million tons in 1996, and then stagnated and declined to 77 million tons in 2010 (FAO, 2014). A study of the fishing industry in Ghana also reveals that production from marine fisheries declined 17% between 2000 and 2013 (Coastal Resources Center, 2013; Nunoo and Asiedu, 2013a, 2013b). Overfishing and the use of unapproved fishing equipment and methods are reported to contribute to the declining marine fish stock in Ghana. In order to reverse the situation and ensure more breeding to replenish the declining fish stocks, the Government of Ghana has put in place regulatory mechanisms including a seasonal fishery closure (Adom et al., 2019; USAID, 2016). The seasonal fishery closure for artisanal fishers is observed from July 1 to July 31 while the closures for industrial fishers are from July 1, 2021 to August 31. In addition, the size of fishing nets has been specified to avoid the harvesting of juvenile fish. However, it has been reported that the enforcement of these fishery management measures has been weak, and noncompliance is common (Adom et al., 2019; USAID, 2016).

While many factors contribute to the declining fish stock trend, pollution and climate change are paramount in the case of lagoon fishing in Ghana (Armah et al., 2012; Eshun, 2011; Jia et al., 2017). Research has shown that lagoons are highly fragile and vulnerable to pollution and climate change (Boateng et al., 2020). Lagoons in Ghana suffer heavy land pollution, which weaken their capacity to provide natural services and ability to adapt to climate change (Coastal Resources Center, 2010). The sources of this pollution are anthropogenic. The Korle and Fosu lagoons are two lagoons in Ghana noted to have water bodies with dead zones (Bentum et al., 2011). Since 1993, various studies have shown that Fosu Lagoon was polluted and continues to be polluted with sediments, heavy metals and refuge from the surrounding settlements and drainage system from the city (Armah et al., 2012). These studies have found high concentrations of minerals and waste, including iron, sulfate, phosphate, dissolved organic matter, nitrate-nitrogen, nitrite-nitrogen chloride, and ammonium-nitrogen, in these lagoons as compared with the waste characteristics and leachate amounts in various types of landfills (Bentum et al., 2011). It has been reported that the aerobic decomposition of the refuse and the metallic ions have led to a reduction of dissolved oxygen in lagoon water that frequently leads to the killing of fish in the lagoon (Floodplain, 2003). Studies by Bentum et al. (2011) have observed that a higher level of cadmium in the lagoon has led to the decline of blackchin tilapia and a reduction in their sizes, and a laboratory analysis of water, sediments and fish samples collected from Fosu Lagoon have confirmed the anthropogenic sources of heavy metals pollution.

To further investigate the impacts of pollution, Armah et al. (2012) analyzed macro-benthic fauna in Fosu Lagoon to determine the ecological health status of the lagoon. The result shows that Fosu Lagoon supported more pollution tolerant species such as tilapia than the Benya Lagoon, indicating various level of anthropogenic sources of pollution (Armah et al., 2012). The sources of pollution in Fosu Lagoon vary widely and range from domestic sewage, industrial effluents, and solid waste to agricultural waste. Pollutants from schools, the district hospital, mechanical garages and spraying shops are discharged into Fosu Lagoon and contaminate the sediments of the lagoon with heavy metal (Armah et al., 2012; Bentum et al., 2011). The concentration of heavy metal in water bodies has affected the size of fishes and other aquatic species found in the contaminated water bodies. (Jia et al., 2017). High eutrophication levels of the lagoon may also result in shallowness, which predisposes it to climatic factors such as flooding and an increase in water temperatures (Boateng, 2012).

The above studies have shown the impact of pollution on Fosu Lagoon; however, the impact of climate change is also taking place concurrently. Inhabitants of the coastal communities engage in a variety of livelihoods that are impacted negatively by climate change and threaten their sustenance (Boateng et al., 2016). Changes in climatic variables such as temperature and wind frequency are a serious threat, as they can modify the primary productivity in coastal lagoons, the structure of the food web, and finally the exploitable resources of the lagoons. Agyapong (2008) noted that a large portion of the lagoon sometimes dries up during the dry season and this situation has led to the dying of fish species. Since lagoon fishing and other socioeconomic activities are directly or indirectly dependent on resources of the lagoons (Boateng et al., 2016), the traditional custodians of the Oguaa area have instituted a seasonal fishery closure that is strictly observed to ensure the sustainability of Fosu Lagoon (Wikipedia, 2021). Many small-scale fishermen have been documented to be poor in Ghana (Belhabib et al., 2015; Bene and Friend, 2011). Despite the increasing threats of pollution and climate change on lagoon fisheries, previous studies have insufficiently addressed the potential threat of pollution and climate change on lagoon fishery and livelihood outcomes. In this study, lagoon pollution and climate change have been identified as critical components in analyzing the livelihood outcomes of fishermen. Our specific objectives are twofold: (1) to assess the impacts of pollution and climate change on fishery activities; and (2) to determine the factors influencing the volume of fish catch, which indirectly influences the above outcomes.

2. Materials and method

2.1. Study area

The study was conducted among the fishermen residents in communities surrounding the Fosu Lagoon. These communities, which were located at the Cape Coast Metropolis in the Central Region of Ghana, included Bakano, Siwdu, Esikafoambantem, Antem village and Zongo of (Fig. 1). The Metropolis is bounded to the South by the Gulf of Guinea, to the West by the Komenda Edina Eguafo Abrem municipality, to the East by the Abura Asebu Kwamankese district, and to the North by the Twifu Heman Lower Denkyira district (Adjei et al., 2017; Armah and Amlalo, 1998a, 1998b). The Metropolis occupies an area of 122 km2 and includes valleys with various streams between the hills. The small streams end in wetlands and the largest stream, Kakum, drains its waters into the Fosu Lagoon at Bakano, a suburb of Cape Coast (Adjei et al., 2017; Armah and Amlalo, 1998a, 1998b). The people in the Fosu Lagoon vicinity are mostly fishermen who fish along the lagoon. Currently the lagoon is surrounded by residential, commercial and industrial settlements. Notable among these settlements are the Siwdu automobile mechanical workshops, the Metro Mass Transport Terminal, the Metropolitan hospital at Ola, St. Augustine's College and the Adisadel estates. Fosu Lagoon was chosen for this study because it was recently added to the list of water bodies with dead zones, raising concerns for the people who depend on it for their sustenance and livelihood (Armah et al., 2012; Bentum et al., 2011).

2.2. Data collection

A cross-sectional survey was used in this study to understand the effects of pollution and climate change on lagoons and their implications for the socio-economic status (livelihood outcome) of fishermen. This study used a formal questionnaire to collect information on variables relating to lagoon pollution, climate change and fishermen's socioeconomic characteristics. The questionnaires were administered to all the small-scale fishermen who fished in Fosu Lagoon during the period of

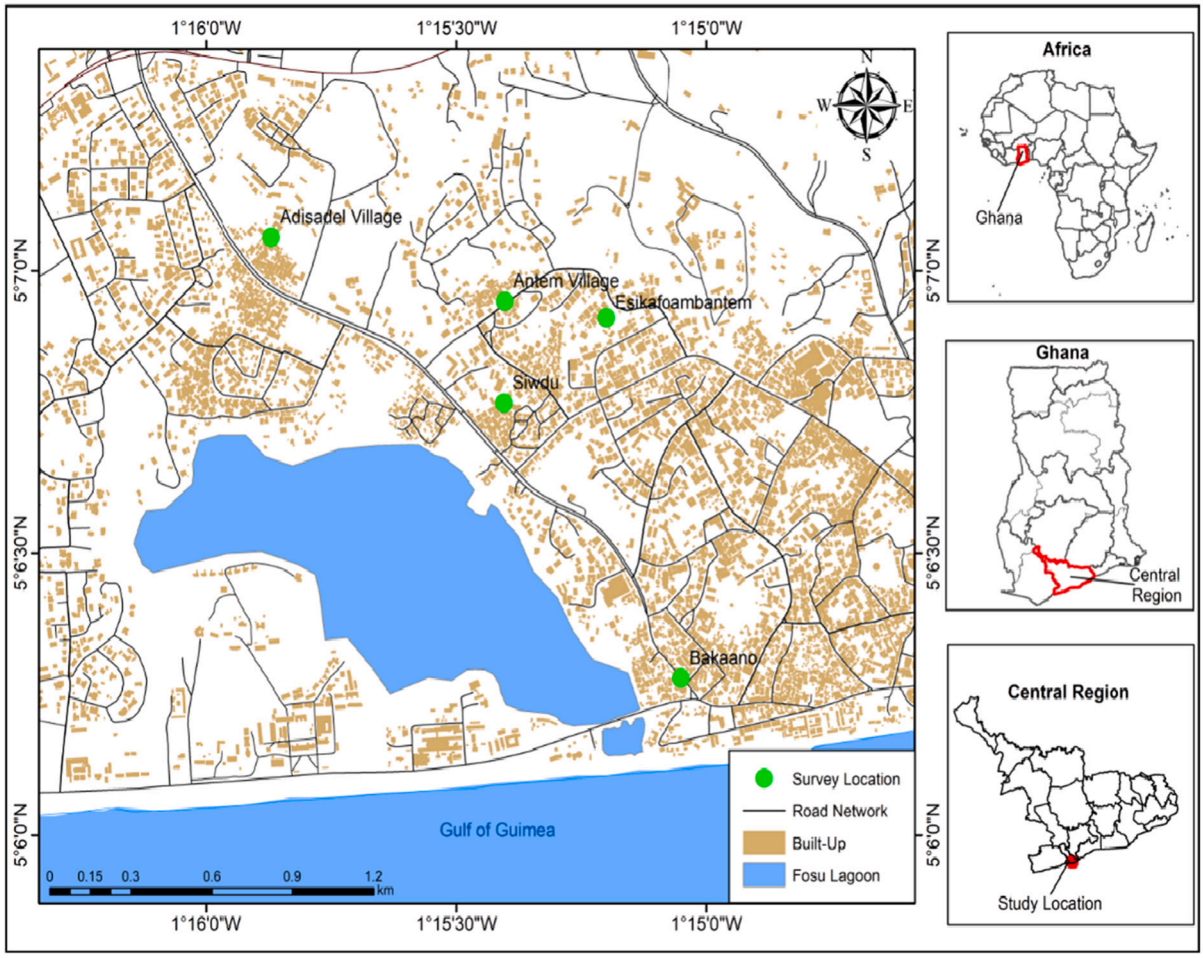

Fig. 1. A map of Fosu lagoon; Source: Adjei et al. (2017).

September 15 to October 4, 2019. Approximately 140 of these fishermen were reported to belong to the Fosu Lagoon Fishermen Association, and 124 out of the 140 responded to the questionnaire. The remaining 16 fishermen were not available during the period of the data collection.

2.3. Data analysis and model specification

In order to determine the effect of lagoon pollution and climate change on the livelihood outcome of fishermen, descriptive statistics and a logistic model were analyzed using Stata version 12. A logistic regression is the appropriate test when a researcher wants to predict the outcome of a categorical dependent variable from a number of predictor (independent) variables.

3. Results

3.1. Respondents' socioeconomic characteristics

The socioeconomic characteristics of the fishermen are presented in Table 1. All the respondents were males, and their mean age was 44.8 years. Response categories to educational attainment were "no formal education," "primary," "middle/junior high," "senior high," and "tertiary." In this study, respondents with only primary education were merged into the "no formal" education category because almost all them reported not completing primary school. The majority (79.8%) of the respondents reported having formal education (mainly up to Junior High JHS/Middle School) while the rest (20.2%) reported having no formal education. Generally, the study respondents were found to have

Table 1
Socio-demographic characteristics of surveyed fishermen.

Variables	Frequency	Percentage
Age (years)		
Mean	44.8	
Gender		
Male	124.0	100.0
Education		
No formal education	25.0	20.2
Formal education	99.0	79.8
Any occupation other than fishing		
Yes	39.0	31.5
No	85.0	68.5
Number of days fishing a week		
Minimum of 2 days	8	6.5
Maximum of 6 days	19	15.3
Mode (5 days)	44	35.5
Mean (4.4 days)	34	
Number of years fishing		
Mean	17.2	
Income from fishing per month (GH cedis)		
Mean	288.2	
Volume fish catch per week\		
Less than 7 local basins catch per week	99.0	79.8
Mean	5.2	

GH cedis of 288.15 is equivalent to US$49.94 at the existing prevailing exchange rate.
Local plastic basin has a capacity of 17 l.
Source: Field survey, 2019.

17.2 years of fishing experience and engaged in fishing activities 4.4 days per week on average. Approximately 6.4% of respondents reported fishing 2 days per week, while 15.3% reported 3 days per week, 27.4% reported 4 days per week, 35.5% reported 5 days per week, and 15.3 reported 6 days per week (data not shown). The average income per month from fishing gained by these fishermen was 288.2 Ghana cedis (52.4 US dollars). About 31.5% of the respondents reported engaging in other jobs to supplement income from their fishing activities in order to meet basic needs of their families. The quantity of fish catch by the respondents was measured using a local plastic basin with a capacity of 17 l. Usually, a quantity ranging from 1 basin to 6 basins per week is considered a low volume of fish catch, while a catch of 7 basins and above is considered a high volume of fish catch. The descriptive statistics of the volume of fish catch by the fishermen show a mean volume of 5.2 local basins. About 79.8% of the respondents were found to land a low volume of fish catch.

3.2. Pollution and types of pollutants in Fosu lagoon

The types of pollutants in the lagoon varied widely. About 78% of the respondents perceived that Fosu Lagoon is polluted and that the state of pollution was of great concern to them. The main types of pollutant identified by the respondents were plastic waste (48.4%), domestic waste (48.4%), and commercial waste (3.2%) (Fig. 2).

3.3. Distribution of fish species in the Fosu lagoon

Different types of fish species exist in lagoons. When the respondents were asked about the distribution of fish species in the Fosu Lagoon, tilapia, catfish, crab, and shrimps were identified as the major species. Of these, the tilapia species were the most dominant, followed by catfish. The respondents reported that catfish and crab had reduced in quantity in recent years, while aquatic species such as shrimps have become extinct due to lagoon pollution and climate change (Table 2).

3.4. Farmers' perceptions of the effects of pollution on fishing activities

Pollution impacts negatively on lagoons which subsequently affects fishing activities. The perception of fishermen about the effects of lagoon pollution on fishing activities was sought on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). 77.8% of the respondents strongly agreed and 22.2% agreed that there has been a decline in water quality due to pollution as a result of anthropogenic activities of the surrounding communities. When the fishermen were asked about their perceptions of the effect of pollution on fishing activities, the majority (82.3%) agreed that pollution was contributing to fish extinction (Table 3). Most of the fishermen (67.7%) strongly agreed and 32.3% agreed that there has been a decrease in fish catch due to lagoon pollution. However, only 32% strongly agreed, while 62.0% agreed, that there has been low fish quality (lack of brightness of the fish body, eyes and gills) due to lagoon pollution. At the same time, the majority of fishermen (68.4%) strongly agreed that there has been decrease in the price of fish due to low fish quality. 44.3% of the fishermen responded that there has been a decrease in consumer interest in the fish caught in the lagoon due to low fish quality. Finally, a large majority of the fishermen (81.6%) agreed that there has been damage to their fishing gear due to deposits of metallic and wooden objects in the lagoon (Table 3).

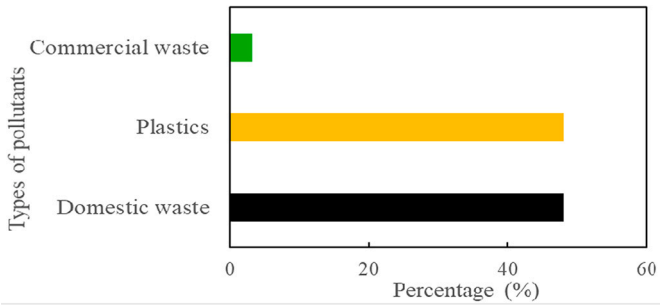

Fig. 2. Percent distribution of major pollutants in Fosu lagoon. Source: Field survey, 2019.

Table 2
Fishermen's perceptions of the distribution of fish species in Fosu Lagoon.

Description of Fish Species	Frequency	Percent
Common Fish Caught		
Cat fish	14	11.3
Tilapia	110	88.7
Fish Species Decreased Over the Past Five Years		
Cat fish	48	38.7
Crab	76	61.3
Fish Species Extinct Over the Past Five Years		
Shrimp	124	100.0

Source: Field survey, 2019.

Table 3
Fishermen's perceived effects of lagoon pollution on fishing activities.

Various fishing activities	5	4	3	2	1	Mean perceived effect on Likert scale of 1–5
Poor water quality	77.8	22.2				4.22
Extinction of fish	7.0	82.3	9.5	1.3		3.94
Decrease in fish catch	67.7	32.3				4.67
Shallowness of water	5.7	63.3	22.8	8.2		3.66
Low fish quality	38.0	62.0				4.37
Decrease in price of fish	68.4	31.6				4.68
Consumer interest in fish	3.2	44.3	10.1	34.8	7.6	3.00
Damage to fishing gear	18.4	81.6				4.18

Key: 5 = Strongly agree, 4 = Agree, 3 = Don't know, 2 = Disagree, 1 = Strongly disagree.
Source: Field survey, 2019.

3.5. Climatic factors influencing Fosu lagoon

Fosu Lagoon like any other aquatic habitat is influenced by different climatic factors. Table 4 shows the climatic factors of the lagoon over the last five years, as perceived by the respondents. These factors include water level, wind frequency, and water temperature. About 98.4% of the respondents indicated that the lagoon water level over the past five years has decreased, while 1.6% maintained that it has remained unchanged. Similarly, 62.9% of the respondents indicated an increase in

Table 4
Fishermen's perceived changes in climatic factors over the last five years.

Changes in Climatic Factors	Frequency	Percent
Lagoon Water Level		
Decreasing	122	98.4
Not Changing	2	1.6
Wind Frequency		
Increasing	78	62.9
Not Changing	9	7.3
Decreasing	37	29.8
Lagoon Water Temperature		
Increasing	59	47.6
Not Changing	13	10.5
Decreasing	52	41.9

Source: Field survey, 2019.

wind frequency, 7.3% reported no change, and 29.8% indicated a decrease in wind frequency. With respect to water temperature, 47.7% of the respondents indicated an increase, 41.9% indicated a decrease, while 10.5% indicated no change in the water temperature (Table 4)

3.6. Farmers' perceptions of climate change effects on fishing activities

Fishing activities in Fosu Lagoon have been greatly affected by climate change. Table 5 shows the perception of the respondents regarding the effects of climate change on the volume of fish catch and the amount of time spent fishing. The effects stem from perceived changes in lagoon water level, wind frequency, and lagoon water temperature. With respect to lagoon water level, almost all (98.4%) the respondents indicated a decrease in their volume of fish catch owing to changes in water levels. With regards to the time spent fishing, 87.9%, 12.1% and 0.0% indicated an increase, no change, and a decrease, respectively. Regarding wind frequency, 2.4% of the respondents thought there was an increase in their volume of fish catch due to changes in wind frequency, while 1.6% indicated no change, and 96.0% indicated a decrease in the volume of fish catch. Finally, with regard to the effects of increased water temperature, the majority of fishermen (49.0%) reported a decrease in the catch of catfish, while 46% indicated an increase in the tilapia fish catch (Table 5).

3.7. Perceived effect of fishing activities on fishermen's livelihood outcome

Fishermen's perception of their ability to meet basic needs of livelihood, including paying for children's school expenses, feeding the family, paying utility bills, purchasing fishing equipment, and paying hospital bills were assessed on a five-point Likert scale ranging from 1 (very difficult) to 5 (very easy). Table 6 shows how fishermen perceived their fishing activities affected their livelihood. It was observed that 48.1% of the respondents believe that fishing activities are no longer sufficient to allow them to pay their children's school related expenses, whereas 32.3% consider themselves moderately able to pay for these expenses. The majority (82.9%) of the respondents reported their ability to feed their family as moderate, while 44.9% found it difficult and the same percentage found it very difficult to pay their utility bills. Similarly, most (60.8%) of the fishermen found it very difficult to purchase fishing equipment. On the issue of paying hospital bills, a slight majority (53.2%) found it difficult to pay these bills.

3.8. Estimation of factors influencing the volume of fish catch

A logistic regression model was estimated to assess the effects of the predictor variables on the dependent variable.

Table 5
Fishermen's perceptions of climate change effects on fishing activities.

Perceived Effect	Increased (%)	No Change (%)	Decreased (%)
Lagoon Water Level			
Volume of fish catch	0.0	1.6	98.4
Time spent fishing	87.9	12.1	0.0
Wind Frequency			
Volume of fish catch	2.4	1.6	96.0
Time spent on fishing	91.1	8.1	0.8
Lagoon Water Temperature			
Volume of fish catch (tilapia)	46.0	23.0	31,0
Volume of fish catch (catfish fish)	37.0	14.0	49.0
Time spent fishing	91.1	5.6	3.2

Source: Field survey, 2019.

Table 6
Perceived effect of fishing activities on fishermen's livelihood outcomes.

Livelihood outcomes	5	4	3	2	1	Livelihood outcome (mean)
Paying child school expenses	–	–	32.3	19.6	48.1	1.84
Feeding the family	–	–	82.9	7.6	9.5	2.73
Paying utility bills	–	–	10.1	44.9	44.9	1.65
Purchasing fishing equipment	–	–	5.1	34.2	60.8	1.44
Paying hospital bills	–	–	7.0	53.2	39.9	1.67

Key: Likert Scale: 5 = Very Easy, 4 = Easy, 3 = Moderate, 2 = Difficult, 1 = Very Difficult.
Source: Field survey, 2019.

3.9. Dependent variable

The fish obtained from fishing activities is often utilized in two ways. Some of the fish caught by the fisherman is directly used to prepare food for the family, whereas the rest is sold for cash to pay for other household needs. This suggests that a high volume of fish catch would make it easier for the fishermen to cover their basic household livelihood needs. In this study, the dependent variable is the volume of fish catch. It is operationalized as the probability of a fisherman landing a high volume (7 or more local basins) of fish catch per week. The respondents were scored 1 for a high volume of fish catch; otherwise, they were scored 0. Data analysis indicated that only 25 fishermen (20.2%) reported landing a high volume of fish.

3.10. Predictor variables

A review of the literature on the volume of fish catch by small scale fishermen indicates that this volume is influenced by socio-demographic characteristics (e.g., age, gender, education, occupation other than fishing, number of days fishing per week, number of years fishing); changes in climate conditions (lagoon water level, wind frequency, and lagoon water temperature); and pollution as indicated by several factors (e.g., depth of lagoon water, poor water quality, extinction of fish and low fish quality) (Bene and Friend, 2011; Boateng et al., 2020; Seggel et al., 2016; Woodford, 2017). In this study, all the predicted variables were not included in the final logistic regression due to a lack of model fitness. For socio-demographic factors, we also included dummy variables to indicate whether the fishermen engaged in other secondary occupations to supplement their main source of income. We included variables of formal educational, number of days of fishing per week, and years of fishing. A dummy variable was set up for educational attainment; those with formal education were recoded 1 and those with no formal education were recoded 0. The number of days of fishing per week and the number of years fishing (a proxy for fishing experience) were continuous variables. Changes in climate factors, depth of lagoon water, and lagoon water temperature were included in the model, while non-shallow water level was the only pollution variable considered.

Table 7
Correlation matrixes of independent variables.

Independent Variables	1	2	3	4	5	6
1. Years of fishing	1.00					
2. No. of days fishing per week	0.29	1.00				
3. Formal Education	0.06	0.26	1.000			
4. Other jobs	0.11	0.42	0.29	1.000		
5. Depth of lagoon water	0.02	0.15	0.13	0.10	1.000	
6. Lagoon water temperature	0.05	0.33	0.25	0.24	0.66	1.000

3.11. Preliminary regression diagnostic

Bivariate correlation matrixes of the predictor variables were analyzed to determine the presence of multicollinearity in the regression model. Majority (80%) of the correlations are less than or very close to 0.2 (Table 7). The correlations suggest general weak associations among the predictor variables. These weak correlations suggest the absence of multicollinearity in the regression models.

3.12. Logistic model

A direct logistic regression was performed to assess the effects of the six predictor variables on the likelihood that respondents would report landing a large volume of fish. The full model, Logit(P) = In(P/1-P) = βo + $\beta 1_{X1}$ + $\beta 2_{X2}$ + $\beta 3_{X3}$ + $\beta 4_{X4}$+ $\beta 5_{X5}$ + $\beta 6_{X6}$,

containing all six predictors showing the likelihood ratio chi-square and with p-value, $\chi 2\ (5, N = 124) = 32.17, p < 0.000$, indicates that this model as a whole is statistically significant (Table 8). Thus, the model fits significantly better than a model with no predictors. The Hosmer and Lemeshow post-test value of $p < 0.8329$ greater 0.05 confirmed the overall fitness of the model. The model as a whole explained 26% (Pseudo R squared = 0.2581) of the variance in the fishermen's volume of fish status, and correctly classified 83.87% of respondents who reported landing high and low volumes of fish (Hosmer and Lemeshow, 2010; Pallant, 2016; Woodford, 2017). As shown in Table 8, four of the independent variables (formal educational, number of days of fishing, years of fishing, other jobs, depth of lagoon water, and lagoon water temperature) made a statistically significant contribution to the model. The results indicate that the odds (likelihood) of a fisherman landing a high volume of fish increases 3.58 times (controlling for all the other variables) with each additional day of fishing per week. The odds ratio of 8.34 indicates that respondents who had formal education are over 8 times more likely to report landing a high volume of fish than those with no formal education. This confirms previous studies showing that socio-demographic factors such as age, working experience, income, household size, and education status influence adaptation practices and livelihood outcomes (Bene and Friend, 2011; Boateng, 2012). Similarly, the odds ratio of 3.90 for other jobs (controlling for all the other variables) indicates that respondents engaged in other jobs are 3 times more likely to land a high volume of fish. This suggests that fishermen who engage in subsidiary work have more income for purchasing new fishing equipment to replace their worn-out equipment. With respect to fishing conditions, lagoon water temperature was positive and significant. Changes in temperature have been found to positively and significantly influence the volume of fish catch (Boateng, 2012). Generally, fish such as tilapia thrive in high water temperatures, while catfish thrive in low water temperatures.

4. Discussions and conclusion

Lagoon fisheries are a major source of livelihood for majority of vulnerable individuals and communities. Nevertheless, pollution and climate change pose threats to fisheries along the lagoon ecosystem. The potential threats of these anthropogenic effects are noted to cause disruption of lagoon fish stock and distribution which can negatively impact the livelihood of fishers and their families. In the empirical analysis of data collected from fishers along the Fosu lagoon, majority (78.0%) of the respondents reported that the Fosu lagoon is polluted and the state of the pollution was worrisome. Whereas domestic and plastic waste formed about 96% of the pollution, commercial waste contributed to only 4% (Fig. 2). Bentum et al. (2011) has documented that the wide size of metropolitan drain entering the lagoon and the open refuse disposal practices in the community are the major causes of high volumes of plastic waste in the Fosu lagoon. On examining the perception of fishermen regarding the effects of pollution and climate change on fishing activities on their livelihood, it was evidently clear that fishing could not sufficiently support their livelihood. In ranking the perceived effects in a decreasing order, most of the fishermen found it difficult to feed their family, followed by paying of their children related school expenses, paying of hospital bills, paying of utility bills and purchasing of fishing equipment being the least due to the effect of fishing activities on their livelihood (Table 6). Reports from Armah et al. (2012) and Essel et al. (2019) highlighted the severity of fishermen plight around the Fosu lagoon (Armah et al., 2012; Baffour-Awuah, 2014).

Fishermen's livelihood outcome is directly linked to the volume of fish catch since fish caught by the fisherman is often used for direct household consumption and the rest of the unconsumed fish is sold to pay for other household expenses. Analysis of the logistic model indicated that volume of fish caught by fishermen was mainly influenced by their formal education attainment, number of days of fishing, other jobs and lagoon water temperature (Table 8). About 98.4% of the respondents reported that the lagoon water level decreased over a period of five years (Table 4). The lagoon has experienced wide fluctuations in water level and sometimes near drying up, especially in the dry seasons (Essel et al., 2019). Thus, buttressing the impact of climate change on the Fosu lagoon, it also supports the reason why fish catch volume decreased significantly (Table 5). Essel et al. (2019) have reported that the volume of fish catch is directly related to climate change, which is in agreement with findings from Baffour-Awuah (2014).

Low fish quality and price were among other effects perceived by the fishermen as issues of concern due to pollution. The study revealed that many fishermen (68.4%) perceived the decrease in price of fish as the major effect of lagoon pollution. Armah et al. (2012) noted that the lagoon had been polluted and that the quality of fingerlings for sale on the market has significantly reduced (Armah et al., 2012). The respondent's average income per month from fishing is GH₵ 288.14 (which is equivalent to $49.94 at existing prevailing exchange rate). On the other hand, Baffour-Awuah (2014) reported that the average monthly income for most Fosu lagoon fishermen is GH₵84.42 (equivalent to $26.26 at that time) (Armah et al., 2012). Due to the fishermen's low level of income, about 31.5% are reported to be engaged in other jobs to supplement their fishing activities to meet basic family needs

Table 8
Logistic regression model estimating factors influencing volume of fish catch.

Variables	Odds Ratio	Std. Err.	z	P > |z|	[95% Conf.	Interval
Years of fishing	1.011527	0.0281327	0.41	0.680	0.9578633	1.068196
No. of days fishing per week	3.582553	1.367544	3.34	0.001**	1.695388	7.570354
Formal Education	8.33967	5.990482	2.95	0.003**	2.040426	34.08606
Other jobs	3.894704	2.48757	2.13	0.003**	1.113799	13.6189
Depth of lagoon water	2.723981	1.491964	1.83	0.067	0.9310836	7.969287
Lagoon water temperature	3.625541	2.05895	2.27	0.023*	1.191171	11.03498
cons	0.0000249	2.05895	−4.52	0.000	2.52e-07	0.002461

chi-square ($\chi 2$) = 32.17, p < 0.000; model correctly classified 83.87% of cases.
Pseudo R squared = 0.2581; Hosmer and Lemeshow test = ($p > 0.8329$).
*Indicates statistically significant level *$p < 0.05$; ** $p < 0.01$.
Source: Field survey, 2019.

(Table 1).

The traditional custodians of Oguaa traditional area with the support of the Fosu lagoon fishermen association over the years have banned fishing in the Fosu lagoon for 4 weeks, from July 1 to July 31, every year prior to their celebration of the Fetu-Afahye festival and the ban is to allow for spawning in fish to increase fish stock in the lagoon (Wikipedia, 2021). In addition, fishing in the lagoon is not allowed on Tuesdays. The executives of the Fosu Lagoon fishermen Association inform the authors that members (fishermen) are not allowed to use unapproved fishing method or equipment such including nets with inappropriate size that could comprise the population of the fingerings (personal communication, September, 2019). The findings of this study seem to suggest that the sustainability of the lagoon ecosystem and fishermen livelihood are threaten by the lagoon pollution and occurrence of climate, which are induced by human activities. Nevertheless, these continue to receive little policy attention. The implication is that external factors are having impacts on their livelihood and resulting in their inability to meet basic household essentials. It becomes necessary that policy makers within the Cape Coast Metropolis address drainage systems that feed pollutants into the lagoon.

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Declaration of Competing Interest

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

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REGIONAL PRODUCTIVITY DIFFERENTIAL AND TECHNOLOGY GAP IN AFRICAN AGRICULTURE: A STOCHASTIC METAFRONTIER APPROACH

Rebecca Owusu
University of Cape Coast, Department of Agricultural Economics and Extension, Ghana, Email: rebecca.owusu @ucc.edu.gh
ORCID: 0000-0003-0683-0278

Moses Kwadzo
University of Cape Coast, Department of Agricultural Economics and Extension, Ghana, ORCID: 0000-0003-4397-0210

William Ghartey
University of Cape Coast, Department of Agricultural Economics and Extension, Ghana, ORCID: 0000-0002-6384-1240

Abstract

Higher agricultural productivity in African agriculture is important for achieving the sustainable development goals of no poverty and zero hunger. However, productivity levels in African agriculture are very low and strategies for improving productivity have not produced the desired outcome. Successful productivity improvement strategies are contingent on identifying sources of productivity growth in African agriculture, and devising strategies to increasing productivity. This paper uses recent advances in the stochastic metafrontier literature to decompose efficiency into technical efficiency and technology gap. Generally, the results show an average efficiency of 71%, indicating about 29% shortfall in efficiency in African agriculture. Specifically, the results show that Central African countries are more productive compared to the other regions. The study also showed that improved agricultural technologies lead to productivity increases. The source of inefficiency is attributable to technological inefficiency rather than technical inefficiency because the empirical estimates show that almost all countries are producing close to the regional frontier. Using the bootstrap truncated regression model, factors such as agricultural research & development, trade openness and literacy were determined as having efficiency increasing effects. The study therefore recommends greater investment in agricultural research and development, and more trade openness to reduce the technology gaps and increase overall productivity of African Agriculture.

Keywords: *African agriculture, productivity growth, technology gap, metafrontier, trade*.
JEL Codes: *D24, Q12, Q16.*

1. Introduction

Over the years, agricultural productivity growth has been recognised as key to overall economic development and achieving the sustainable development goals of no poverty and zero hunger in many developing countries, in particular, Africa (World Bank, 2004; Alene, 2010). Improving agricultural productivity has therefore been a common strategy to improving

the poverty status of rural households in Africa. Given rapid productivity gains in technological advances in the Green revolution in Asia, introduction of new technologies was seen as a panacea for agricultural productivity growth in Africa. However, the Green revolution failed to achieve the desired outcome in Africa, as was observed in Asia. Despite its poor outcomes, lots of investments are still being made in African agriculture to improve agricultural productivity. It is therefore important to examine productivity and its drivers to inform evidence-based policies in the second green revolution anticipated in Africa.

Productivity measurement has long been of interest to economists (Ali & Byerlee 1991; Bravo-Uretha & Pinheiro, 1993; Diewert & Lawrence 1999; Thiam et al. 2001). Over the years, economists have examined productivity using production functions with the assumption that all decision-making units (DMUs) use common underlying technology (Alem et al. 2019). However, in reality, the underlying production technology and production possibilities could differ (heterogeneity) because of locational differences and resource endowments (O'Donnell, Rao et al. 2008). Specifically, farms in different locations make choices from different sets of possible input and output combinations. Therefore, estimations based on the homogeneity assumption may result in biased efficiency estimates and consequently, wrong policy conclusions (Orea & Kumbhakar 2004). It is therefore important to account for heterogeneity in productivity measurement.

In the production economics literature, several methods have been proposed to address heterogeneity issues in the production function estimation. While some researchers make use of cluster algorithms to account for heterogeneity, others use latent class or metafrontier models (Alem al. 2019). The cluster algorithm and the latent class models are statistical methods. For instance, the latent class model assumes that a finite number of groups exist in the data and uses statistical algorithm to estimate the production frontier for the underlying groups. The metafrontier, is based on apriori assumption where physical characteristics are employed to segregate the data for separate model estimation. All the methods used to account for heterogeneity have their advantages and disadvantages. However, the metafrontier approach is the common method for examining heterogeneity in the production frontier literature.

The metafrontier defines a boundary of unrestricted technology set that envelops group frontiers and allows one to decompose efficiency into technical efficiency and technology gap ratio. Decomposing efficiency into technical efficiency and technology gap will help policy makers to adopt appropriate strategies to improve agricultural productivity. If the agricultural sector in the various African countries is efficient, then investment in more productive inputs and technology will be an appropriate strategy to improve agricultural productivity. On the other hand, if current input or technology can be used more productively, then the target would be on improving efficiency (Nkamleu, 2006).

The original metafrontier model proposed by Battese and Rao (2002) was based on the meta production function idea of Hayami (1969) and Hayami and Ruttan (1970). Battese et al. (2004) extended the metafrontier model into the stochastic framework. The metafrontier is a two-step estimation process. In the Battese et al. (2004) and O'Donnell et al. (2008) stochastic metafrontier model, the first step estimation is conducted using stochastic frontier methods and the second step uses linear programming (LP) methods. However, researchers have identified potential problems with the application of the LP method to construct the metafrontier. For instance, Huang et al. (2014) postulate that the LP approach leads to biases in the technology gap estimates. The authors therefore proposed a stochastic metafrontier model where the metafrontier itself is estimated as stochastic.

In this paper, a stochastic metafrontier approach is adopted to examine sources of productivity variations in African agriculture. The stochastic metafrontier approach adopted in this paper deviates from the data envelopment approach Nkamleu (2006) adopted in the study of African agriculture, and the bias-corrected data envelopment approach used in the Mugera and Ojede (2013)

study. The approach has the advantage of accounting for noise in both the estimation of the stochastic regional frontiers and the metafrontier.

The data for empirical application come from Food and Agriculture Organisation Statistics database. The data comprise production and input information of 19 African countries for the period 1971-2004. Empirical estimates reveal that many African countries are operating close to the regional frontiers, however, many of the countries are producing far below the industrial agricultural production technology. Overall, there is inefficiency in agricultural production in African agriculture. Further synthesis based on pre, during and post structural adjustment period in Africa show slight improvement in agricultural productivity during and post structural adjustment period.

The rest of the paper is organised as follows. Section 2 presents methods including empirical models and data used in the empirical application. Section 3 presents the results and discussion and finally the paper concludes in Section 4.

2. Methods

This section describes empirical models used in estimating the productivity differentials in African agriculture. Specifically, the section highlights the stochastic frontier and metafrontier theoretical and empirical models. The data for empirical application are also discussed in this section.

2.1 Stochastic Frontier Analysis

The stochastic frontier model incorporates a composed error structure with a two-sided symmetric and a one-sided component (Aigner et al. 1977, Van den Broeck et al. 1994). The one-sided component reflects inefficiency whiles the two-sided one captures the random effects outside the control of the production unit as well as measurement errors and other statistical noise typical of empirical relationships. The stochastic frontier analysis (SFA) is usually specified as:

$$y_{it} = f(x_{1it}, x_{2it}, \dots, x_{nit}; \beta^k) e^{v_{it}^k - u_{it}^k} \quad (1)$$

where v_{it} is the stochastic random term, which is iid with $(0, \sigma_v^2)$ and u_{it} is the technical inefficiency term, which may assume either half-normal, exponential, truncated-normal or gamma distribution (Stevenson, 1990; Aigner et al, 1997;1990; Meeusen & Broeck, 1977). This paper, however, adopts the exponential inefficiency distribution.

The SFA model is usually estimated using either maximum likelihood (MLE) or Bayesian inference methods. Although the MLE methods are commonly applied in the production economics literature (Alem et al. 2019), this paper applies the Bayesian inference approach because of the advantage in generating probability statements about unknown parameters and the ease with which statistical inference can be made. The Bayesian approach is based on Bayes theorem. The application of the Bayesian approach in the stochastic frontier framework was introduced by Van den Broeck et al. (1994). The authors used the posterior model densities and mix of several inefficiency distributions to resolve the uncertainty pertaining to the sampling approach.

2.2 Stochastic Metafrontier

The metafrontier enveloping all group frontiers $f_{i(k)}$ is assumed to have a similar functional form where the function is the same for all groups but a different set of parameters. Specifically, the relationship between metafrontier f_i and the group frontier is formulated as

$$f_{i(k)}(x_{i(k)}, \beta_{(k)}) = f_i(x_{i(k)}, \beta^*) \quad e^{-U_i{}^M} \quad (2)$$

where $U_i^M \geq 0$, implying that $f_i(.) \geq f_{i(k)}(.)$.

The metafrontier in (2) was originally implemented using O'Donnell et al. (2008) linear programming (LP) approach. However, Huang et al. (2014) observed challenges associated with estimating the metafrontier as an LP function. Specifically, the authors raised issues with statistical interpretation of the metafrontier parameter estimates and also the problem that the LP approach does not account for noise in the metafrontier. On the basis of these challenges associated the original metafrontier approach, Huang et al. (2014) proposed the use of stochastic production function approach in the second step estimation to overcome the set challenges. Estimating the metafrontier as stochastic frontier requires a reformulation of (2) as

$$lnf_{i(k)}\left(x_{i(k)}, \beta_{(k)}\right) = lnf_i\left(x_{i(k)}, \beta^*\right) - U_i^M \quad (3)$$

The group frontier is unobservable but its values can be estimated from the first step since the fitted values differ from the true frontier. Hence, (3) can be re-specified as

$$lnf_{i(k)}\left(x_i, \beta_{(k)}\right) = lnf_i(x_i, \beta^*) - U_i^M + V_i^M \quad (4)$$

where V_i^M is the statistical noise denoting deviation between predicted and the true frontier,

$$ln\hat{f}_{i(k)}\left(x_i, \beta_{(k)}\right) = ln\hat{f}_i(x_i, \beta^*) + V_i^M \quad (5)$$

Equation (5) therefore holds resemblance with typical stochastic frontier model and therefore can be estimated as stochastic. This model, which is described as a stochastic metafrontier regression model is usually implemented using maximum likelihood methods.

The efficiency of this actual output against the metafrontier output can be disaggregated into two elements. The first element is the meta-technology ratio (MTR), which is the ratio between the regional production function and the metafrontier. The model of the first element is specified as:

$$MTR_i^k = \frac{f_{i(k)}(x_i, \beta_{(k)})}{f_i(x_i, \beta^*)} = e^{-U_i^M} \leq 1; \quad (6)$$

And the estimated MTR is computed as follows

$$\hat{MTR}_i^k = \hat{E}\left(e^{-U_i^M} | \hat{\varepsilon}_i^M\right) \leq 1 \quad (7)$$

where $\hat{\varepsilon}_i^M = ln\hat{f}^k\left(x_i, \beta_{(k)}\right) - ln\hat{f}^M(x_i, \beta^*)$

The second element is the technical efficiency (TE) as already specified in (2) and the meta-technical efficiency (MTE_i^*), which measures overall technical efficiency of the *i-th* observation relative to the metafrontier. In other words, the MTE compares observed output relative to metafrontier output, adjusted for corresponding random error as specified in (7):

$$MTE_i^* = \frac{Y_{i(k)}}{\boldsymbol{f_i}(x_i, \beta_{(k)})e^{V_i}} = TE_i^k \; x \; MTR_i^k \quad (8)$$

2.3 Model Estimation

Although Cob Douglas functional form is the common production function often applied in empirical literature, the translog functional form is assumed for both the regional and metafrontiers because of its flexibility. The Translog functional form may be specified as:

$$\ln y_i = \beta_o + \sum_{j=1}^{m} \beta_{ij} \ln X_{ij} + \frac{1}{2}\sum_{j=1}^{m}\sum_{k=1}^{n} \beta_{jk} ln\, X_{ij}\, lnX_{ik} + v_{i(k)} - u_{i(k)} \quad (9)$$

where: β is a vector of parameters to be estimated; y is output and x is a vector of inputs; $v_{i(k)}$ is the symmetric noise or error term which might be distributed as half-normal or exponential; and $u_{i(k)}$ is a non-negative inefficiency term.

2.3.1 Regional Frontier Estimation

The regional frontiers were estimated using Bayesian inference approach. The Bayesian

inference approach is based on Bayes theorem, which specifies the posterior probability density function (PDF) as proportional to the product of the likelihood function ($L(y|\beta,\sigma)$) and the prior density function ($p(\beta,\sigma)$). Mathematically, the theorem is specified as $p(\beta,\sigma|y) \propto L(y|\beta,\sigma)\, p(\beta,\sigma)$, where; y is the observed data and $p(\beta,\sigma|y)$ is the PDF. Similar to the maximum likelihood estimation, the unknown parameters of interest in the model are vector of coefficients ($\beta's$) and standard deviations (σ) for the noise and inefficiency terms.

The Bayesian approach involves evaluating complex integrals that are analytically intractable (Coelli et al. 2005) and therefore requires simulation techniques to solve. Coelli et al. (2005) noted that the simulation techniques could either be simple Monte Carlo methods that produce independent sample observations or more sophisticated methods that result in chains of correlated observations that have properties of Markov processes (known as Markov Chain Monte Carlo (MCMC) algorithm). There are different algorithms of the MCMC methods including Gibbs sampling and Metropolis-Hastings.

In this paper, following Osiewalski and Steel (1998), the Gibbs sampling algorithm is employed in the model estimation. The MCMC with Gibbs sampling is a technique for obtaining a sample from a full joint distribution of a vector θ by taking random draws from conditional distributions (Osiewalski and Steel 1998; Griffin and Steel 2007). Specifically, we can partition θ into $(\theta_i', \dots, \theta_p')$ such that sampling from each of the conditional distributions $f(\theta_i' \mid \theta_{1,}' \dots, \theta_{i-1,}' \theta_{i+1,}' \dots, \theta_p')$ is straightforward. The Gibbs sampler is then composed of drawing from these distributions in a cyclical manner. More details on the Gibb sampling and other sampling procedures can be obtained from Koop and Steel (2001).

The Bayesian regional frontier estimation uses 2 chains running for 100000 steps with the first 50000 used as burn in, thinning every 15th draw. The priors adopted are similar to those suggested by Griffin and Steel (2007) for the exponentially distributed error structure. For the exponential error structure, $V_{i(k)} = p(v|h) = 2\pi^{-1/2} h^{\frac{1}{2}} exp\left\{-\frac{h}{2}\sum_{i=1}^{l} v_i^2\right\}, where\ \ h = \frac{1}{\sigma_v^2}$, the prior distribution of the precision parameter, h, is assumed to be gamma with shape and scale set to uninformative priors as specified in Griffin and Steel (2007). The β parameters were assumed to come from a normal multivariate distribution. The estimation of the Bayesian stochastic frontier model requires an assumption of a median prior efficiency value (r-star). Following Van den Broeck et al. (1994), an r-star value of 0.9 was used in the final model estimation. The models were estimated in the R programming software using "appear" package (Hailu 2013).

2.3.2 Metafrontier Estimation

Based on Huang et al. (2014) formulation, the metafrontier was constructed using predicted output from the regional frontiers. The estimations were implemented in the Bayesian framework in R using 100000 steps with the first 50000 steps used as burn in. The priors adopted here are similar with those used in estimating the regional frontiers. The model was estimated in R programming software using the "appear" package.

2.4 Description of Data Sources

Panel data on agricultural production for 19 African countries for the period 1971-2004 were accessed from the Food and Agriculture Organization statistics (FAOSTAT). FAOSTAT data is compiled by the Statistics Division of the Food and agriculture Organization. FAOSTAT data has widely been employed in empirical literature (O'Donnell et al. 2008; Mugera & Ojade 2013) and therefore becomes a reliable data source for the problem of study.

The site for the FAOSTAT data can be assessed using the URL: www.fao.org/faostat.

Following Alene (2010) and Nkamleu (2006), one output and five inputs are considered in the estimation of the models. Agricultural output is measured as the volume of agricultural production in millions of 1999-2001 international dollars. Geary-Khamis method was used to compute the aggregated output for the base year. The aggregated base year figures were then extended to cover the study period from 1971 to 2004. Agricultural land (X1) is measured as the sum of arable land and land under permanent crops and permanent pastures in thousand hectares. The labour input (X2) is defined as the active working population in agriculture for each year in a country. Economically active population in agriculture is defined as all persons engaged or seeking employment in agriculture, forestry, hunting or fishing sector, whether as employers, own-account workers, salaried employees, or unpaid workers (Nkamleu et al. 2006). The machinery input (X3) includes total number of wheeled and crawler tractors used in agriculture excluding garden tractors. The fertilizer (X3) input is also measured as the sum of nitrogen, potassium (P_2O_2) and phosphate (K_2O) in tons. Livestock input (X5) is the number of five animals (buffaloes, cattle, pigs, sheep and goats) measured in sheep equivalent. Detailed description of the data can be found in previous studies on agricultural productivity in Africa (Nkamleu 2004; Alene, 2010).

The countries are classified into five regions: Western, Eastern, Southern, Northern and Central based on the standard geographical classification (Benin 2016). The Western region consist of eight countries, including: Benin, Burkina Faso, and Cote devoir, Ghana, Mali, Niger, Nigeria and Senegal. The Eastern region countries comprise Kenya, Ethiopia, Madagascar and Zambia. The Southern region consists of South Africa, Malawi and Botswana. Central region comprises Cameroun, Burundi and Chad and finally, the Northern region comprises Egypt, Mauritania and Morocco.

3. Results and Discussion

This study considered five standard geographical classification of regions in Africa: Western, Eastern, Southern, Northern and Central. The results for the selected regional frontier estimation are presented in Tables 1 and 2. Also, the metafrontier parameter estimates and the performance indicators (technical efficiency, meta-technology ratio and meta-technical efficiency) are presented in Tables 2-5. Following are detailed discussions of the model estimation results.

3.1 Regional Frontier and Metafrontier Estimates

Using the two-step stochastic metafrontier estimation technique, the technical efficiency of five African regions (Western, Eastern, Southern, Northern and Central) are estimated and compared. The first- step, which comprises the estimation of the regional frontiers results in the regional frontier parameter estimates and the regional technical efficiencies. The results of the parameter estimates are presented in Table 1 and Table 2. Results for Western region (Region 1) are located in columns 2-5, while results for Eastern region (Region 2) are in columns 6-9, results for Southern region (Region 3) are presented in columns 10-13, Northern region (Region 4) in columns 2-5 in Table 2 and columns 6-9 for Central region (Region 5) in Table 2.

Posterior density estimates at the sample mean from the Bayesian stochastic frontier model are similar but vary depending on the region. From the results, we observe that output is most responsive to fertilizer input use than to non-fertilizer input use in Region 1. For Regions 2 and 4, output is most responsive to labour input use in agricultural production (see Table 1 and Table 2) and Region 3 is more responsive to land input use while Region 5 is more responsive

to livestock input (Table 2). Specifically, for Region 1, the input elasticity estimates are 0.60, -0.29, 0.04, 0.81 and -0.94 for land, labour, tractor, fertilizer and livestock inputs, respectively. The corresponding estimates for Region 2 are 0.25, 0.82, -0.02, -0.21 and 0.32 for land, labour, tractor, fertilizer and livestock inputs, respectively. Similarly, the input elasticity estimates for Region 3 are 0.82, 0.57, 0.36, -0.54 and 0.76 for land, labour, tractor, fertilizer and livestock inputs, respectively. For Regions 4 (5), the input elasticity estimates are 0.20 (-0.70), 1.09 (0.13), 0.09 (0.24), -0.04 (-0.11) and 0.66 (0.78) for land, labour, tractor, fertilizer and livestock inputs, respectively.

We can infer from the input elasticity estimates that both Regions 1 and 5 experience decreasing returns to scale at the sample mean, while Regions 2-4 exhibits increasing returns to scale at the sample mean. The increasing return to scale experienced by Regions 2-4 show that for these regions, production is at a sub-optimal level and there is more room to increase production. However, for Regions 1 and 5, production is at super optimal level and to increase production, new techniques of production are required. The Gamma values for Regions 1-5 indicate that 79%, 67%, 75%, 79% and 70%, respectively of the variations of the observed output and the metafrontier output can be attributed to managerial inefficiencies. The metafrontier parameter estimates are slightly different from the regional frontier parameters (Table 3). Generally, the metafrontier output is driven highly by labour input compared to non-labour inputs, implying that a percentage change in labour input will increase the industrial output by about 73%.

3.2 Technological Changes

Technological change gives an indication of the change in productivity due to adoption of new production practices. Consistent with O'Donnell et al. (2008) suggestion of accounting for technological change in the metafrontier estimation, a time trend was introduced into the model to account for that change. The first order coefficient of the time trend variable estimates are estimates of the annual rate of technological change (Alem et al. 2019) and the squared time trend (second order) coefficient indicates the speed in which technical change operates. In all regions, with exception of Region 5, there has been an outward shift of the production frontier, suggesting that there was an increase in productivity resulting from the use of improved agricultural technologies.

3.3 Various Performance Indicators

The average regional technical efficiency (TE), meta-technology ratio (MTR) and the meta-technical efficiency (MTE) are presented in Table 4. The results from the regional frontiers (Table 4) show that throughout the study period, (1971-2004), many of the regions in Africa were producing close to the regional frontiers. On average, Region 1 was producing about 88% of the regional frontier output while Region 2 was producing at 95%. Region 3, Region 4 and Region 5 were producing between 94%, 93% and 96% of the regional outputs, respectively.

The estimated MTR values show that on average, Region 1 is producing 80% of the potential output given the technology available in the agricultural sector, whiles Region 2, Region 3, Region 4 and Region 5 are producing at 60% and 81%, 77% and 84%, respectively of the potential output in the agricultural sector.

Table 1. Parameter Estimates of the Stochastic Frontier Model: Exponential Inefficiency Distribution

	Western Region (Region 1)				**Eastern Region (Region 2)**				**Southern Region (Region 3)**			
	Coef.	**MCE**	**2.5%**	**97.5%**	**Coef.**	**MCE**	**2.5%**	**97.5%**	**Coef.**	**MCE**	**2.5%**	**97.5%**
Constant	0.78	6.7E-04	0.62	0.94	-0.72	1.2E-03	-0.99	-0.49	0.01	2.7E-03	-0.53	0.60
lnx1	0.60	7.2E-04	0.45	0.78	0.25	8.7E-03	-1.60	2.37	0.82	2.4E-03	-0.88	1.69
lnx2	-0.29	1.7E-03	-0.66	0.14	0.82	2.4E-03	0.29	1.30	0.57	6.3E-03	-0.37	1.79
lnx3	0.04	3.2E-04	-0.03	0.11	-0.02	8.6E-04	-0.22	0.15	0.36	1.0E-03	0.11	0.57
lnx4	0.81	6.3E-04	0.66	0.97	-0.21	2.1E-03	-0.77	0.19	-0.54	4.0E-03	-1.17	0.43
lnx5	-0.94	1.0E-03	-1.18	-0.73	0.32	2.2E-03	-0.23	0.81	0.76	2.2E-03	0.28	1.20
lnx1xlnx1	-0.66	7.3E-04	-0.82	-0.49	1.67	2.5E-02	-3.73	7.43	-0.02	4.8E-03	-0.85	0.94
lnx1. lnx2	-0.80	1.2E-03	-1.07	-0.52	1.15	8.2E-03	-0.54	3.15	-0.06	4.3E-03	-0.86	0.88
ln**x1. lnx3**	-0.05	1.2E-04	-0.08	-0.02	-0.13	3.5E-03	-0.86	0.60	0.42	8.5E-04	0.25	0.62
lnx1. lnx4	0.13	2.7E-04	0.07	0.20	0.32	7.4E-03	-1.07	2.22	-0.43	3.1E-03	-0.99	0.13
lnx11. X5	0.77	7.6E-04	0.60	0.94	-1.41	7.9E-03	-3.31	0.31	0.49	2.1E-03	-0.07	0.86
lnx2x lnx2	3.72	3.5E-03	2.87	4.48	-0.76	3.5E-03	-1.66	-0.10	-0.21	5.1E-03	-0.96	0.78
lnx2. lmx3	-0.14	4.2E-04	-0.23	-0.04	0.30	1.2E-03	0.02	0.61	0.16	9.4E-04	-0.05	0.36
lnx2. lnx4	-0.25	6.4E-04	-0.40	-0.11	0.10	2.9E-03	-0.60	0.64	-0.08	3.0E-03	-0.57	0.57
lnx2. lnx5	0.17	1.4E-03	-0.13	0.48	0.59	2.9E-03	0.05	1.18	0.23	2.1E-03	-0.21	0.61
lnx3 x lnx3	0.04	1.1E-04	0.02	0.06	-0.04	6.9E-04	-0.22	0.11	0.02	6.1E-04	-0.11	0.17
lnx2. lnx4	-0.02	9.4E-05	-0.05	0.00	0.05	8.7E-04	-0.14	0.23	-0.20	7.8E-04	-0.37	-0.07
lnx3. lnx5	0.07	3.3E-04	0.00	0.15	-0.25	1.0E-03	-0.47	-0.02	0.05	1.2E-03	-0.21	0.29
lnx4 x lnx4	0.26	1.7E-04	0.22	0.30	-0.16	2.8E-03	-0.76	0.42	0.65	2.3E-03	0.19	1.02
lnx4. lnx5	-0.19	4.5E-04	-0.29	-0.08	-0.03	3.1E-03	-0.69	0.70	-0.02	1.4E-03	-0.27	0.27
lnx5 x lnx5	-0.93	1.6E-03	-1.25	-0.56	-0.32	3.6E-03	-1.07	0.39	-0.61	1.6E-03	-0.96	-0.27
t	0.03	3.2E-05	0.02	0.04	-0.01	3.8E-05	-0.02	0.00	0.01	8.5E-05	-0.01	0.03
t^2	0.00	8.7E-07	0.00	0.00	0.00	1.0E-06	0.00	0.00	0.00	2.2E-06	0.00	0.00
Sigma2	4.E-03	6.3E-06	1.7E-03	8.8E-03	1.E-03	4.5E-07	5.3E-04	2.5E-03	2.E-03	5.5E-07	5.6E-04	3.5E-03
Gamma	0.79	4.5E-05	0.52	0.93	0.67	1.8E-04	0.38	0.90	0.75	3.8E-05	0.47	0.93

Note: X1= Land; X2=Labour; X3=machinery; X4=fertilizer; X5=livestock; MCE=MCMC error

Table 2. Parameter Estimates of the Stochastic Frontier Model: Exponential Inefficiency Distribution

	Northern Region (Region 4)				**Central Region (Region 5)**			
	Coef.	**MCE**	**2.5%**	**97.5%**	**Coef.**	**MCE**	**2.5%**	**97.5%**
Constant	0.42	1.9E-03	-0.03	0.83	-0.01	2.8E-03	-0.72	0.63
lnx1	0.20	2.5E-03	-0.31	0.87	-0.70	3.1E-03	-1.40	-0.15
lnx2	1.09	5.3E-03	-0.09	2.23	0.13	8.3E-03	-1.32	1.67
lnx3	0.09	1.0E-03	-0.20	0.26	0.24	5.7E-04	0.07	0.35
lnx4	-0.04	1.8E-03	-0.48	0.28	-0.11	7.2E-04	-0.31	0.08
lnx5	0.66	1.4E-03	0.30	0.95	0.78	1.6E-03	0.41	1.14
lnx1xlnx1	0.11	2.0E-03	-0.32	0.67	-0.47	1.3E-03	-0.79	-0.25
lnx1. lnx2	0.57	3.0E-03	-0.20	1.26	-0.50	2.1E-03	-0.89	-0.06
ln**x1. lnx3**	0.10	9.4E-04	-0.12	0.30	-0.04	3.3E-04	-0.10	0.05
lnx1. lnx4	0.00	9.1E-04	-0.21	0.22	-0.10	8.8E-04	-0.24	0.07
lnx11. X5	-0.34	1.3E-03	-0.59	-0.02	0.46	9.0E-04	0.30	0.67
lnx2x lnx2	0.38	4.9E-03	-0.51	1.28	-2.24	1.2E-02	-4.42	0.15
lnx2. lmx3	0.00	7.9E-04	-0.22	0.15	-0.28	1.2E-03	-0.55	-0.03
lnx2. lnx4	0.12	2.2E-03	-0.24	0.58	-0.15	1.3E-03	-0.42	0.13
lnx2. lnx5	0.03	2.8E-03	-0.60	0.54	1.58	2.1E-03	0.99	1.95
lnx3 x lnx3	0.01	4.6E-05	0.00	0.02	0.01	4.7E-05	0.00	0.02
lnx2. lnx4	0.03	2.1E-04	-0.03	0.06	0.08	1.3E-04	0.05	0.11
lnx3. lnx5	-0.02	6.7E-04	-0.20	0.13	0.04	4.9E-04	-0.08	0.14
lnx4 x lnx4	-0.22	7.3E-04	-0.39	-0.06	-0.03	3.0E-04	-0.10	0.03
lnx4. lnx5	0.22	1.5E-03	-0.06	0.53	0.02	5.2E-04	-0.09	0.15
lnx5 x lnx5	-0.69	2.7E-03	-1.32	-0.05	-0.80	2.1E-03	-1.31	-0.49
t	0.01	4.9E-05	0.00	0.02	0.02	4.5E-05	0.00	0.02
t^2	0.00	1.8E-06	0.00	0.00	0.00	1.5E-06	0.00	0.00
Sigma2	1.E-03	8.5E-07	2.9E-04	3.3E-03	1.E-03	3.1E-07	4.2E-04	1.9E-03
Gamma	0.79	1.4E-04	0.47	0.96	0.70	3.4E-05	0.43	0.89

Note: X1= Land; X2=Labour; X3=Machinery; X4=Fertilizer; X5=Livestock; MCE=MCMC error

Table 3. Performance Indicators (Averages for 19 Countries, 1971-2004)

	Mean	MCE	2.5%	97.5%
Constant	0.76	4.8E-04	0.66	0.88
lnx1	0.56	3.4E-04	0.48	0.64
lnx2	0.73	3.2E-04	0.66	0.80
lnx3	0.14	2.1E-04	0.09	0.18
lnx4	0.37	2.5E-04	0.31	0.42
lnx5	-0.45	4.2E-04	-0.54	-0.35
lnx1xlnx1	0.30	3.4E-04	0.23	0.39
lnx1. lnx2	0.44	4.8E-04	0.34	0.55
ln**x1. lnx3**	-0.07	1.6E-04	-0.11	-0.04
lnx1. lnx4	0.29	1.9E-04	0.25	0.34
lnx11. X5	-0.61	4.2E-04	-0.70	-0.51
lnx2x lnx2	0.16	5.5E-04	0.04	0.29
lnx2. lmx3	-0.11	2.1E-04	-0.16	-0.07
lnx2. lnx4	0.29	1.5E-04	0.25	0.32
lnx2. lnx5	-0.59	6.4E-04	-0.74	-0.45
lnx3 x lnx3	0.04	9.2E-05	0.03	0.07
lnx2. lnx4	-0.04	9.5E-05	-0.06	-0.02
lnx3. lnx5	0.16	2.7E-04	0.10	0.22
lnx4 x lnx4	0.17	1.5E-04	0.13	0.20
lnx4. lnx5	-0.44	2.6E-04	-0.50	-0.38
lnx5 x lnx5	1.03	7.3E-04	0.86	1.19
t	0.03	3.9E-05	0.02	0.04
t^2	0.00	1.1E-06	0.00	0.00
Sigma2	0.88	7.6E-05	0.01	0.02
Gamma	0.01	5.5E-06	0.81	0.94

Note: X1=Land, X2=Labour, X3=Machinery, X4=Fertilizer, X5=Livestock, MCE=MCMC error

This finding confirms the study outcome of Nkamleu (2006) that although many countries are producing close to the regional frontiers, they are far below the overall industrial production frontier. Interestingly, the difference between the regional technical efficiency scores and the metafrontier performance indicators is quite huge. Specifically, the average efficiency values for Region 2 relative to the metafrontier is about 60% while the mean for the regional efficiency value is 95% (Table 4).

The agricultural sector in Region 5 on average achieved the highest mean technical efficiency relative to the metafrontier at 84% followed by Region 1 at 80%. Although Region 2 achieved one of the highest mean technical efficiency relative to the regional frontiers, the region tend to be further away from the potential output defined by the metafrontier function. The five Eastern African countries have productivity potential ratio ranging from 17% and 96% with an average of 77%. Region 2 has the lowest productivity potential ratio suggesting that even if all countries from the region achieved best practice with respect to the technology observed in the regions, they are still lagging behind the Africa industrial technology gap ratio of 77%. The estimates from the metafrontier show that Region 5 is closer to the agricultural production frontier for Africa and for that matter is more productive (84%) compared with the remaining regions.

Table 4. Performance Indicators (Averages for 19 Countries, 1971-2004)

	Technical efficiency			Meta-technology ratio			Meta-technical efficiency		
Country	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
Western Africa (Region 1)									
Benin	0.90	0.75	0.98	0.62	0.32	0.87	0.56	0.30	0.83
Burkina Faso	0.92	0.80	0.97	0.73	0.50	0.92	0.67	0.48	0.86
Cote Devoir	0.90	0.72	0.97	0.89	0.64	0.96	0.80	0.60	0.92
Ghana	0.86	0.66	0.98	0.87	0.71	0.92	0.74	0.60	0.86
Mali	0.87	0.70	0.97	0.73	0.60	0.84	0.64	0.51	0.74
Niger	0.89	0.69	0.97	0.89	0.74	0.95	0.79	0.64	0.88
Nigeria	0.91	0.78	0.97	0.87	0.61	0.96	0.79	0.50	0.91
Senegal	0.83	0.52	0.97	0.85	0.75	0.93	0.70	0.41	0.90
Average	0.88	0.52	0.98	0.80	0.32	0.96	0.71	0.30	0.92
Eastern Africa (Region 2)									
Kenya	0.96	0.90	0.98	0.74	0.62	0.87	0.71	0.59	0.84
Ethiopia	0.96	0.92	0.98	0.65	0.28	0.88	0.62	0.27	0.84
Madagascar	0.96	0.89	0.98	0.80	0.51	0.93	0.77	0.50	0.89
Zambia	0.92	0.52	0.99	0.77	0.17	0.96	0.71	0.16	0.95
Average	0.95	0.77	0.99	0.60	0.17	0.93	0.58	0.16	0.89
Southern Africa (Region 3)									
South Africa	0.94	0.82	0.98	0.85	0.64	0.92	0.80	0.58	0.89
Botswana	0.95	0.91	0.98	0.76	0.36	0.95	0.73	0.35	0.90
Malawi	0.92	0.69	0.98	0.81	0.66	0.91	0.75	0.60	0.88
Average	0.94	0.69	0.98	0.81	0.36	0.95	0.76	0.35	0.90
Northern Region (Region 4)									
Egypt	0.96	0.92	0.97	0.96	0.47	0.93	0.78	0.45	90
Mauritania	0.95	0.93	0.98	0.76	0.61	0.92	0.73	0.57	0.89
Morocco	0.89	0.70	0.99	0.73	0.55	0.85	0.65	0.50	0.83
Average	0.93	0.70	0.99	0.77	0.47	0.93	0.72	0.45	0.90
Central Region (Region 5)									
Cameroun	0.96	0.86	0.99	0.90	0.73	0.96	0.86	0.70	0.95
Burundi	0.96	0.87	0.98	0.77	0.19	0.93	0.73	0.18	0.92
Chad	0.95	0.82	0.99	0.84	0.36	0.90	0.80	0.34	0.88
Average	0.96	0.82	0.99	0.84	0.19	0.96	0.80	0.18	0.95
All Africa	0.92	0.64	0.99	0.77	0.17	0.96	0.71	0.16	0.95

We also observe from the findings that Region 5 is more technically efficient (80%), followed by Region 3 (76%), Region 4 (72%) with the least being Region 2 (58%). However, we find that there is substantial inefficiency in agricultural sector in Africa. Specifically, the average MTE of 71% for all regions is very low, suggesting that the level of inefficiency is resulting from low technology gap ratio in African agriculture. Comparing the results of the study with previous studies, it is observed that generally, the values obtained from the study are higher than those as obtained in Nkamleu (2006) and O'Donnell et al. (2008).

Specifically, it is observed that the average regional technical efficiency of 92% is higher compared with 74% obtained in Nkamleu (2006) study and 50% of O'Donnell et. al's (2008) study. The results generally give an indication that the technical efficiency of the various

regions has improved, but the value of 71% is still relatively low compared to other values as reported in O'Donnell et.al's (2008) study. The reason for the variations in the performance indicators as measured in this study compared with others could be attributed to the study period, the methodology employed, and the countries examined.

Table 5. Performance Indicators for the structural Adjustment Period (1971-2004)

	Pre-structural adjustment period: 1971-1980			**During structural Adjustment period: 1981-1990**			**Post structural Adjustment period: 1991-2004**		
Country	**TE**	**MTR**	**MTE**	**TE**	**MTR**	**MTE**	**TE**	**MTR**	**MTE**
Western Africa (Region 1)									
Benin	0.86	0.50	0.43	0.88	0.50	0.44	0.93	0.78	0.73
Burkina Faso	0.92	0.62	0.58	0.90	0.75	0.68	0.92	0.79	0.73
Cote Devoir	0.83	0.82	0.67	0.90	0.90	0.81	0.95	0.93	0.88
Ghana	0.88	0.80	0.70	0.75	0.89	0.67	0.92	0.90	0.83
Mali	0.94	0.67	0.62	0.88	0.77	0.68	0.82	0.75	0.62
Niger	0.87	0.92	0.80	0.92	0.84	0.78	0.89	0.89	0.79
Nigeria	0.91	0.80	0.72	0.89	0.86	0.76	0.93	0.93	0.87
Senegal	0.80	0.92	0.73	0.87	0.88	0.77	0.82	0.78	0.64
Average	0.88	0.75	0.66	0.87	0.80	0.69	0.90	0.84	0.76
Eastern Africa (Region 2)									
Kenya	0.96	0.75	0.72	0.96	0.78	0.75	0.96	0.70	0.68
Ethiopia	0.97	0.39	0.38	0.96	0.64	0.62	0.96	0.84	0.80
Madagascar	0.96	0.88	0.85	0.96	0.89	0.85	0.97	0.69	0.67
Zambia	0.92	0.26	0.24	0.91	0.21	0.19	0.93	0.20	0.19
Average	0.95	0.57	0.55	0.95	0.63	0.60	0.95	0.61	0.59
Southern Africa (Region 3)									
South Africa	0.94	0.77	0.72	0.94	0.89	0.83	0.93	0.88	0.82
Botswana	0.95	0.88	0.84	0.96	0.89	0.85	0.95	0.59	0.56
Malawi	0.93	0.78	0.72	0.93	0.83	0.77	0.91	0.83	0.76
Average	0.94	0.81	0.76	0.94	0.87	0.82	0.93	0.78	0.72
Northern Region (Region 4)									
Egypt	0.96	0.91	0.87	0.95	0.87	0.83	0.96	0.70	0.67
Mauritania	0.95	0.76	0.72	0.96	0.85	0.81	0.95	0.70	0.67
Morocco	0.92	0.99	0.62	0.89	0.72	0.64	0.88	0.77	0.68
Average	0.94	0.78	0.74	0.93	0.81	0.76	0.93	0.73	0.68
Central Region (Region 5)									
Cameroun	0.96	0.95	0.91	0.95	0.72	0.88	0.96	0.85	0.81
Burundi	0.96	0.50	0.48	0.96	0.88	0.88	0.96	0.85	0.81
Chad	0.95	0.80	0.77	0.95	0.93	0.81	0.95	0.86	0.82
Average	0.96	0.75	0.72	0.95	0.90	0.86	0.96	0.85	0.82

Now we classify the performance indicators based on the structural adjustment period to examine whether the structural adjustment programmes implemented across the African continent had any effect on productivity. On that basis, we have three classifications: pre-structural adjustment period (1971-1980), during structural adjustment period (1981-1990) and post-structural adjustment period (1991-2004). Results are reported in Table 5. Generally, we observe from the table that there were slight variations in the performance indicators during the structural and post structural adjustment period (Table 5). Specifically, there was a slight

increase in the MTR values for Region 1 during the structural adjustment and post structural adjustment periods. For Region 2, the improvement in the performance indicators during and post structural adjustment periods are not significantly different from the values recorded pre-structural adjustment period. For Region 3, Region 4 and Region 5, the regional frontier values were stable over the period, but the MTR values increased during the structural adjustment period and declined slightly post structural adjustment period, but the MTR and MTE values are greater compared to the pre structural adjustment period.

3.4 Drivers of Technical Efficiency

In examining drivers of technical efficiency, two approaches are commonly adopted in the production economics literature. The first is the two-stage approach where the drivers are regressed on the technical efficiency scores obtained from the first-stage estimation. The second approach relates to estimating the technical efficiency drivers as part of the production frontier estimation in a single stage. Although the single stage estimation is recommended in the literature, this study adopts the two-stage estimation technique because of missing data for some countries in the sample. Specifically, the bootstrap truncated regression method was adopted to regress research and development, literacy and trade openness on the regional technical efficiency scores. Agricultural research and development (R&D) are of particular interest because it is important in boosting agricultural productivity (Alston 1995; Alene 2010). Literacy which is used as a proxy for education accounts for labour quality differences. It is often assumed that more educated farmers have better access to information in the production process and therefore are more productive. Trade also serves as a standard measure of openness of an economy giving an indication of a possibility of new technology adoption. The estimated results are reported in Table 6.

Table 6. Drivers of Technical Efficiency

	Mean	**SE**
Constant	0.804**	0.587
Agricultural R&D	0.001**	0.001
Literacy	0.002**	0.001
Trade openness	0.004**	0.016

Note: SE=Standard error

The sign of the estimated coefficients gives the relationship between technical efficiency and agricultural R&D, literacy and trade openness. A positive estimated coefficient gives an indication of efficiency improvement while a negative sign is an indication of efficiency reducing effect. On that basis, it is observed that the estimated coefficient on agricultural R&D is positive, giving an indication of efficiency increasing effect. That is, higher investment in agricultural research and development improves regional technical efficiency. The coefficients on literacy and trade openness are also positive and significant confirming the general hypothesis that education (literacy) and trade openness are important drivers of technical efficiency. The findings are consistent with that of Alene (2010) study on productivity growth and the effects of agricultural R&D on African agriculture.

4. Conclusion

Productivity improvement in African agriculture is perceived as an important driver for achieving sustainable development goal 1 (zero hunger), and 2 (no poverty). However, the agricultural sector in many African countries is characterised by low levels of productivity. Over the years, a number of strategies have been adopted including development and

introduction of new technologies to boost productivity in African agriculture. Besides the introduction of new technologies to improve productivity, managerial capabilities of farmers could also serve as a measure of increasing productivity. The challenge for many policy makers has been about whether to pursue technology introduction or improvement in managerial capacities. In instances where farmers are efficient, then the policy should be directed towards introducing new technologies. However, if farmers are inefficient, then their managerial capacities have to be improved. The purpose of this paper therefore was to identify the sources of inefficiency in African agriculture by decomposing efficiency into technical efficiency and technology gap using a stochastic metafrontier model.

Altogether, 19 African countries were selected and classified into five regions based on standard geographical classification: Western region, Eastern region, Southern region, Northern region and Central region. Using a panel dataset for the period 1971-2004, the results show that many countries are producing close to the regional frontier and therefore are technically efficient. However, many of the countries are producing far below the regional meta-technology, particularly, Zambia in Eastern Africa. Generally, considering the entire industry frontier, we observed some levels of inefficiency (about 29%) in African agriculture. Since the overall efficiency was computed using the regional frontier values and the meta-technology, the level of inefficiency is arising from the technology gaps and not technical efficiency. The results show that African countries are lagging behind technology wise. It is therefore important to close the technology gap by developing and introducing useful technologies that are country specific across the continent.

Considering the drivers of efficiency, the results revealed that agricultural research and development, education and trade openness among nations have efficiency increasing effects. Therefore, it is important to invest in agricultural research and development as well as improving trade openness among African countries to ensure generation of improved technologies and technology transfer among countries. Such a measure would decrease the technology gaps and improve overall efficiency in African agriculture.

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Research article

Factors determining individuals' participation in volunteer work: A study of the Cape Coast Metropolis in the Central Region of Ghana

Moses Kwadzo *

Department of Agricultural Economics and Extension, University of Cape Coast, Ghana

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ABSTRACT

Person-organisation fit is the compatibility between individuals' and the organisations' attributes. Researchers have used a variety of dimensions to measure this compatibility. In measuring the similarity between the individual and organization, this study has focused on goal and value congruence. The current study aimed to investigate the person-organization fit factors that influence individuals' participation in volunteer activities. A 16-item scale that consisted of two 8-item subscales was constructed to measure the individual and organization congruence. About 404 respondents completed the questionnaire in the Cape Coast Metropolis in Ghana. The data were analyzed using descriptive statistics, cross tabulation and principal component analysis. The study revealed that diverse group of people were involved in NGO volunteer activities. The factor analysis show a two-component solution that explained a total of 61.83 % of the variance, with component 1 (person factor) contributing 54.57 % and component 2 (organization factor) contributing 7.26 %. The high communality values of the individual items for the person and organization factors, ranging from .413 to .766, are indicative of the similarity of the goals and values. The strong positive correlation between the two subscales (r = .63) shows that fit exists between the individuals and organizations' factors might have a positive influence on the study respondents' participation in volunteer activities. It is imperative that NGOs, especially those in the Cape Coast Metropolis pay particular attention to specific person-organization fit factors to attract, recruit and retain potential volunteers in the future.

1. Introduction

In most third world countries, including those in Africa, both the states and markets are too weak to promote socioeconomic development (The Borgen Project, 2018; Naipanoi, 2017). The failure of both governments and markets in Africa to deliver economic development has led to the rapid growth and expansion of non-governmental organizations (NGOs) on the continent. At national and local levels, the nonprofit organizations have provided tremendous socioeconomic development services, including provision of health services, food security, humanitarian assistance and policy advocacy (Anheier, 2008; Herman and Associates, 2005). Even though there is an increasing demand for NGOs services in developing countries such as Ghana, the sector is constrained with financial challenges. A recent study conducted by Ghana Philanthropy Forum in 2018 on the status of local and smaller nonprofit organizations in Ghana revealed that the NGO sector in Ghana is operating under difficult financial conditions (Ghana Philanthropic Forum, 2018). Many of the NGOs are compelled to look for alternative ways to resource their operations, such as volunteer mobilization (Batti, 2014). Using volunteers is an effective way to save limited organizational resources, build community support, improve the community and acquire hard-to-get skills.

Studies on factors influencing participation in volunteer work have received much attention in research literature (Bekkers and de Wit, 2014; Biswas and Bhatnagar, 2013; Xiao and Houser 2014). Recent studies estimate that approximately one hundred million people volunteer each year in developed nations including the United States (McKeever, 2015a, b). Comparatively, individuals' participation in volunteer activities in developing countries such as Ghana is low in profile (Batti, 2014; Ghana Philanthropic Forum, 2018). The Cape Coast Metropolis, one of the regional capitals in Ghana, is home to many NGOs (GSS, 2015). Many of these NGOs have limited human resources due to financial limitations. Human resource mobilization involving volunteers is a valuable component for strengthening these NGOs (Batti, 2014; Ghana Philanthropic Forum, 2018). Person-organisation (P–O) fit is the compatibility between individuals and the organisations they will like to work with

* Corresponding author.
E-mail address: moses.kwadzo@ucc.edu.gh.

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((Boon and Biron, 2016; Tak, 2011). The concept of P–O fit is crucial to NGOs because it supports the fact that if people fit well with a particular NGO subsector, they are likely to participate in volunteer activities (Studer and Schnurbein, 2013; Ünal and Turgut, 2015). Even though the influence of person-organisation fit on people attitudes towards and identity with particular organizations have recently received considerable attention from researchers, the study of the person-organization fit in developing countries is limited (Boon and Biron, 2016; Tak, 2011). In addition, there are few studies on person-organization fit within the NGO sector (Studer and Schnurbein, 2013; Ünal and Turgut, 2015). Studer and Schnurbein (2013) also noted that most research on volunteer participation is in the form of socio-psychological studies that focus on volunteers' motives and incentives. A study on the person-organization fit factors would help to improve the attraction and retention of people who may participate in NGO volunteer activities. The current study aimed to investigate the person-organization fit factors that influence individuals' participation in volunteer activities in the Cape Coast Metropolis in Ghana.

2. Literature review

2.1. The role of NGOS and the experience of volunteering in Africa

The African continent is endowed with immense natural and human resources, as well as great cultural, ecological, and economic diversity The Borgen Project (2018); Naipanoi (2017). Although significant economic progress has been made in some African countries, statistical trends in the region indicate the ongoing depth and scale of the socio-economic challenges. The majority of countries classified by the UN as least developed are in Africa, and most African nations suffer from many socioeconomic problems (The Borgen Project, 2018; Naipanoi, 2017). Half of the African population has been found to live in poverty without access to basic human needs, such as nutrition, clean water, and shelter. However, despite many years of public sector intervention, the spread and intensity of social problems continues to persist. The roles played by government have failed to address the key socio-economic issues. In recent years, non-governmental organizations (NGOs) have played supportive roles with the governments of developing nations. According Agere (2014), many NGOs depend on grants and donations to accomplished their missions and goals. The availability of funding to service delivery of NGOS is very crucial. However most NGOs in developing countries especially the smaller local NGOS in Africa are not living to their expectations of solving social problem due to declining level of donation to NGOs (Davis, 2013).

Volunteers are a significant human resource utilized by NGOs and often undertakes unpaid work (Allen and Bartle, 2014; De Clerck et al., 2019). This study defined a volunteer as a non-professional person who is willing to give his/her time and service to a specific task, without remuneration. Volunteering is the act of providing a volunteer service. Volunteering offers important benefits to individuals, communities and society (Allen and Bartle, 2014). It helps to create a stable and cohesive society by bringing people together to act for the good of the community. According to De Clerck et al. (2019) and Mati (2016), voluntary action builds social capital that adds value to the services that governments provide.

A study conducted by CICICUS (2011) on voluntary action and trends in nine African countries including Ghana, Guinea, Liberia, Morocco, Rwanda, Senegal, Tanzania, Togo and Zambia revealed that volunteering in Africa is shaped by the cultural, socio-economic and political dynamics of the African societies. Maes (2010) and Ngatia (2010) also pointed out that the socio-cultural and economic conditions of the nations of Africa have triggered the emergence of volunteerism in African societies. The finding of the study also noted that NGOs in Africa depend heavily on volunteers to fulfil their functions (CICICUS, 2011). Nonetheless, the study revealed rather low levels of individual volunteers' participation in NGO activities. This finding by CICICUS (2011) is consistent with other studies in Africa that show low levels of African citizen's participation in voluntary activities. Even though heterogeneous cultures exist across Africa countries, these patterns of volunteering have been found to be quite similar (Mati, 2016).

2.2. The concept of person-organization fit

Person-Organization (P–O) fit is the compatibility between people and broader organizational attributes (Studer and Schnurbein, 2013; Ünal and Turgut, 2015). Regarding a volunteer selecting an organization, the P–O fit could be conceptualized as the match between a prospective volunteer and the organization attributers. The concept is based on the Schneider's Attraction-Selection-Attrition framework, which states that individuals are not randomly assigned to organizations but rather seek out organizations that are attractive to them (Schneider, 1987). Schneider (1987) argues that persons are always on the lookout for situations attractive to them rather than fit any assigned situation. Schneider noted that an organization could be considered as a situation, which implies that people can be attracted to it, be selected to be a part of it, remain if they have good P–O fit or leave the organization in case there is no good fit. A low level of P–O fit can led to negative outcomes such as intention to quit the organization (Boon et al., 2011; Farooqui and Nagendra, 2014). Studer and Schnurbein (2013) have classified two main factors, person and organization factors that explain why some people with specific characteristics are more or less likely to be associated with some particular organizations.

A review of the literature shows that the main areas of matching between person and organization are value, goal, needs and integrate congruence (Studer and Schnurbein, 2013; Tak, 2011; Ünal and Turgut, 2015). The value congruence is a fit between the individual's intrinsic values with that of an organization values system while the goal congruence is a fit between individual objectives with that of an organization's main goals. According to Studer and Schnurbein (2013), and Ünal and Turgut (2015), value and goal based congruence are found to be more stable characteristics of person and organization fit. The current study aimed to investigate the person-organization fit factors in term of value and goal based congruence that influence individuals' participation in volunteer activities in the Cape Coast Metropolis in Ghana.

3. Materials and methods

3.1. Study area and research design

This study sought to assess relevant individual-organization fit factors that influence people participation in volunteer work in the Cape Coast Metropolis. Cape Coast is the capital city of the Central Region of Ghana. It is the administration, cultural, educational and commercial center of the Central Region. The Cape Coast Metropolis is known to suffer from poverty, child prostitution and child labor. Findings of a study on child prostitution in the Cape Coast Metropolis presented at the Center for Gender Research, Advocacy and Documentation at the University of Cape Coast revealed that children between the ages of 14 and 17 were indulging in child prostitution due to untold poverty, and peer pressure (Mensah, 2018). The poverty incidence in the Cape Coast Metropolis is 2.6 % (GSS, 2015). About 21.8 % of children in Ghana is estimated to be involved in child labor and children in the Cape Coast Metropolis are of no exception (Government of Ghana/UNICEF, 2017).

The Metropolis is home to a number of NGOs addressing social problems in the Metropolis. Even though there has been an increasing call for the NGOs services in the Metropolis, many of these NGOs have been constrained by human resources due to financial limitations. Promoting volunteer's participation is an alternative strategy to resource NGOs operations in the Metropolis. It is in this spirit that that the Cape Coast Metropolis was used as a study area for this study to examine the person-organization fit factors influencing individuals' participation in volunteer work. A cross-sectional survey in which data is collected at a

single period of time was employed for the study. Cross-sectional studies are relatively inexpensive and quick to conduct (Monette et al., 2002).

3.2. Target population and sampling unit

The target population for this study was individuals who live within the Cape Coast Metropolis who are qualified to participate in volunteer activities. Adults who are sick or mentally or physically challenged to engage in volunteer activities were excluded from this population. In addition, minors less than 15 years old per labor law were also excluded from this study. A multi-stage sampling procedure was used to select the individual respondents for the study. The choice of using the multi-stage technique was informed by the absence of a sample frame (Sarantakos, 2013). Moreover, in view of the fact that studying the entire population over a short time frame is difficult, portions of the population were drawn from particular areas within the Metropolis (Sarantakos, 2013).

The Metropolis was grouped into clusters based on exceptional features: population size, location, and economic activities. The Metropolis has 10 major sub-metros: Abura, Pedu, Kingsway, University of Cape Coast, Ankafu, Regional Office, Agric, Cape Coast Polytechnic (now Cape Coast Technical University), Aggrey/Ekow and Kotokruaba. A simple random sampling was used to select five of the 10 sub-metros including; Abura, Kotokruaba and Kingsway sub-metros are among the busiest market centers and host a high proportion of self-employed people. The University of Cape Coast has a high concentration of students due to the number of schools and the University of Cape Coast in this sub-metro. While the Agric sub-metro has some government offices, its unique feature is the location of a pensioner's house for a monthly meeting of pensioners. Many government and private employees are located in the Kotokruaba and Kingsway, University of Cape Coast, and Agric. metros. The unemployed are located within all five selected sub-metros. Finally, convenient sampling technique was used to reach individual respondents who were available and willing within the various metros to participate in the study. One advantage of using this sampling technique (multi-stage) lies in the fact that the research could be representative and economically moderate. Other studies employed the same approach and found reliable results (Sarantakos, 2013).

3.3. Samples size determination

Since there was no preexisting determination of the size of the population for the study, the sample size was determined by using the formula proposed by International Fund for Agriculture Development (2009) for an unknown population.

The formula for is

$$n = \frac{t^2 \, x \, p \, (1-p)}{m^2}$$

t = confidence level set at 95 % (Z score = 1.96).

p = estimated proportion of target population with similar characteristics (set at 50 % or 0.5).

m = margin of error set at 5 % (standard value = 0.05).

By substituting the value into the formula,

$$n = \frac{(1.96)^2 \, x \, 0.50 \, (1-0.50)}{(0.05)^2}$$

$$n = \frac{3.8416 \, x \, 0.25}{0.00255}$$

$$n = 384.16$$

A calculated 384.16 was obtained as the desired sample size. In the view of this, it was recommended that at least 384 individuals in Cape Coast Metropolis should be involved in the study.

3.4. Data collection instrument

The researcher developed a structured and validated questionnaire for the study. The researcher ensured the face validity of the survey instrument while some experts in the NGO sector helped to check the content validity. The questions on the instrument were closed ended questions separated into three parts. The first section covered the demographic characteristics of individuals, such as gender, marital status, age, educational level, and religion. The second section covered issues relating individuals' participation in volunteer activities within the Metropolis. The third section covered person-organization fit factors that may influence a person's participation in volunteer work. It is a 16-item scale that consisted of two 8-item subscales designed to measure the person and organization factors respectively on a five-point Likert scale. Variables captured in the items in the subscale are based on literature and previous work on person-organization fit factors and related to individuals' participation in volunteer activities (Studer and Schnurbein, 2013; Tak, 2011). The respondents were to rate the extent of which the person factors and the organization factors influence their participation in NGO volunteer activities. The instrument was pre-tested on thirty individuals in the Cape Coast Metropolis. The pre-test helped to modify the instrument to improve its internal consistency. The Cronbach's alpha coefficient computed to determine the internal consistency of the sub-scales was 0.70 or more, implying that the sub-scales are reliable (Pallant, 2016).

3.5. Data collection

Data was collected from 404 respondents. The study was also deemed to generate reliable results given a sample size adequate for the data analyses. This is a self-sponsored study and the researcher was not required by any agency to receive ethical approval for the study. However, all the respondents agreed to participate in the research study and they were free to participate with or without any justification. The consent to publish individual data in any form was obtained from the participants interviewed.

3.6. Data analysis

This study aimed to examine person-organization fit factors that influence individuals' participation in volunteer activities in the Cape Coast Metropolis in Ghana. Descriptive statistics consisting of frequencies, parentages, and means were used to explain the demographic characteristics of respondents and various subgroups' participation in volunteer work. Cross tabulation was performed to compare and explain the pattern of the subgroups' participation in volunteer activities. Cronbach alpha values were analyzed to determine the reliability of items measuring the person and organization fit factors.

Factor analysis is employed to identify a set of factors that represents the underlying relationships among the person-organization fit variables. In order to conduct the factor analysis, the suitability of the data was examined. The Cronbach alpha value for the 16 variables was .9. This value is above the recommended value of .7, indicating adequate internal consistency (Pallant, 2016). The 16 variables were subjected to principal components analysis (PCA).

4. Results and discussion

4.1. Respondent's demographic characteristics

The analysis of the demographic characteristics of respondents showed that males were 58.4 %. About 92.7 % of respondents were married. The minimum age of the respondents was 15 years with a maximum age of 89 years, while the mean age was 35.5 years. The majority of the respondents (92.8 %) had formal education distributed among the levels of educational attainment as follows: primary education

- 26 %; secondary - 17.5 %; and post-secondary education - 49.3 %. About 67.3 % of the respondents were Christians.

4.2. Distribution of subgroups and volunteer work participation

As shown in Table 1, 404 respondents participated in this study. The cross tabulation provided information that compare the subgroups and their volunteer work participation. The percentage distribution of the various subgroups consisted of 28.7 % students, 24.3 % public or private employees, 22.1 % self-employed, 11.4 % unemployed, and 13.6 % pensioners. Out of the 404 study respondents, 251 representing 62.1 % of the study sample was found to participate in volunteer activities last year. Interestingly, a little more than 50 percent of respondents in each subgroups was found to engage volunteer activities last year.

4.3. Subgroups' future volunteer participation in various NGO subsectors

In order to understand respondents' consideration of future participation in volunteer work, they were asked to indicate the NGO subsector in which they would most likely prefer to volunteer in the near future. It was revealed that 88.9 % of respondents were willing to participate in volunteer activities in the near future in the Cape Coast Metropolis (Table 1). Information from a cross tabulation of the various subgroups of respondents and their preferred NGO subsectors for future volunteering had been used to create a clustered bar chart. The result of the bar chart provided vital information useful for future recruitment of potential NGO volunteers. As shown on Figure 1, in the exception of the Pensioner subgroup, each of the different subcategories indicated interest in future volunteer participation with all the NGO subsectors.

It is interesting to know that the proportion of respondents who show interest in future volunteer participation varied with specific NGO subsectors. The data revealed that the Education NGO subsector might benefit from 84 respondents' future volunteer participations followed by the Religion NGO subsector with 68 respondents. The Children and Youth NGO subsector is the third and Health NGO subsector the forth to receive future volunteer participation from the respondents. Figure 1 shows that the Human Right NGO subsector (18 respondents) as well as the Art and Culture NGO subsector (12 respondents) might receive fewer proportions of the respondents providing future volunteer activities.

4.4. Pattern and structure matrix for PCA with oblimin rotation of two factor solution

Pallant (2016) points out that data is considered to be appropriate for factor analysis if its sample size is found to be adequate and there is intercorrelation among the items. Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) are the two statistical measures used to assess the factorability of suitable data. The Kaiser-Meyer-Olkin (KMO) with index ranges from 0 to 1, measures the sampling adequacy. The KMO index of .6 suggested as the minimum value for a good factor analysis. The Bartlett's test of sphericity is expected to be significant ($p < .05$) for a factor analysis to be conducted. The Kaiser-Meyer-Olkin value was .9, which is above the suggested value of .6. The Kaiser and Bartlett's Test of Sphericity was statistically significant at .000, which supports the factorability of the data. The principal component analysis has shown the presence of two components with eigenvalues exceeding 1. Interestingly, the assessment of the scree plot also revealed a sharp clear break after the second component as shown on Figure 2.

By applying the Catell's scree test, the two components were retained for advanced investigation (Pallant, 2016). To aid the interpretation of the two components, Direct Oblimin rotation was performed. Following the Oblimin rotation, the 16 variables showed strong loadings and all the variables loaded substantially on the two components.

The two-component solution explained 61.83 % of the variance, with component 1 contributing 54.57 % and component 2 contributing 7.26 % respectively. The rotated solution revealed the presence of a simple pattern and structure. The pattern matrix showed two clear factor solutions with the first factor termed "person factor" and the second factor, "organization factor." Each of the two factors has eight items respectively. The first factor (person factor) accounted for the total highest variance explained (54.57 %) with an eigenvalue of 8.73. The person factor (other than demographic characteristics) has five major loadings (Table 2). In order of decreasing loading on the person factor, item 4 (religious activities) has the highest loading of .786, followed by item 1 (helping the disadvantaged) with a loading of .782, and item 2 (personal satisfaction) with the lowest loading of .583. The second factor accounted for the total variance explained (7.26 %.) with eigenvalue of 1.06. Not surprisingly, the organization factor has three major loadings consisting of item 15 (NGO has internship program) with a loading of .887, followed by item 14 (NGO promotes volunteer's career development) with a loading of .777, and then item 13 (NGO volunteer recognition) with a loading of .531. The other five items of the organization factor loaded strongly but inappropriately onto the person factor: item 9 (NGO has flexible volunteering time) = 872; item 10 (NGO closer to my place of residence) = .760; item 11 = .766; item 12 (NGO project matches my skills) = .684; item 16 = .741. The structure values provide information about the correlation of items within a factor. For the person factor, the structure values range from .542 to .805, while, for the organization factor, the structure values ranges from .355 to .866. The high structure values are indicative that the items do fit well with the other items in each component. Correspondingly, the two factors showed a strong intercorrelation (r = .63). Communality values give information about how much of the variance in each item is explained. The high communality values of the individual items ranging from .413 to .766 in Table 2 indicated that each item is well fitted with the others in the components. Overall, the statistical results of the PCA analyses suggest that most of the contents of the two components of the person-organization fit factors could strongly determine respondent participation in volunteer activities in the near future in the Cape Coast Metropolis in the Central Region of Ghana.

Table 1. Distribution of subgroups and volunteer work participation.

Subgroups	Study Sample N = 404 (100 %)	Sample Volunteered Last Year N = 251 (62.1 % of the 404)	Sample to Volunteer in the Near Future N = 359 (88.9 % of the 404)
Student (%)	116 (28.7)	70 (17.33)	112 (27.72)
Public/Private employee (%)	98 (24.3)	64 (15.84)	88 (21.78)
Self-employed (%)	89 (22.0)	56 (13.86)	72 (17,82)
Unemployed (%)	46 (11.4)	27 (6.68)	39 (9.65)
Pensioners (%)	55 (13.6)	34 (8.42)	48 (11.88)
Total	404 (100)	251 (100)	359 (100)

Source: Field Survey, 2019.

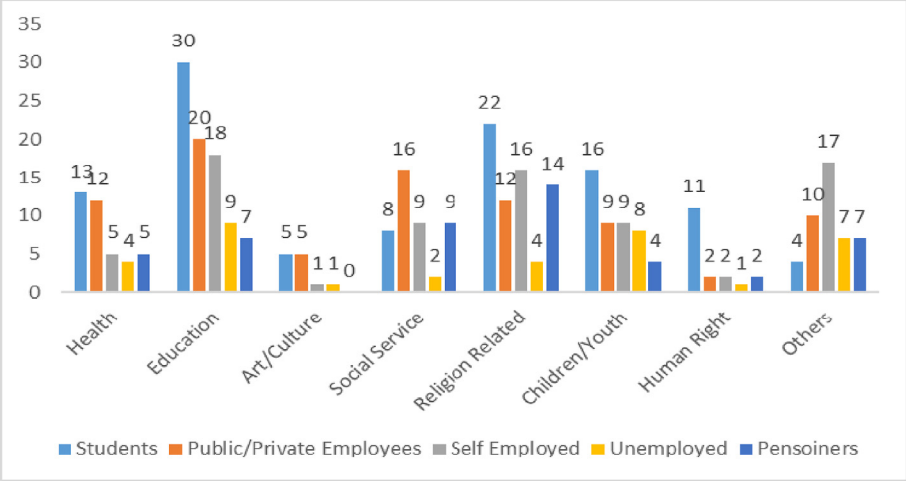

Figure 1. Subgroups' future volunteer participation in various NGO subsectors.

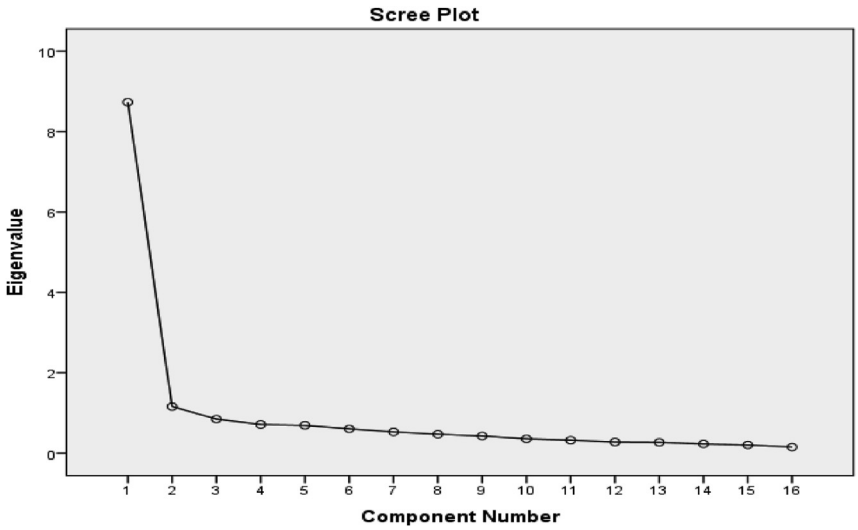

Figure 2. Scree plot showing a sharp clear break.

5. Discussion

Non-governmental organizations play vitae supportive roles with the governments of developing nations in addressing many social problems. Most of the local NGOs face financial limitations in the wake of increasing social problems. Although NGOs in Africa depend on volunteers, as an alternative to their financial constraint the level of individuals' participation in NGO volunteer activities is rather low. About 251 representing 62.1 % of the study sample of 400 was found to participate in volunteer activities last year (Table 1). It is necessary to understand how the P–O fit concept could be applied to promote individuals participation in NGOs volunteer activities. The respondents rating the extent to which the person-organization fit factors will influence their participation in NGO volunteer activities has revealed that majority (88.9 %) of respondents are willing to participate in volunteer activities in the near future in the Cape Coast Metropolis (Table 1). As shown on Figure 1, in the exception of the Pensioner subgroup, each of the different subcategories indicated interest in future volunteer participation with all the NGO subsectors. The findings of this study is consistent with P–O fit works by Boon et al. (2011), and Farooqui and Nagendra (2014). The concept of P–O fit is crucial to volunteers' recruitment on the basis that if people fit well with the NGO sector, they are more likely to participate in its volunteer activities (Studer and Schnurbein, 2013).

The study found a high correlation between the person-organization fit factors which might influence the respondents' increased interest in volunteer activities in the near future in the Cape Coast Metropolis. This observation could be attributed to the similarity of goals and values as captured by the items of in the two factors. According to Studer and Schnurbein (2013), the congruence of goals and values increase the mutual understanding and trust between the individual and organization. The specific values and goals captured under person factor include religious activities, helping the disadvantaged, and personal satisfaction. The major specific values and goals captured under organization factor include NGO has internship program; NGO promotes volunteer's career development; NGO volunteer recognition; NGO has flexible volunteering time; NGO closer to my place of residence; and NGO project matches volunteer skills. It is imperative that NGOs in the Cape Coast Metropolis pay particular attention to these factors to recruit and retain a large number of these potential volunteers in the near future.

5.1. Contribution to literature

In this study, the author examined factors that influence individuals' participation in NGOs volunteer activities in the Cape Coast Metropolis. The paper makes significant contributions to existing volunteering literatures by focusing on person-organization fit factors. Most of the previous studies on volunteering tend to understand the effects of socio-

Table 2. Pattern and Structure Matrix for PCA with Oblimin Rotation of two Factor Solution.

Item No.	P–O Fit Items	Person Factors		Organization Factors		Commonalities
		Pattern	Structure	Pattern	Structure	
1	Helping the disadvantaged	**.782**	.805	.038	.532	.650
2	Personal satisfaction	**.583**	.655	.115	484	.438
3	Giving back to community	**.671**	.760	.141	.566	.590
4	Religious activities	**.786**	.784	-.003	.494	.615
5	Local communal service (compulsory)	**.692**	.640	-.083	.355	.413
6	Acquiring a new skill	**.588**	.765	.279	.651	.632
7	Gaining work experience	.519	.778	.409	.738	.706
8	Educational Internship	-.050	.518	**.897**	.866	.751
9	NGO has flexible volunteering time	**.872**	.808	-.100	.452	.660
10	NGO closer to my place of residence	**.760**	.684	-.121	.360	.476
11	NGO mission matches my area of interest	**.766**	.831	.102	.587	.696
12	NGO project matches my skills	**.684**	.799	.181	614	.657
13	NGO volunteer recognition	.285	.621	**.531**	.711	.554
14	NGO promotes volunteer's career development	.118	.611	**.777**	.852	735
15	NGO has internship program	-.019	.542	**.887**	.875	.766
16	NGO focuses on religious activities	**.741**	745	.006	.475	.554

Note: Bolded items indicate major loadings for each item.

psychological factors such as individuals' motives and incentives on their participation in NGOs volunteer activities. While person-organization fit has been found to improve people participation in NGOs volunteer activities, nonetheless, the person-organization fit research in developing countries is limited. This study adds to the limited literature on P–O fit in developing countries. The findings of the current study confirm that person-organization fit does influence individual participation in NGOs volunteer activities. In the view that NGOs in Africa depend heavily on volunteers to fulfil their functions, the findings of this study have provided a better understanding of the influence of P–O fit factors on individuals participation in NGOs volunteer activities in developing countries.

6. Conclusion

The roles of NGOs in the socio and economic development cannot be overemphasized in many countries. The need to increase the activity of NGOs especially in developing countries is more urgent due to increasing social problems such as poverty, child labor and prostitution. However, smaller local NGOS in Africa are not living to their expectations of solving social problem due to declining level of donation to NGOs. Although NGOs in Africa depend heavily on volunteers to fulfil their functions, previous study revealed rather low levels of individual volunteers' participation in NGO activities. The engagement of individuals to participate in volunteer activities provides an alternative mean to sustain NGOs sector. Understanding and documenting volunteer engagement is a precondition for any meaningful policy interventions. This study investigated the person-organization fit factors that influence individuals' participation in volunteer activities in the Cape Coast Metropolis in Ghana. The result found a high correlation between the person-organization fit factors. The specific person factors include religious activities, helping the disadvantaged, and personal satisfaction while the specific organization factors include NGO has internship program; NGO has flexible volunteering time; NGO closer to my place of residence; and NGO project matches volunteer skill. It is imperative that NGOs, especially those in the Cape Coast Metropolis pay particular attention to the specific person-organization fit factors to attract, recruit and retain potential volunteers in the future.

Declarations

Author contribution statement

Moses Kwadzo: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data included in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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Environmental Systems Research

RESEARCH

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Health risk factors associated with pesticide use by watermelon farmers in Central region, Ghana

Michael K. Miyittah[1,2*], Moses Kwadzo[3], Abigail Peprah Gyamfua[1] and Daniel E. Dodor[4]

Abstract

Background: The export drive for watermelon production is huge and so is pesticide usage. However, the health and safety of the farmers, as well as threat to the environment lie in the shadow. The purpose of the study is to evaluate watermelon farmers' knowledge and application of pesticides in the Central region of Ghana, to ascertain factors associated with the pesticides application.

Methods: A field survey of 300 farmers were conducted in six communities through questionnaire. Logistic regression model was used to describe and explain burning sensation as the response variable and the factors that likely affect appropriate pesticide usage.

Results: The results show that farmers were aware of the environmental and health impacts of pesticides use. However, their knowledge of the risks associated with pesticides is not translated into actual practice to avoid the exposure of pesticides. The farmers experienced various levels of health risks symptoms. Health risks symptoms of headache, burning sensation, fever, watering eyes, chest pains, etc., were reported. The most common symptom is burning sensation. A model capturing biosocial factors influencing predisposition to burning sensation was developed. The model revealed that knowledge to identify pests, knowledge to identify diseases and wearing coverall were the most significant factors farmers experienced to influence burning sensation.

Conclusion: Significant number of watermelon farmers' experienced health risks symptoms. In order to minimize the health risk symptoms and environmental consequences, educational training programs must involve the farmers and retailers through strong policy intervention.

Keywords: Watermelon, Health risk, Smallholder farmers, Pesticides, Exposure

Background

In controlling pests and diseases affecting fruits and vegetables, food crops (yam, maize, rice, cassava), cocoa and watermelon for cultivation, smallholder farmers in Ghana and in Africa apply various pesticides (Wumbei and Houbraken 2019; Afari-Sefa et al. 2015; Kwadzo et al. 2015; Mattah et al. 2015; Ngowi et al. 2007). Reports from Wumbei and Houbraken (2019) revealed that smallholder farmers were applying pesticides more than the recommended dose on yam, and do not take into consideration health protection when applying the pesticides in Northern part of Ghana. Similarly, work done by Afari-Sefa et al. (2015) in Ashanti and Western region of Ghana showed that farmers experienced health impacts of pesticides after application. Further, Kwadzo et al. (2015) investigated pesticides use and health hazards among small-scale commercial vegetable growers in the Eastern region of Ghana. The results showed that due to inadequate knowledge on personal protective equipment use during pesticide application, farmers were exposed to health risk factors of skin/eye irritation, but those with

*Correspondence: m-miyittah@ucc.edu.gh
[1] Department of Environmental Sciences, University of Cape Coast, North Campus, University Avenue, Science Building, Cape Coast, Ghana
Full list of author information is available at the end of the article

training and education on pesticide usage had low levels of health effects. The study further showed clearly the impact of education and training in minimizing the negative effects of pesticides and this is consistent with data from Ethiopia (Mesele et al. 2019).

Data from other parts of Africa, Northern Tanzania on pesticides use among smallholder vegetable farmers also demonstrated that vendors often dispensed smaller quantities of pesticides in unlabeled containers, and in addition about one-third of the farmers applied pesticides in mixtures of various doses. About 68% of the farmers reported having felt sick after routine pesticides application (Ngowi et al. 2007). In Botswana, Machekano et al. (2019) reported pesticides residues were detected in 74% of cabbage samples from three vegetable markets (farmgates, vendors and supermarkets), and such public health concerns of excess pesticides residues is also found in Ghana (Donkor et al. 2016; Osei-Fosu et al. 2017).

The above investigations on pesticides application and health impacts are indicating weak law enforcement of pesticides use in Africa, and untrained personnel in use of pesticides application. Generally, the farmers level of education is low and respective African governments are showing lackadaisical action on pesticides registration and control, for swift policy change to demonstrate how serious the problem is. As the pesticides contamination escalates, there is the need for analytical and environmental scientists to understand the sources of the pollution, the socio-behavioral drivers beneath the problem, and how to deal with residues of pesticides in crops and pollution in environmental media of soil and water.

In this study, we investigated pesticides use and application among watermelon farmers in Central region of Ghana. To the best of our knowledge scanty information is available in the literature regarding watermelon farmers' knowledge and behavior towards pesticides application. In this study it is hypothesized that inadequate knowledge in pesticides use would be associated with pesticide health risk factors among smallholder watermelon farmers in the Central region of Ghana. Specifically, our objectives were: (1) to assess farmers' knowledge and practices towards pesticides use; (2) to assess health risk factors associated with pesticides use.

Materials and methods

The study area and data collection

The study was conducted at the Komenda-Edina-Eguafo-Abirem (KEEA) Municipal, which is one of the twenty districts in the Central region of Ghana. The KEEA municipality is situated along the coastal zone with series of lagoons and wetlands. The lagoons include, Brenya, Brenu, Susu, Abrobi and Ankwanda which support a vibrant salt industry (GSS 2014). Elmina as the municipal capital is a major tourist destination in Ghana, having two UNESCO World Heritage protected sites; the castle of St. George d'Elmina and Fort Coenraadsburg on St. Jago Hill attracts over 100,000 visitors annually (GSS 2014). Agriculture (crop farming) and fishing are major economic activities in the municipality. In particular, the watermelon farming helps to supply watermelon fruits to the residents and tourists who often visit the World Heritage sites. Six communities along the coastal zone and within the district were selected for the study, namely; Nsadwir, Awona, Ayensudo-Junction, Enyinase, Abakano and Ayensudo-Newtown. These communities are bounded on the South by the Atlantic Ocean (Gulf of Guinea), the East by the Cape Coast Municipality, the North by the Twifo-Hemang-Lower Denkyira District and the West by the Mpohor-Wassa East District. Annual rainfall ranges between 750 mm and 1000 mm while in the more interior areas, it ranges between 1200 and 1500 mm (Ministry of Food and Agriculture 2015) (Fig. 1).

Descriptive research design was used for this study and data was collected through questionnaire. The questionnaire covered the following areas: demographic profile of farmers, knowledge of pesticide use and health risk factors associated with pesticides application. Three hundred watermelon farmers participated in the study. The population of our study includes all the 700 farmers within the KEEA who benefited from Ministry of Food and Agriculture (MoFA) extension services (anecdotal evidence from extension officer, MoFA). Our target population was watermelon farmers in the KEEA. Based on anecdotal knowledge from the extension officer, our target population was three-hundred and eighty watermelon farmers. However, due to lack of sample frame on the watermelon farmers, we collected data from 300 out of 380 watermelon farmers who were available and willing to participate in the research. The questionnaire was presented in English and majority of participants read and answer the questions themselves. However, for few of the participants, the researcher read out the translated questionnaire in their local language. Majority of the questions had answers available with only a few of them having open ended. In this study the participants were neither coerced nor financially induced to take part in the research. They were informed that the information provided will contribute to the overall knowledge about the effects of pesticide use on their health.

Statistical analysis

Univariate analysis involving simple percentage, frequency and mean scores were computed for respondents' socio-demographic variables and knowledge on pesticides. Ranking was computed to gain insight on farmer's need towards pesticide use and health symptoms

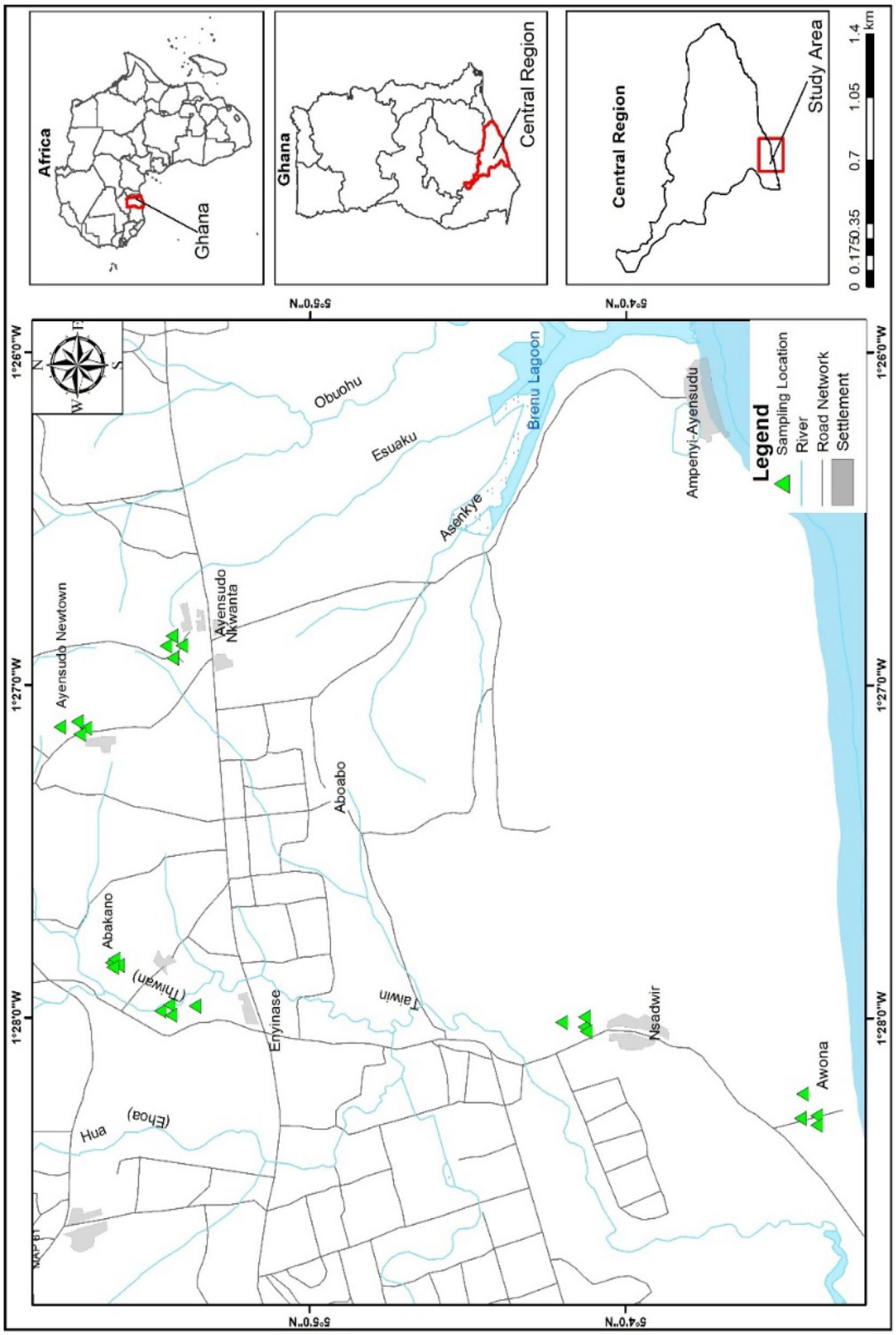

Fig. 1 A map showing the study area

experienced due to pesticides application. Correlation was used to ascertain positive or negative relationships between the response and explanatory variables using Cramer's v. Multivariate analysis was used to gain further insights on factors associated with the response variable. Specifically, logistic regression model was used to describe and explain the relationship between response variable and explanatory variables. In this study, the researchers considered the outcome variable as burning sensation, since it is the foremost symptoms that majority reported as heat or sharp or prickly pain at any part of the body during or after the application of pesticides. Factors that likely affect appropriate pesticides usage includes but not limited to farmers' educational level, use of protective clothing, ability to read pesticides manual, ability to identify specific pests and diseases that affect a given fruit such as watermelon. The explanatory variables likely to affect the outcome variable (burning sensation) in this study were respondents educational level, wearing coverall, ability to read manufacturer's instruction, knowledge to identify watermelon related pests, and knowledge to identify watermelon related diseases. The logistic regression model provides transformed (logit) probability as a linear relationship with the predictor or explanatory variables. The probability (p) of farmers experiencing burning sensation, is such that the logit (p):

$$\log it(p) = \ln p/1 - p = \ln (\text{odds ratio}) \quad (1)$$

$$= \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k \quad (2)$$

where p is the probability of burning sensation as affected by sets of explanatory variables and 1-p, the probability of not to be affected; and the odds ratio is the ratio of the two probabilities: $p/(1-p)$, β_o = the constant of the equation, β_1 = the coefficient of the explanatory variables 1. And $X_1,\ldots,X_k$ as sets of explanatory variables. Confidence interval was set at 95%, Hosmer–Lemeshow goodness of fit test was used to find out how well the data fits the logistic model (Hosmer and Lemeshow 2010; Bewick et al. 2005).

For the avoidance of doubts regarding sample distribution and representativeness, bootstrap technique was used to provide additional support. Bootstrap is a resampling method which allows for estimation or approximating the sampling distribution of the statistics. It can be used to measure the accuracy of a given parameter estimate, and to provide additional strength in estimating the stability of the sample result, statistical model, and test parameters of SE (standard error of the mean) and CI (confidence interval). The bootstrap method does not require knowledge of the data generated, but uses the sample information as proxy population. The method takes a sample with replacement from the original sample and calculates the statistic of interest repeatedly (Islam and Begum 2018). Through this repeatedly resampling approach, bootstrap can be used to quantify the uncertainty associated with a given estimator or statistical method. In this study, the proxy sample population was 300, and large sample size of 2000 was estimated in the bootstrapping. Bootstrapping is known to produce highly accurate results than traditional methods of estimating sample distribution of a statistic of interest, and is found to be applicable for both parametric and non-parametric tests (Efron 1979; Efron and Tibshirani 1993; Wright et al. 2011). All data were coded and analyzed using Statistical Package for Social Sciences (SPSS) version 20 (SPSS Inc, Chicago, IL, USA) and Microsoft Office Excel 2010 (Microsoft Corporation, Redmond, WA, USA). An alpha (α) level of ≤ 0.05 was used as a criterion for statistical significance.

Results

The Socio-demographic profile

Table 1 presents the socio-demographic characteristics of farmers. The study revealed that 80% of respondents were males while the remaining 20% were females. It was evident from the results that males dominated in watermelon farming. Majority of the farmers (40.7%) of the respondents had ages between 35 and 49 years and 30%

Table 1 Socio-demographic profile of farmers

Variable	Frequency	Percentage
Gender		
Male	240	80.0
Female	60	20
Age (years)		
≥ 20	6	2.0
20–34	90	30.0
35–49	122	40.7
≥ 50	82	27.3
Educational level		
No formal education	40	13.3
Primary education	152	50.7
Secondary education	100	33.3
Tertiary education	8	2.7
Economic activity of household		
Farming	260	88
Secondary jobs	40	12
Family size		
1–2	10	3.3
2–4	58	19.3
≥ 5	226	75.3
None	6	2.0

of the respondents had ages between 20 and 34 years. Only 1.3% of the farmers were less than 20 years while 27.3% were above 50 years. On education, 13.3% of the farmers had no formal education, 50.7% primary education, 33.3% of farmers had secondary level education and 2.7%, with tertiary education.

Most economic activity of the respondents was farming (88%), and other secondary jobs (12.4%) such as being engaged as a casual worker or having a small retailing business in addition to the main farming activity. Majority of respondents have family size of 5 and above (75.3%) and the least family size of respondents was 1 or 2 representing 3.3%. The data of the respondents show that they were smallholder farmers with 30.7% of the farmers with 3–4 acres of land, 5–6 acres (17.3%), 1–2 acres (21.3%) and 26% had more than 6 acres. Watermelon cultivation is their main activity with 74% engaging in it with other food crops like okra (20%) were grown together (data not shown). The main occupation was farming (79.3%), while others (18.7%) engage in other occupation but the least occupation (2%) was both farming and fishing (data not shown).

Farmers knowledge on pesticides safety and use

Table 2 shows farmers' knowledge on pesticides use and safety with respect to health effects, routes of exposure, environmental impacts, food safety, and pesticides use compliance. The farmers admitted that pesticides are detrimental to the health (80%) with 144 farmers supporting that all pesticides have the same health effect. In addition, 79.3% of the respondents confirmed that pesticides can be dangerous. Knowledge on the route of entry of the pesticides was clearly understood with 88.7% identifying that pesticides can enter the body through inhalation, 90% of the respondents agreeing of the entry through the skin, and 86% mentioning that pesticides can enter the body through the mouth. 89.3% of the respondents are aware that pesticides residues can be left in the air, pesticides residues can be left in the soil (82%), pesticides residues can be found in groundwater (56.7%), pesticides residues can be found in fruits (54%), pesticides residues can be found in vegetables (66%). 58% farmers responded that they read manufacturer's instructions, with 61.3% farmers said they respect manufacturers notification (Table 2). In addition, 91.3% farmers had no knowledge on any forbidden pesticides but 3.3% of farmers are aware that DDT is a forbidden pesticide, and with 4% of the respondents aware of the existence of forbidden pesticides, however, do not know them by name, and 1.3% did not show any response (data not shown).

Pesticides acquisition knowledge and usage

Table 3 shows how the farmers have access to the pesticides, why and how the farmers use the pesticides. The data shows that 52% farmers purchase pesticides at local agrochemical shops in village, while 40.7%

Table 2 Farmers' knowledge on pesticides safety and use

Variables	Yes		No		Not sure	
	N	%	N	%	N	%
Health effects						
Pesticides cause negative health effect	240	80.0	28	9.3	32	10.7
All pesticides have the same health effect	144	48.0	110	36.7	46	15.3
Pesticides be dangerous to use	238	79.3	32	10.7	30	10.0
Routes of exposure						
Pesticides enter the body through inhalation	266	88.7	32	10.7	2	0.7
Pesticides enter the body through the skin	270	90.0	16	5.3	14	4.7
Pesticides enter the body through the mouth	258	86.0	40	13.3	2	0.7
Environmental impacts						
Pesticides residues be left in the air	268	89.3	14	4.7	18	6.0
Pesticides residues be left in the soil	246	82.0	22	7.3	32	10.7
Pesticides residues be found in groundwater	170	56.7	96	32.0	34	11.3
Food safety						
Pesticides residues be found in fruit	162	54.0	112	37.3	26	8.7
Pesticides residues be found in vegetable	198	66.0	78	26.0	24	8.0
Pesticides compliance						
Read manufacturer notification	174	58.0	114	38.0	12	4.0
Respect manufacturer regulation	184	61.3	70	23.3	46	15.3

N = number of respondents, (%) indicates percentage

Table 3 Pesticides acquisition, knowledge and use

Variables	Frequency	Percentage
Access to pesticides		
Agrochemical shops in town	122	40.7
Local agrochemical shops in the village	156	52.0
Extension officers	6	2.0
Cooperative societies	2	0.7
Both agrochemical and local shops	14	4.7
Why use pesticides		
Protect crops against insects	216	72
Make crops grow better	40	13.3
Advised to use pesticides	2	0.6
Make crops grow better	38	12.6
Control weeds	4	1.3
Knowledge to identify common pest disease		
Yes	240	80.0
No	60	20.0
Knowledge to identify common crop disease		
Yes	144	48.0
No	156	52.0
Time to apply pesticides		
Presence of pest	208	69.3
Degree of pest infestation	16	5.3
Date of planting	66	22.0
On calendar spray schedules	10	3.3
Knowledge of pesticides application methods and rate		
Agrochemical shops	86	28.7
Extension officers	48	16.0
Pesticides labels on packages	40	13.3
Fellow farmers	104	34.7
Both agrochemical shops and extension officers	2	0.7
Both agrochemical shops and fellow farmers	4	1.3
Own experience	16	5.3
Dilute pesticide before application		
Mix more than one types of pesticides with water in container	264	88.0
Mix one type of pesticides with water in a container	32	10.7
Depending on the instructions on the label	4	1.3

acquire theirs at agrochemical shops in town. The data shows that, 72% of the farmers use pesticides to protect crops against insects while 13.3% use it for better crop growth. Also, 12.6% of the farmers use pesticides because of insects as well as to make crops grow better. Only few farmers (1.3% and 0.6%) use pesticides because of both insects and to control weeds; because the individual was advised. 80% of the farmers were able to identify common pest disease but 52% were unable to identify common crop disease. 69.3% of the farmers apply pesticides at the presence of pest but 5.3% use it during the degree of pest infestation. 3.3% of the farmers administer pesticides on calendar spraying schedules where as 22% apply pesticides using the date of planting. The knowledge of pesticides application methods and rates were obtained from fellow farmers (34.7%), agrochemical shops (28.7%), extension officers (16%), pesticides labels on packages (13.3%), own experience (5.3%). Before spraying, 88% of the respondents' mix more than one types of pesticides with water in container, 10.7% dilute one type of pesticide with water in a container and 1.3% use the instructions labeled on the container (Table 3).

Practices on use of protective wear, storage and disposal of pesticides

The responses of pesticide applicators to questions related to use of protective wear, disposal of empty containers, storage location of pesticides, washing of sprayers and period of last spraying before selling are presented in Table 4. On the question of the reason for not using protective wear during pesticides application, about one-fourth (39%) of the respondents gave the high cost of buying personal protective gear as the main contributing factor. Similarly, about 13.3% of the respondents were reluctant to use protective wear due to general lethargy and feel discomfort especially in the hot and humid climate of the study area. Also from observations, there existed no monitoring mechanism to ensure continue use.

With reference to the disposal of empty pesticides containers after use, interestingly, the respondents used

Table 4 Use of protective wear; disposal of empty containers after use; storage location of pesticides; washing of sprayers; and period of last spraying before selling

Variables	Frequency	Percentage
Reason for not using protective wear		
No response	30	10
High buying cost	118	39.3
Do not feel comfortable in them	40	13.3
Do not have it	32	10.7
Not interested	12	4.0
Others	68	22.7
Disposal of empty pesticides container		
Put in other uses	62	20.7
Throw away on the farm	140	46.7
Throw away in the village	52	17.3
Burry in the ground on the farm	26	8.7
Burn on the farm	18	6
Others	2	0.7
Disposal of remnant of pesticides after end of application		
On field	230	76.7
Throw in river, lakes or irrigation canal	4	1.3
Leave it for next spraying time	24	8.0
Apply on the farm again	6	2.0
Other	36	12.1
Pesticides storage by respondents		
Animal houses	2	1.3
Living room	140	46.7
In the bush	84	28
In the kitchen	48	16
In the food store	2	0.7
Others	24	7.4
Where they wash sprayers after application of pesticides		
In the river, lake or irrigation canal	52	17.3
At home using tap or bucket water	66	22.0
Do not wash	22	7.3
On the farm with the leftover water	160	53.3
Period for last spraying to selling of crops		
1–2 days	28	9.3
3–6 days	100	33.3
1 week	42	14.0
> 1 week	130	43.3

unscientific way of disposal, as 45.7% of them throw away empty pesticides containers on their farms. This social behavior coupled with disposal of remnant pesticides after end of application accounted for 76.7% of the respondent's behavior. Thus, this is suggesting that pesticides ecological impacts may be coming from these sources.

When asked how they stored pesticides, several practices emerged. Almost, one-fourth of the respondents (46.7%) stored pesticides in their living rooms. This is followed closely by 28% of the respondents stating that they stored the pesticides in the bush, which has no guarantee of safety to the environment or public health. Surprisingly however, some of the farmers (16%) reported storing the pesticides in the kitchen. Pesticides stored in the home can easily contaminate drinking water and food and can threaten the health and safety of growing children in the home.

Bizarrely, when asked where they wash the sprayers after application of pesticides, more than half of the respondents (53.3%) indicated that they wash on farms, and with 17.3% stating that they wash the sprayers in rivers, lakes or irrigation canal. Incidentally some of the sources of drinking water of the community is from the same river that they pollute. In addition, the water bodies are the source of fish and many habitats of aquatic organisms. The above methods of storing disposing of pesticides containers need critical interventions, so that awareness of public health concerns and safety during pesticide application can be enhanced (Jin et al. 2017; Jallow et al. 2017).

With reference to the last spraying to the selling of crops, several observations came to the fore. About one-third (33.3%) of the respondents sell the crops after spraying between 3 and 6 days. Majority of the respondents, about one-fourth (43.3%) stated, selling the crop after 1 week spraying (Table 4). The varying responses from the farmers indicate the inconsistencies with regulatory practices and the dangers of pesticides residues on crops from the local farmers. Anecdotal evidence shows that there are no regulatory agents at the point of sales cross-checking the public health safety of watermelons release for public consumption. Watermelons are transported directly from the farm gate to the nearest urban road for distribution to market centers across the country.

Famers need towards pesticides use

In order to promote appropriate use of pesticides among the respondents, their need was assessed by asking them to respond to a number of questions related to their pesticides knowledge need, knowledge on minimal health risk, precaution to be taken, limit use of pesticides etc.

Farmers responses include the option on a scale of 1 to 5; strongly disagree (1), disagree (2), don't know (3), agree (4), and strongly agree (5). As presented in Table 5, what farmers' need the most to achieve proper pesticides use was precautions in pesticides use with a mean score of 4.31 and ranked the highest on the scale, and with 99.3% of the respondents agree and strongly agree on the question. The second need of the farmers was pesticides use to protect crops with a mean score of 3.41. These first-two scores implied that the respondents desire is to know more about pesticide and the need to know how pesticide helps to protect their crops against pests and disease infestation. Key intervention needed is training regarding pesticides usage so as to enforce the necessary precaution required by the farmers.

As shown on Table 5, the 4th and the 5th scores suggest lack of clear understanding of the respondents on the need of pesticides effects on human health and the need to limit the use of pesticides. The median score for pesticides knowledge needed is 3.38 on the five point Likert scale, implying that the respondents have the desire to know more about pesticides and its' application.

Use of protective wears and health risk

Respondents were asked to indicate the protective measures they use during pesticides application. These measures were the use of gloves to protect the hand, use of goggles to protect the eyes against incidental and accidental pesticides droplets to affect the eyes, wearing special boots, oral or nose masks for protection against inhalation and wearing coverall. The use of protective measures during pesticides application is presented in

Table 5 Farmers need towards pesticides use

Variables	Strongly disagree	Disagree	Don't know	Agree	Strongly agree	Mean score	Rank
Precautions in pesticides use	–	2 (0.7)	–	202 (67.3)	96 (32.0)	4.31	1st
Pesticides protect crops	–	2 (0.7)	–	172 (57.3)	126 (42)	3.41	2nd
Pesticides knowledge	2 (0.7)	10 (3.3)	16 (5.3)	150 (50.0)	122 (40.7)	3.38	3rd
Limit use of pesticides	6 (20)	48 (16.0)	–	210 (70.0)	36 (12)	2.92	4th
Knowledge on minimal health risks	32 (10.7)	62 (20.7)	4 (2.7)	158 (52.7)	44 (14.7)	2.73	5th

Values in parenthesis indicate percentages

Table 6 Use of protective measures during pesticides application

Protective Gears	Yes	Percentage	No	Percentage
Gloves	80	26.7	220	73.4
Goggles	44	14.7	256	85.3
Something on the head	154	51.3	146	48.7
Special boots	188	62.7	112	37.3
Oral/nose masks	64	21.3	236	78.7
Coverall	90	30.0	210	70.0

Table 6. A majority 73.4% of the respondents reported they do not use gloves during pesticides spraying. Similarly, 85.3% reported not using goggles to protect their eyes during application. On the other hand, 51.3% reported they use something to cover the head, and 62.7% also on the affirmative that they wear special boots.

Further, 78.7% reported not using oral or nose masks and 70% of the responses indicated not wearing coverall before spraying the crops with pesticides. The result in Table 6 shows clearly that the farmers were most likely exposed to health risks due to pesticides application since basic personal protection is inappropriately addressed.

Health risk symptoms experienced due to pesticides use

Pesticides can cause health risks and damages during short term application and long term use. Several health symptoms were reported by the respondents which is buttressing that, the farmers lack critical use of protective measures during spraying. As seen in Table 7, the most frequently reported symptoms were burning sensation (78%), headaches (67%), weakness (60.7%), fever (64%), watering eyes (60.7%), itching and skin irritation (63%), and chest pain (68%). The ranking of burning sensation as number one, suggested that it is a common issue and burning sensation is a function of several drivers leading to health risk predisposition. These drivers could be biosocial or biophysical factors. These factors must be tested to help elucidate clearly the contributing risk variables.

Table 7 Health symptoms experienced due to pesticides use

Symptoms	No	Yes	Rank
Burning sensation	66	234	1st
Chest pain	94	206	2nd
Headache	98	202	3rd
Fever	108	192	4th
Itching and skin irritation	112	188	5th
Weakness	118	182	6th
Watering eyes	118	182	6th
Dizziness	166	134	7th
Skin rashes	168	132	8th
Forgetfulness	240	60	9th
Diarrhea	254	46	10th
Vomiting	272	28	11th

Relationship between burning sensation and explanatory variables

From literature factors such as gender, age, use of PPEs, education, farm size, knowledge of pest and diseases presence, and years of farming experience (Lorenz et al. 2012; Kwadzo et al. 2015; Wumbei and Houbraken 2019) may influence on watermelon farmers' experience of burning sensation when applying pesticides. Correlation between burning sensation and various explanatory variables were computed using Cramer's v and presented in Table 8. The result of the association between burning sensation and explanatory variables indicated positive, negative and one ambiguous relationships, although some were not significant. This implies that various explanatory variables have some relationship with the dependent variable and therefore deem appropriate in the logistic model, which was tested in Table 9. Four factors were significant ($p < 0.05$), which are gender, age, knowledge to identify crop pest and knowledge to identify crop disease to burning sensation. In contrast, low educational level, reading to manufacturer instruction and wearing coverall showed no significant relationship with burning sensation during pesticide usage.

Logistic regression modeling

There are several factors that might cause farmers to be predisposed to health risks. Burning sensation is taken as a dependent variable since it is one of the first signs or symptoms that the farmers will experience as a result of not wearing protective gears and/or with other variables. We modeled the factors that might be the drivers

Table 8 Correlation relationship between burning sensation and explanatory variables

Variables	Sign	Significance
Gender	Ambiguous (±)	s
Age	+	s
Low educational	+	ns
Reading manufacturer's instruction	+	ns
Knowledge to identity crop pest	−	s
Knowledge to identity crop disease	+	s
Wearing of cover all	−	ns

Significant for coefficient: $p < 0.05$; s for significant and ns for non-significant; + and − signs indicate positive or negative correlation

Table 9 Factors likely to predispose burning sensation using logistic regression model

Variables	Estimated parameter (B)	Standard error (SE)	Wald	p-value	95% CI	
					Lower	Upper
Read manufacturer's instructions	−0.169	0.299	0.321	0.571	0.470	1.516
Knowledge to identify pest	−0.941	0.426	4.882	0.027*	0.169	0.899
Knowledge to identify disease	0.795	0.299	7.091	0.008**	1.234	3.976
Wear coverall	−0.634	0.311	4.161	0.041*	0.289	0.975
Low education	−0.450	0.311	2.089	0.138	0.346	1.174

Hosmer and Lemeshow test = (0.55, $p > 0.05$)

* Indicates statistically significant level $p < 0.05$; ** $p < 0.01$

influencing burning sensation using logistic regression. In this model, our explanatory variables were ability to read manufacturer's instructions, knowledge to identify pest, knowledge to identify diseases, wearing coverall, and low education (no formal and/or primary education). These variables were selected after testing for multicollinearity among several variables. The explanatory variables were found to have a tolerance level of at least 0.953, and in addition these variables were retained since they yielded a good fit model with Hosmer and Lemeshow test greater than 0.5. The logistic model is presented in Eqs. (1) and (2), respectively. The burning sensation is a dichotomous dependent variable and specified as Yes = 1 and 0 = otherwise. And as in Eq. (2), $X_1,\ldots,X_k$ are the explanatory variables and with coefficient β. Using Eq. (2) we run the model and presented the result in Table 9. The Hosmer and Lemeshow test = 0.55, $p \hat{} 0.05$ indicating that the model is well fit and confirms the significance of some of the selected explanatory variable at $p < 0.05$. Also, the Wald tests of the explanatory variables are all greater than zero indicating that the parameters are associated with the dependent variable.

In Table 9 and from the model, three main explanatory variables were found to be statistically significant to influence the farmers' likelihood to experience burning sensation in their usage of agrochemicals. The coefficient for farmers with knowledge to identify pest is negative and significant ($\beta = -0.941$, C.I. = 0.169–0.899; $p = 0.027$). Thus, the coefficient indicates that if a farmer has knowledge to identify pest, he or she would have a lower probability in experiencing a burning sensation during pesticide application. Conversely, the coefficient for the famers with knowledge to identify disease is positive and significant ($\beta = 0.795$, C.I. = 1.234–3.976, $p = 0.008$), which is surprising since farmers' knowledge to identify disease should be associated with less likelihood to experience burning sensation during pesticides application. This observation might likely be due to the fact that farmers' ability to identity disease is more difficult and required technical expertise. On the other hand, the coefficient for wearing coverall was negative and significant ($\beta = -0.634$, C.I. = 0.285–0.975, $p = 0.041$). Thus indicating that, farmers wearing coverall are 0.63 times less likely to experience burning sensation than farmers who do not wear coverall. Although low education and ability to read manufacturers' instructions were expected to influence the farmer's likelihood to experience burning sensation during pesticides application, their estimated parameters were not significant but with positive association with the outcome variable. However, in this case the variables are not significant because education is componential in structure since continuous education is critical in achieving appropriate agronomic practices. Farmers low level of education might have accounted for the non-significant of their ability to read manufacturer's instructions. Intervention strategy like regular training is needed to have reduce impacts on burning sensation during pesticide application.

Bootstrapping the model statistics

In order to confirm the model statistics, and avoid doubts of sample distribution, bootstrapping was used as an additional technique to measure the accuracy of the logistic parameter estimates. Table 10 shows the result of the bootstrapping. In this study, a sample size of 300 as obtained from the survey is used as a proxy population. The bootstrap method estimates the sampling distribution empirically using the given sample size and estimate the parameters on large scale of 2000 sample size. In this way, bootstrapping serves as an internal replication mechanism for assessing the stability and replicability of sample results (Efron 1985; Thompson 1993). The results show that there are no differences between the standard errors in Table 9 for logistic regression and that of the bootstrap method in Table 10. In addition, the p-values were identical as predicted by both logistic regression and bootstrap method. The obvious implication is that

Table 10 Bootstrap results generated after 2000 samples using proxy sample population

Variables	Estimated parameter (B)	Standard error (SE)	p-value	95% CI	
				Lower	Upper
Read manufacturer's instructions	−0.169	0.330	0.604	−0.854	0.445
Knowledge to identify pest	−0.941	0.608	0.037*	−2.223	−0.128
Knowledge to identify disease	0.795	0.310	0.007**	0.230	1.465
Wear coverall	−0.634	0.325	0.038*	−1.295	−0.024
Low education	0.450	0.313	0.136	−0.125	1.108

Hosmer and Lemeshow test = (0.55, $p > 0.05$)

* Indicates statistically significant level $p < 0.05$; ** $p < 0.01$

the sample size distribution and parameter estimates were accurate and correctly predicted by the model.

Discussion

In order to have sound educational policies and strategies, it is necessary to understand farmers level of knowledge and practices regarding pesticides application. This is to prevent ecological damage and health risk among watermelon farmers. In this study, a considerable number of farmers with more than 60% (no formal and primary level) of education, were engaged in pesticide application. Their level of understanding the hazards associated with pesticide use was so poor. Majority of the farmers (Table 2) indicated that they know the hazards and the health impacts associated with pesticides application. However, that understanding did not reflect or translate into precautionary measures that must be put in place i.e. wearing of protective gears and reading manufacturer's instruction before pesticide use. Our result is consistent with report from Wumbei and Houbraken (2019) in which yam farmers were exposed to various levels of pesticide hazards. Similar nature of exposure was recorded by Strong et al. 2008 in which the authors called for multiple stakeholder engagement in order to have a holistic approach in controlling the exposure. On the other hand, Feola and Binder (2010) described the farmers' attitudes of knowing the hazardous nature of pesticides and still engaged in such dangerous practices without precautionary measures due to lack of understanding social norms. Although factors associated with social norms were not addressed in this study, it is concurred that structural changes are needed to have behavioral change at a collective and systematic level.

On the issue of access and acquisition of pesticides, majority of the farmers (92.7%) buy the pesticides from local agrochemical shops in town and village. Thus suggesting that agrochemical shop retailers must be included in the chain of educational training regarding pesticides distribution and their proper usage. Retailers are necessary because the farmer-extension officer ratio is so low within the region and the country and can help prevent the misconception of application rate error to avoid repetition and error propagation. Extension services and related programs have been noted to improve farmers condition (Danso-Abbeam et al. 2018). As can be observed that 88% of the farmers mixed more than one type of pesticides with water before spraying. This practice must be unlearned as information across the region is indicating negative impacts of pesticides use on bees' pollination (Thompson 2010; Johnson et al. 2010).

Table 4 shows clearly that farmers acclaimed knowledge regarding hazards of pesticide is not translated into actual practice as can be seen with the manner they dispose empty pesticides containers, where they store pesticides and how they wash the sprayers after use. Surprisingly and troubling is the fact that they put the empty container to other use, and even stored the pesticides in the living room by almost half of the respondents (46.7%). These actions predispose the growing child in the family to severe risks if expose to the hazards. On the contrary in developed countries, critical control points were established where empty containers, pesticides leftovers and other waste related to pesticides are picked by competent organizations for safe disposal (Devi 2009; Jin et al. 2017). Further, and bizarrely to the environment, the respondents wash the sprayers after use in rivers, lakes or irrigation canals and throw empty or unused container on farms and in the nearby bushes. This appalling behavior and practices are the sources of pesticides contamination in the environment and strong regulatory practices and policies must be formulated and enacted to control the behavior. In most of the rural communities, rivers, lakes are the sources of drinking water and contamination by this approach must not be allowed. In addition,

the ecological organisms would be affected if the intensity of these actions are not curtailed.

It is not surprising that the farmers reported health symptoms (headache, chest pain, weakness, etc.) during pesticide application. Burning sensation was first in ranking by the farmers followed by chest pain. A closer look at burning sensation revealed that it is the common symptom, but dependent on several explanatory variables. Logistic regression was used to model burning sensation and the associated explanatory variables to gain further insights regarding selected biosocial factors influencing burning sensation. The modeling (Table 9) revealed that factors likely to predispose burning sensation were knowledge to identify pests, knowledge to identify diseases, and wearing coverall. These variables were expected and shows clearly that farmers own intrinsic attributes such as ability to identify pest and diseases, and wearing coverall are within the reach of the farmers and can be managed effectively to minimize the burning sensation. In another study involving cocoa farmers, Okoffo et al. (2016) found educational level to be significant with respect to decision in wearing personal protective equipment. On the contrary in this study, low education was not significant. This might be due to strong social norms which was described by Feola and Binder (2010) and must be taken into account to have a behavioral change at collective and systematic level. Furthermore, educational training can help through policy intervention in addressing the health symptoms. In order to be sure of the modeling result of the sample size/distribution and estimation of the parameters, bootstrapping method was added as an internal mechanism to support the model. The result (Table 10) confirmed the strength and accuracy of the parameters estimated.

Conclusions

Watermelon production in Ghana is increasing due to export drive of the country. Similarly, the use of pesticide is growing to control pests and diseases by farmers in general. Understanding and documenting pesticide use is a prerequisite for any meaningful policy interventions. We investigated pesticides use by watermelon farmers in six communities in the Central region, Ghana. The result shows that farmers have knowledge and understanding of the hazardous nature of pesticides use. However, the knowledge about the environmental and health hazards of pesticide use is not translated into actual practice. Health hazards were reported and experienced by the farmers with various levels of symptoms. Burning sensation is the foremost symptom experienced by the farmers. Factors underlining and explanatory to the burning sensation were modeled. The most probable variables influencing burning sensation were knowledge to identify pests, knowledge to identify diseases, and wearing coverall. The implication is that educational training programs should be enhanced; extension services must be increased. The current farmer-extension officer ratio in Ghana is low and insufficient to cause any critical mass influence on farmers regarding the use of pesticides. The extension services and capacity should therefore be enhanced to increase the educational information flow. Pesticides retailers must be brought into the equation of pesticides education to augment the proper use of pesticides. The current approach of unregulated buying and usage without scientific base demands new policy interventions. With sound policy, heath risk impacts on the farmers and ecological implication and its' consequences would be minimized.

Abbreviations

MoFA: Ministry of Food and Agriculture; SPSS: Statistical Package for Social Sciences.

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Authors' contributions

MKM conceived and designed the work with APG, MK and DED validated the method section. All authors MKM; MK, APG, and DED participated in the analysis, validation and writing of the paper. All authors read and approved the final manuscript.

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Availability of data and materials

Part of the data that supports the findings are included in the manuscript. However, the raw data of the study are available from the corresponding author upon request.

Ethics approval and consent to participate

All participants agreed to participate in the research study, and they were free to participate with or without reservation.

Consent for publication

Consent to publish individual data in any form was obtained from the Watermelon farmers interviewed.

Competing interests

The authors declare that they have no competing interests.

Author details

[1] Department of Environmental Sciences, University of Cape Coast, North Campus, University Avenue, Science Building, Cape Coast, Ghana. [2] ACECoR-Centre for Coastal Management, University of Cape Coast, Cape Coast, Ghana. [3] Department of Agricultural Economics and Extension, University of Cape Coast, Cape Coast, Ghana. [4] Department of Soil Science, School of Agriculture, University of Ghana, Legon, Ghana.

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Research article

Factors influencing adoption of integrated soil fertility management technologies by smallholder farmers in Ghana

Moses Kwadzo [a,*], Emmanuel Quayson [b]

[a] Department of Agricultural Economics and Extension, University of Cape Coast, Sasakwa Center, Cape Coast, Ghana
[b] Department of Agricultural Science, Aggrey Memorial Zion Senior High School, Accra-Cape Coast Highway, Cape Coast, Ghana

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ABSTRACT

This study examines smallholder farmers' adoption of both a full set of and multiple bundles of integrated soil fertility management technologies, and estimates the determinants of and assesses the relationship among adoption practices using the logistic model and multivariate probit model respectively. A cross-sectional survey was used to collect data from 300 smallholder farmers who benefitted from a sustainable food security and environmental health project in three districts in Ghana. Four ISFM technologies (zero or minimal tillage, inorganic fertilizer, leguminous crop, and crop rotation) serve as outcome variables. The result revealed that only 26.7% of the respondents adopted the full set of the ISFM technologies. Agroecological zone, a spatial variable has been found to significantly influence smallholder farmers adoption of the full ISFM technologies. One or more of the predictor variables, purpose of farming, land ownership, distance from house to the nearest input shop, access credit and agroecological zone, have been found to significantly influence the adoption of the multiple ISFM technologies. However, the computed correlation coefficients of the independent determinants show inconsistent significant values. The implication of this finding is that the adoption of multiple ISFM technologies cannot be estimated utilizing common determinants. Therefore, extension service in the region should focus on crucial factors that influence adoption of specific multiple ISFM technologies to maximize adoption options.

1. Introduction

More than 60% of the world population depends on agriculture for its livelihood (World Bank, 2014). In many developing countries such as Ghana, about 70% of the population engages in agriculture and related activities to supply food and raw materials and generate income (FAO, 2002; World Bank, 2014). Despite the importance of agriculture to socioeconomic development, the annual agricultural growth rate at the global level is only 2–4% (Zavatta, 2014). According to the FAO (2002) and the World Bank (2014), world agricultural production, especially crop yield, has declined in recent years. This situation is likely to threaten the sustainability of food supply to meet the growing global population (FAO, ECA & AUC, 2020). Many researchers point out that low agricultural productivity is directly linked to land and soil fertility degradation, particularly in developing nations (FAO, 2015; Tully et al., 2015). Most of rural population depends on agriculture for their livelihood in the sub-Saharan Africa (SSA). For more than three decades, the agricultural growth in the sub-region is stagnant with an annual growth rate below 2% (FAO, 2015). Gomiero and Rosen (2016) point out that diminishing soil fertility is the main cause of decreasing agricultural outputs in the sub-region.

In the past, smallholder farmers in developing countries practiced natural fallowing, which involved land rotation through shifting cultivation. Farmers cultivated a piece of fertile land for a few years, moving to another area when crop yields began to decline (Collinson, 2000; Ker, 1995). Over the past five decades, high population densities have rendered these fallowing practices unrealistic, and the current situation requires the introduction of sustainable agricultural strategies such as integrated soil fertility management (ISFM) (AGRA 2015; Aura, 2016). The ISFM is a technologies package that is seen as the most ideal in addressing the problem of environmental degradation and low agricultural productivity. The ISFM technologies can be grouped into inputs and practices. The farm inputs that are advocated to be used include fertilizer, improved seeds and herbicides while recommended conservation practices are no-tillage, crop residues, mulching, cover crops, intercropping and crop rotation. The farmer has the option to choose from a number of inputs and practices. Thus, the ISFM concept emphasized multiple combinations of these technologies (AGRA 2015; Aura, 2016;

* Corresponding author.
E-mail address: moses.kwadzo@ucc.edu.gh (M. Kwadzo).

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Bellwood-Howard 2014). Vanlauwe et al. (2015), however provides a slightly different definition to ISFM. According to Vanlauwe et al. (2015), ISFM is a bundle of soil fertility management practices that essentially embrace the use of fertilizer, organic inputs and quality germplasm, combined with the knowledge of adjusting these practices to local conditions, meant to improve nutrients utilization and crop productivity. Vanlauwe's ISFM concept emphasizes the use of a full set of technologies that consists of fertilizer, quality seed and organic matter with additional practices to optimize efficiency of nutrient use.

Although agriculture remains the predominant economic activity in rural Ghanaian communities, the country's agricultural production is characterized by low yields (MoFA, 2019). According to CSIR (2018), poor agricultural crop production is largely attributed to the low organic matter content of Ghana's arable soils, which ranges from 0.00 to 5.63 percent. To address the challenge of land degradation in the country, the Ministry of Food and Agriculture (MoFA) has promoted ISFM projects in districts including Hohoe, Jasikan, and Kadjebi. These districts depend largely on agriculture, with 70% of their populations involved in agricultural activities (MoFA, 2019). Anecdotal evidence shows that farmers in these districts generally practice slash-and-burn agriculture, and do not apply inorganic fertilizer to maize crop (data not available). Concerns over these practices led MoFA to partner with AFRICARE, a non-governmental organization, to implement a sustainable food-security and environmental health project that trained smallholder farmers on ISFM technologies, including zero or minimal tillage, inorganic fertilizer, leguminous crop (organic input), and crop rotation. Maize was the project entering crop grown by all the project beneficiaries. While the benefits of ISFM technologies in improving soil fertility and agriculture production have been reported in literature, previous studies show that adoption of ISFM technologies remains low among smallholder farmers in developing countries such as Ghana (Fairhurst, 2012; Ollenburger, 2012).

Though MoFA's ISFM project activities have been carried out for more than five years in these three districts, data on ISFM adoption and practices are scant. With comparison to empirical work examining adoption of a single soil fertility management technology, few studies have examined factors that influence adoption of ISFM technologies (AGRA 2015; Aura, 2016; Bellwood-Howard 2014; Vanlauwe et al., 2015). The current study aimed to assess factors influencing adoption of ISFM technologies by smallholder farmers in the three districts in Ghana. Considering previous studies that show the adoption of ISFM technologies varies from one country to another, this study contributes to topical literature specifically within the Ghanaian context.

2. Materials and methods

2.1. Research design and study area

The current study employs a cross-sectional design, and was conducted in the three districts of Hohoe, Jasikan, and Kadjebi in the Oti and Volta Regions of Ghana. These regions are positioned along the eastern border of the country and share common boundaries with Greater Accra, Eastern, Brong-Ahafo, and Northern Regions (CWSA, 2020; GSS, 2014).

2.2. Study population and sampling techniques

The target population of the study included all individual farmers who live within the three districts and who participated in the ISFM technologies training project. These farmers belonged to different registered farmer-based organizations (FBOs) that had been receiving advisory services from MoFA. There were approximately 25 FBOs in each district, each consisting of an average membership of 20 farmers. In all, the study sample frame was 1200 farmers. The Krejcie and Morgan Table for population and sample size was used to determine the sample size for the study (Krejcie and Morgan, 1970). For a population of 1,200, a sample size of 291 is appropriate. Thus, a sample size of 300 was selected. A multi-stage sampling method was employed to choose the study sample. In the first stage, 10 FBOs were randomly selected from the registered farmer group organizations in each district. The second stage involved random sampling of 10 registered farmers from each of the sampled FBOs. This sampling technique and procedure resulted in 100 individual smallholder farmers in each of the three districts (n = 300), from the sample frame population of 1200. While the researcher was not required to obtain ethical approval to conduct this study, permission was nevertheless obtained from the research participants prior to data collection and subsequent publication. The data collected by means of a structured questionnaire administered with the assistance of MoFA field staff who were not part of the ISFM project team. Data collected included individual or household characteristics, institutional factors, farm characteristics, farming systems, and implementation of ISFM technologies and practices.

2.3. Dependent variables

The concept of ISFM emphasizes the use of a full set of ISFM technologies or multiple ISFM technologies by the smallholder farmers (AGRA 2015; Aura, 2016; Vanlauwe et al., 2015). The criterion variable, adoption of ISFM technologies, is operationalized in two different ways as the likelihood of a farmer using the full set of ISFM technologies or multiple bundles of ISFM technologies (zero or minimal tillage, inorganic fertilizer, legume crop, and crop rotation).

2.4. Explanatory variables

A review of technology adoption literature reveals that individual attributes (e.g., age, gender, education, household size, farmer main occupation and main purpose of farming), institutional features (e.g., land ownership, extension services, farm based organization membership, and distance from farmer's residence to central input shop), and farm characteristics (e.g., farm size, farm land fertility status, extend of land degradation and agroecological zone of the farm) can influence farmers' adoption of a given ISFM bundle (Kassie et al., 2015; Teklewold et al., 2013).

2.5. Model specification and data analysis

Data was analyzed using univariate, bivariate and multivariate analyses. In order to predict factors determining adoption of the full set of the SFM technologies and multiple bundles of the ISFM technologies by the smallholder farmers, binary logistic model and multivariate probit model were utilized respectively.

2.6. Binary logistic model

A logistic regression is a suitable test model to predict the likelihood of an event. The dependent variable is dichotomous. The predictor variables can be either categorical or continuous, or a mix of both. The likelihood of occurrence of an event can a value from 0 to l (Pallant, 2013). Using the binary logistic regression, we estimate factors influencing the likelihood of the respondents to adopt the full ISFM technologies using Statistical Packages for the Social Sciences (IBM SPSS version 25). Maize being the project entering crop was grown by all the project beneficiaries. The respondents were coded “1” for adopting the full set of ISFM technologies (zero or minimal tillage, inorganic fertilizer, legume crop (organic input), and crop rotation) at the same time, otherwise ‘0.’

2.7. Multivariate probit (MVP) model

The ISFM concept encourages the use of multiple bundles of a given ISFM technologies by farmers so as to address a number of agricultural challenges. A multivariate probit (MVP) model is useful for jointly estimating several correlated binary outcomes. In contrast, the ordinary probit model considers only one binary dependent variable (Kassie et al., 2015). The MVP model, therefore, helps to overcome problems or

weaknesses associated with the univariate probit model (Dougherty, 2011).

The general specification for the MVP is (Cappellari and Jenkins, 2003; Greene, 2000)

$$yim^* = \beta m + xim + \varepsilon im,\ m = 1,2 \ldots 4 \quad (1)$$

$$yim = 1\ if\ yim^* > 0,\ 0\ otherwise \quad (2)$$

where

yim* is a dormant variable that relates to the choice of a practice m.

βm represents a vector of parameters.

xim is an observed characteristic found in linear relation with yim* .

Ɛim is the stochastic error term,

yim are manifest binary variables which specify whether a farmer used a particular technology.

To predict the relative contribution of factors influencing the probability of adoption a mix of ISFM technologies, univariate and multivariate probit analyses were carried out using STATA 13.0.

3. Discussion of results

The descriptive statistics of the demographic features of the surveyed farmers are presented in Table 1.

3.1. Age

Older farmers have been found to have greater experience of production practices and to have accumulated more physical capital. However, older farmers also tend to be more risk averse, as well as susceptible to declines in physical energy. Consequently, the influence of age on technology adoption is ambiguous (Kassie et al., 2015). The mean age of respondents in this study was 43.34 years.

Table 1. Descriptive statistics of the socio-demographic characteristics of surveyed farmers.

Variables	Frequency	Percentage
Age (years)		
More than 45	135.0	
Mean	43.34	45.0
Gender		
Male	160	53.3
Female	140	47.7
Main occupation		
Farming	278	92.7
Other than farming	22	7.3
Main purpose of farming		
Commercial	234	78
Subsistence	66	31
Education		
No formal education	31	10.3
Primary school	35	11.7
Junior high/middle school	192	64.0
Senior high secondary school	30	10.0
Tertiary education	12	4.0
Household size		
Mean	6.42	
Land ownership	91	30.3
Obtained credit	67	22.3
Get extension service	300	100
Farm based organization membership	300	100
Distance from house to the nearest input shops (Km)		
Mean	15	
Farm size (hectares)		
Less than 1	186.9	62.30
Less than 2	264.0	88.00
Mean	.96	
Farmland being degraded	157	52.3
Extent of farmland degradation		
No/low	112	37.3
Moderate	164	54.7
High	24	8.0

3.2. Gender

A smallholder farmer may opt to adopt ISFM technologies regardless of his or her gender status because other production resources such as ownership of farmland may influence his decision to use such technologies. Thus, the nature of the relationship of gender to the likelihood to adopt a new technology is ambiguous. In this study, gender is coded 1 if the respondent is male, otherwise 0. About 53.3% of respondents were male.

3.3. Main occupation

Literature on small-enterprise development posits that smallholder entrepreneurs will devote most of their time and labor to develop farm enterprises if these are their main occupation, rather than representing extra income activities (FAO, 2011; Kahan, 2012). The surveyed respondents were asked to indicate their main occupation with these response categories: a = farming; b = formal employment; c = vocational employment; d = others. A dummy variable was set for farmer's main occupation. Farmers whose main occupation was farming were coded '1'; otherwise, '0.'

3.4. Main purpose of farming

The purpose of farming is to produce food for family consumption and/or to generate profit. Agribusiness enterprise enables farmers to increase their income and raise living standards. Respondents were asked to indicate their main purpose for farming, with these response categories: 1 = commercial or income generation, and 2 = household food security. About 93% of respondents indicated that their main purpose of farming is commercial.

3.5. Education

Formal education is a huma cn development factor that increases individuals' capability to acquire and apply new information. It suggests that individual farmers who obtain high education are more likely to use new technologies. Education was measured as accomplishment of a specific level of formal education. About 86% of the respondents had no or low formal educational attainment, which was defined as up to middle or junior high school level.

3.6. Household size

The variable household size is a proxy for labor availability. It is assumed that a larger household size will make more labor available to adopt a new technology, which may require the farmer to carry our labor-intensive activities. It is expected that a farmer with a large household will readily adopt new technologies (Kamau et al., 2014). The mean household size of the respondents is 6.42 persons.

3.7. Land ownership

Land ownership has been found to influence a farmer's likelihood to invest in agricultural technologies such as ISFM (Kamau et al., 2014). Because investment in some farming technologies may take a long time to realize their benefits, individual land ownership will encourage the adoption of such technologies. Land ownership is measured as a categorical variable and was coded 1 if the respondent owns farmland, otherwise, 0. Just over 30% of the respondents reported that they owned farmlands.

3.8. Credit

Farmers' ability to obtain financial resources. On the other hand, financial constraints inhibit the farmer's ability to purchase farm inputs such as inorganic fertilizer or quality seeds. Consequently, farmers who readily obtained credit will more likely adopt ISFM technologies. A farmer with obtained credit is coded 1, otherwise, 0. Only 22.3% of respondents had gotten loan.

3.9. Agricultural extension

Agricultural extension is a non-formal education system that supports farm families through educational activities to improve their farming practices (Axinn, 1988). Hence, agricultural extension service tends to facilitate technology transfer. Farmers who benefit from extension service has a tendency to promote adoption of technologies. All the study respondents benefitted from extension service as part of ISFM technology training provided by the staff of MoFA.

3.10. Distance from house to input shop

The distance from the farmer's residence to a central input shop represents additional transaction costs to be incurred by the farmer. A long distance from the farmer's residence to a central input shop is negatively associated with to find agro-inputs, such as to inorganic fertilizer or improved seeds, as these also impose costs. Distance measured in kilometers. The average distance from house to central input shop was 15 km.

3.11. Group membership

A farmer's membership with a FBO provides him with the opportunity to obtain relevant information on farm inputs and operations. Additionally, FBOs present a stronger front that increase farmers bargaining power in the marketing arena (Kamau et al., 2014). All study respondents were members of FBOs that registered with MoFA for its advisory and training services, so can be considered farm group members.

3.12. Farm size

Farm size is the total farmland under cultivation. A larger land holding may inspire farmers to finance and adopt a new technology. Additionally, a small farm size may inspire the farmer to intercrop to maximize land used. Therefore, farm size may not influence the adoption of ISFM technologies in one specific direction in an empirical model. Farm size is measured in hectares. The average area of smallholdings was 0.96 ha.

3.13. Land fertility status

This is a measure of a respondent's perception of their farmland fertility status, indicating whether the farmer should address soil fertility status. A farmer who perceives their farmland as degraded is more likely to use the appropriate technology to restore soil fertility status. Respondents were to indicate whether their farmland was degraded. The responses are categorical, with 1 = yes and 0 = no. In total, 52.3% of respondents perceived their farmland to be degraded.

3.14. Extent of farmland degradation

Land degradation occurs in agroecological areas due to factors such as farming system and extent of land use. This variable measures the extent of farmland degradation. Respondents were asked to indicate the extent of degradation of their farmlands. This variable is an ordinal scale ranging from 1-3, where 1 = No or low degradation and 3 = high degradation.

3.15. Agroecological zone

Farmers residing in agroecological zone featuring degraded farmlands are more likely to adopt ISFM technologies. The spatial analysis of farmlands degraded within the study revealed that greater proportion of the farmers in Jasikan and Hohoe reported their farmlands to be degraded than those in Kadjebi (data not shown). In this study, Hohoe and Jasikan districts are reference agroecological areas with degraded farmlands and coded as agroecological zone 1 and agroecological zone 2 respectively.

3.16. Pattern of surveyed farmers adopting various ISFM technologies

The ISFM technologies considered in this study are zero or minimal tillage, inorganic fertilizer, leguminous crop, and crop rotation. Zero or minimal tillage is the reduction in the number of times a farmland is tilled during a cropping period using an orthodox tillage method (Eitelberg et al., 2015). Inorganic fertilizer has been seen as a major solution to solving soil nutrient deficiency that causes falling crop yield. Inorganic fertilizer, such as NPK and ammonia, help to improve essential nutrient supply to the soil for high crop performance (Bationo et al., 2018; Vanlauwe et al., 2015). The growing of leguminous crops such as cowpea allows the smallholder farmers to increase organic content of their soil. The practice of growing leguminous crops is advantageous where land is limited, allowing crops such as cowpea to fix substantial amounts of atmospheric nitrogen into the soil as part of the crop fallow (Arslan et al., 2014). Crop rotation is a cropping strategy that involves the growing of dissimilar crops in a precise order on the same farmland. It encourages the growing of crops with different characteristics that use the soil nutrients sequentially to sustain the productivity of the cropping system, and in addition, reduces crops infestation by destructive pests and diseases (Teklewold et al., 2013).

Table 2 presents the different combinations of ISFM technologies adopted by the farmers. Only 12.99% of the smallholder farmers used only one of the four ISFM technologies, while 30.32% of the surveyed farmers adopted and used combinations of two ISFM technologies. Almost 22% of the smallholder farmers who used the zero or minimal tillage also applied inorganic fertilizer and crop rotation. About 29% and 27% of the smallholder farmers adopted and used combinations of three

Table 2. Proportion of farmers adopted different bundles of the ISFM technology.

Possible ISFM technologies combination	Frequencies of farmers	% of farmers
Only “zero/minimum tillage”	19	6.33
Only “inorganic fertilizer”	12	4.00
Only “leguminous crop”	0	.00
Only “crop rotation”	8	2.66
“Zero/minimum tillage” and “inorganic fertilizer”	46	15.33
“Zero/minimum tillage” and “leguminous crop”	32	10.33
“Inorganic fertilizer” and “leguminous crop”	1	.33
“Inorganic fertilizer” and “crop rotation”	13	4.33
“leguminous crop” and “crop rotation”	0	,00
“Zero/minimum tillage” and “inorganic fertilizer” and “leguminous crop”	1	.33
“Zero/minimum tillage” and “inorganic fertilizer” and “crop rotation”	66	21.99
“Zero/minimum tillage” and “leguminous crop” and “crop rotation”	9	3.00
“inorganic fertilizer” and “leguminous crop” and “crop rotation”	11	3.66
All four	80	26.66
None of the four	2	.66
Total	300	100.00

and all the four of the ISFM technologies, respectively. Results show that the smallholder farmers used various bundles of ISFM technologies that they considered relevant. This points to the benefits farmers might be deriving through such combinations of ISFM technologies. The farmers' adoption of zero or minimal tillage may be attributed to the fact that, in minimal tillage, soil disturbance is kept to a minimum, while in zero tillage, no soil disturbance occurs, thereby reducing soil degradation (Zavatta, 2014). The farmers reported practicing crop rotation by using leguminous crops with other crops. Prolonged planting of the same type of crop tends to deplete specific nutrients in the soil. The farmers surveyed noted that they rotated cowpea with maize, or in a few instances with cassava (data not shown). The use of nitrogen-fixing legumes such as cowpea helps to improve soil fertility, and prevents the reoccurrence of pests and diseases on the farm (Vanlauwe et al., 2015).

3.17. Complementarities and substitutionarity of ISFM technologies

Considering the varied bundles of ISFM technologies adopted by the farmers, it is likely that the farmers' use of one particular ISFM technology correlates with the adoption of other ISFM technologies. As presented in Table 3, pair-wise correlation coefficients across the residuals of the multivariate probit model were computed after the influence of the observed factors were accounted for. The binary correlation coefficients measure the correlation between the different technologies (Dougherty, 2011; Greene, 2000). The positive sign of the correlation coefficients proposes that the farmer adoption of one particular technology will likely lead to the implementation of one or more other technologies. The negative sign connotes substitutionarity between the two associated technologies. The results show that most of the ISFM technologies are complements. In this model, it appears that farmers who adopt zero or minimum tillage tend also to adopt inorganic fertilizer or leguminous crop. Furthermore, farmers who adopt inorganic fertilizer tend also to adopt crop rotation or leguminous crop. Inorganic fertilizer and crop rotation are substitutes. Many of the pair-wise correlation coefficients of the residuals of the ISFM technologies adoption are significant, confirming the suitability of the model and that new technology adoption is not mutually exclusive.

3.18. Econometric results

3.18.1. Determinants of the adoption of the full set of ISFM technologies

Adoption of ISFM is operationalized as the likelihood of the smallholder farmers adopting all the four ISFM technologies ((zero or minimal tillage, inorganic fertilizer, leguminous crop, and crop rotation) at the same time. Maize being the project entering crop was grown by all the project beneficiaries. The descriptive statistics shows that 80 (26.7%) of respondents adopted all the four technologies at the same time.

3.18.2. Regression diagnostic

The logistic model does not assume a linear correlation between dependent and predictor variables. Nevertheless, the model is sensitive to multicollinearity (McCormick and Salcedo, 2017). Tolerance and Variance Inflation Factor (VIF) were calculated in order to test for multicollinearity among the predictor variables in the model as shown in Table 4. Following a number of regression diagnostics, the predictor variables with correlations than 0.60 were selected for the logistic modeling. The computed Tolerance values for the variables are high, with a range of .636–.974, showing an overall weak relationship among the predictor variables. These values confirm the absence of multicollinearity (McCormick and Salcedo, 2017).

A logistic model was run to examine the effects of the predictor variables on the likelihood that respondents would adopt the complete ISFM technologies. The model contained eight independent variables (gender, main occupation, main purpose of farming, land ownership, getting credit, distance from house to the nearest input shops, farmland being degraded, agrological zones-Jasikan and Hohoe). The model was statistically significant, $\chi 2\ (9, N = 300) = 53.47$, $p < .000$, signifying that the model was able to differentiate between farmers who adopted and did not adopt the full ISFM technologies. The Hosmer and Lemeshow value of a good-fit logistic model is expected to that be greater than .05 (McCormick and Salcedo, 2017), and this is true for the model with its Hosmer and Leeshawn's value being .803. The model as a whole explained 23.8%) of the variance in adoption status, and correctly classified 73.7% of cases. (percentage accuracy in classification: PAC) (Pallant, 2013). Only three of the predictor variables, land ownership and agroecologicalzone, had been found to make a statistically significant influence to the model (Table 5).

Table 3. Correlation coefficients between ISFM technologies.

Combination of ISFM technologies	Correlation coefficient	Standard error
"Zero/minimum tillage" and "inorganic fertilizer"	.060	.119
"Zero/minimum tillage" and "leguminous crop"	.245*	.115
"zero/minimum tillage" and "inorganic fertilizer"	.115	.107
"Inorganic fertilizer" and "leguminous crop"	.029	.115
"Inorganic fertilizer" and "crop rotation"	-.017	.114
"leguminous crop" and "crop rotation"	.765*	.167

Correlation coefficients between the residuals from the multivariate probit equations.
* Indicate statistical significance at the 1% level.

Table 4. Collinearity statistics on predictor variables.

Variables	Tolerance	VIF
Gender	.973	1.027
Main occupation	.974	1.026
Main purpose of farming	.971	1.012
Land ownership	958	1.044
Obtained credit	.958	1.044
Distance from house to the nearest input shops	.913	1.095
Farmland degraded	.860	1.163
Agroecologicalzone1	.636	1.571
Agroecologicalzone2	.624	1.603

Table 5. Results of logistic model for the adoption of full ISFM technologies.

Independent Variables	*B* (S.E.)	Odds Ratio (B).	95% C.I. for EXP	
			Lower	Upper
Gender	.336 (.287)	1 .399	.797	2.496
Main occupation	364 (.620)	1.438	.427	4.851
Main purpose of farming	.204 (.324)	1.226	.650	2.314
Land ownership	-.858 (.339)	.424*	.218	.824
Obtained credit	.297 (.330)	1.345	.704	2.570
Distance from house to the nearest input shops	-.001 (.008)	.999	.982	1.015
Farmland being degraded	.093 (.312)	1.098	.595	2.024
Agroecologicalzone1	2.521 (.536)	12.445***	4.352	35.591
Agroecologicalzone2	2.479 (.524)	11.930***	4.269	33.337
Constant	-3.410			
-2Log-Likelihood	294.478			
N	300			
Pseudo R Square	.238			
Hosmer & Lemeshow	.803			
Goodness-of-Fit Prob > chi2	.000			
PCA	73.7			

Significant for coefficients: p*<.05; p**< .01; p***< .001.

Table 6. Results of probit models for the adoption of multiple bundles of ISFM technologies.

Variables	Zero or minimum tillage b (SE)	Inorganic fertilizer b (SE)	Leguminous crop b (SE)	Crop rotation b (SE)
Age	.004 (.009)	-.014 (.008)	.002 (.008)	.001 (.007)
Gender	.129 (192)	.120 (.187)	.058 (.167)	.007 (.167)
Main occupation	.295 (.344)	.219 (.333)	.362 (.355)	.042 (.295)
Main purpose of farming	.647**(.259)	-.186 (.185)	-.087 (.183)	-.073 (.183)
Education	.092 (.234)	.228 (.218)	-.273 (.202)	-.097 (.205)
Household size	.033 (.037)	.059 (.036)	-.002 (.032)	-.017 (.030)
Land ownership	-.661***(.205)	-.139 (.201)	-.240 (.185)	-.124 (.180)
Obtained credit	-.305 (.217)	.345 (.241)	.061 (.196)	.654***(.222)
Distance from house to the nearest input shops	.011 (.007)	.020**(.008)	-.000 (.000)	.007 (.006)
Farm size	.130 (140)	-.022 (.100)	-.088 (.093)	-.059 (.090)
Farmland degraded	.029 (.207)	-.123 (.197)	-.168 (.185)	.040 (.183)
Extent of farmland degradation	.127 (.161)	-.247 (.157)	.066 (.146)	.235 (.151)
Agroecologicalzone1	.407 (.256)	1.166***(.275)	1.086***(.248)	.628**(.226)
Agroecologicalzone2	.824***(.256)	.646**(.228)	1.096***(.241)	.800***(.220)
_cons	-.564 (.649)	.334 (.612)	-1.395 (.595)	.224 (.555)
N = 300 Wald chi2 (56) = 126.83*** Log likelihood = -553.38				
Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0: chi2 (6) = 42.56 Prob > chi2 = 0.0000				

Note. Regression coefficient is significant for coefficients: $p^{*}<.10$ $p^{**}<.05$; $p^{***}< .01$.

The strongest predictor of respondent's adoption of the full ISFM technologies is agroecologicalzone recording an odds ratio of 12.45 and 11.93 for Jasikan and Hohoe agroecological zones respectively. This indicated that farmers in Jasikan and Hohoe who adopted the full ISFM technologies are about 11 times more likely to adopt the full ISFM technologies than farmers in kadjebi, adjusting for all other variables in the model. Smallholder farmers in agroecological zones with degraded farmlands are more likely to adopt ISFM technologies (Assefa and Hans-Rudol, 2016; Lahmar et al., 2012). Greater proportion of the farmers in Hohoe and Jasikan reported their farmlands to be degraded than those in Kadjebi. This observation is not surprising since the two agroecological zones, Hohoe and Jasikan, are more populated and hence more likely to be degraded than those in Kadjebi (GSS, 2014). In unexpected direction, land ownership has been found to have significant negative relationship with the adoption of the full ISFM technologies (Fosu-Mensah et al., 2012). The finding could be attributed to the fact that cocoa is the main cash crop in the study area (MoFA, 2019). Because cocoa is a perennial crop, it is often grown by farmers who own lands. When the smallholder farmers own farmlands, they might more likely divert them to cocoa production.

3.18.3. Determinants of the adoption of ISFM technologies

Previous studies show that farmers do not always adopt a complete package of a technology even when extension service attempts to promote innovative technologies. They instead adopt a part or components of a recommended technology (AGRA, 2015; Aura, 2016; Mulwa et al., 2017). The probability of adopting a part or multiple bundles of the ISFM technologies is jointly estimated using multivariate probit. The likelihood ratio test is significant: χ^2 (6) = 42.56; ρ = 0.000. This implies the equations (models) are independent, and the use of MVP models is justified for capturing a wider effect than a single probit model. The significant null likelihood ratio tests for all the models suggest that the farmers jointly adopted multiple of the four ISFM technologies. The marginal effects of the explanatory variables were computed to predict the probabilities change in dependent variables as the independent variable changes. The values of the computed marginal effects are found to be same as the coefficient estimates (b) of the MPV models (data not shown). Previous studies have shown that technology adoption may be influenced by individual, institutional factors, and farm characteristics (Ashraf et al., 2014; Ghimire et al., 2015; Ndlovu et al., 2014; Rogers, 2003). The computed correlation coefficients of the independent determinants in the probit model show inconsistent significant relations to the adoption of the multiple ISFM technologies, zero or minimum tillage, inorganic fertilizer, leguminous crop and crop rotation (Table 6). Previous studies on ISFM technologies adoption have been found to show similar patterns of varying values of correlation coefficients for predictor variables (Arslan et al., 2014; Bonabana et al., 2016; Murendoa et al., 2016). One or more of the independent variables including purpose of farming, land ownership, distance from house to the nearest input shop, obtaining credit and agroecological zone have been found to significantly influence the adoption of the multiple ISFM technologies.

Smallholder farmers often engage in farming enterprise to produce enough for consumption and/or for sale. Most farmers in this study cited their main farming purpose as commercial. Interestingly, the main purpose of farming has a positive and significant effect on respondents' adoption of zero or minimal tillage. The farmers' likelihood to adoption the zero or minimal tillage may increase by 0.65 times due to their main purpose of farming. A farmer's engagement in any form of agriculture enterprise requires the management of various types of risk, such as soil degradation, or taking the opportunity to adopt innovative, yield-increasing technologies. The farmers were more likely to practice zero or minimum tillage to prevent soil erosion and thereby increases crop (Achterbosch et al., 2014).

Previous studies indicate that land ownership has a positive effect on a technology adoption (Fosu-Mensah et al., 2012). The results of the current study show significant negative associated between land ownership and the adoption of the zero or minimal tillage. The coefficient value of -0.66 for land ownership means farmers likelihood to practice zero or minimal tillage will decrease by 0.66 times. The unexpected negative coefficients could be explained by the fact that cocoa is the main cash crop in the study area (MoFA, 2019). Because cocoa is a perennial crop, it is often grown by farmers who own land. Most farmers in Ghana do not own farmland and therefore tend to grow arable crops including cereals and legumes. When the smallholder farmers own farmland, they may divert it to cocoa production. However, land preparation for cocoa production often involves heavy tillage including clearing of undergrowth, felling of trees and stumping. Thus, land ownership may cause farmers to divert to cocoa farming with less zero r minimal tillage. Many studies have reported a positive association between getting financial resource and technology adoption (Nhemachena

et al., 2014; Tesfaye and Seifu, 2016). The result of the study shows positive significant correlation (0.65) between getting fund and adoption of maize-cowpea rotation. The positive significant correlation between getting fund and adoption of maize-cowpea rotation implies that farmers having fund would more likely increase their adoption of maize-cowpea rotation since they readily have money to purchase farm inputs including cowpea seed.

The coefficient for distance from house to the nearest input shop is 0.02 and has a significant positively correlation to the adoption and use of inorganic fertilizer. Ordinarily, the further the input shop from the farmer's house, the less the likelihood of the farmers adopting the new technologies, because of the extra transactional costs involved in doing so. The unexpected positive coefficient for distance from house to the nearest input shop could be explained by the fact that the study respondents often buy their agro-inputs from a specific shop called "One Shop Center". The "One Shop Center" is a special agro-input shops built by Africare in Hohoe and Jasikan districts for the farmers. Because the farmers own these shops, they are willing to travel any distance to buy inputs from these shops. Literature shows that the nature of agroecology can have a negative or positive effect on the adoption of ISFM technologies (Lahmar et al., 2012). It is expected that farmers in districts with farmland more relatively degraded are more likely to adopt the ISFM technologies. Most farmers in both Jasikan (Agroecologicalzone1) and Hohoe (Agroecologicalzone2) districts reported of their farmlands being degraded, compared to those at Kadjebi (data not shown). The econometric results show that farmers in Agroecologicalzone1 and Agroecologicalzone2 are more likely to adopt the zero or minimal tillage, inorganic fertilizes, leguminous crop and crop rotation.

Generally, the correlation coefficients of the probit model show that the adoption of the multiple ISFM technologies does not provide common determinants.

4. Conclusion

This paper assesses factors that affect the adoption of full and multiple ISFM technologies by smallholder farmers in three districts Ghana. The result revealed that only 26.7% of the respondents adopted the full ISFM technologies. This confirmed previous findings that farmers do not often adopt a complete package of a technology. Agroecological zone with its farmlands being degraded has been found to significantly influence farmers adoption of the full ISSFM technologies. Instead of adopting the full ISFM technologies, majority of the smallholder farmers adopted parts of the recommended technology. One or more of the independent variables including main purpose of farming, land ownership, distance from house to the nearest input shop, getting credit and agroecologicalzone have been found to significantly influence the adoption of the multiple ISFM technologies. The computed correlation coefficients of the independent determinants in the probit model show inconsistent significant relations to the adoption of the four ISFM technologies, zero or minimum tillage, inorganic fertilizer, leguminous crop and crop rotation (Table 6). Five out of six bundles of ISFM technology adoption options complement one other, since most of the correlation coefficients are positive. The implication of this finding is that the adoption of multiple ISFM technologies cannot be predicted using common determinants. **T**herefore, extension service in the region should focus on crucial factors that influence adoption of the multiple ISFM technologies and in addition emphasizes the complementarities between the technologies to widen farmers' adoption options.

Declarations

Author contribution statement

Moses Kwadzo: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Emmanuel Quayson: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data will be made available on request.

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The authors declare no conflict of interest.

Additional information

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UNIVERSITY OF CAPE COAST

SUMMARY REPORT ON STUDENTS' APPRAISAL OF COURSES & TEACHING (SANDWICH PROGRAMMES)

Name of Lecturer	DR. MOSES KWADZO	Year	1
Course Code & Title	NSM 808S: PROJECT DESIGN, IMPLEMENTATION, MONITORING AND EVALUATION		
No. of Students in Class	7	No. of Respondents	6
Department that mounted the course	AGRICULTURAL ECONOMICS AND EXTENSION	Date of Assessment	10/07/2017
Status	FULL-TIME	No. of Lecturers	1

CORE AREAS		WEIGHTED AVERAGE RATING	MEAN RATING	REMARK	GRAND MEAN RATING	GRAND MEAN REMARK
COURSE CONTENT	Course content based on outline provided	4.00	4.00	VERY GOOD	3.99	VERY GOOD
	Course content likely to be covered	4.00				
	Detailed course content	4.00				
ATTENDANCE	The Lecturer was regular	4.00	4.00	VERY GOOD		
	The Lecturer was punctual	4.00				
	The Lecturer stayed up to the end of class	4.00				
MODE OF DELIVERY	Knowledge of the subject matter	4.00	3.95	VERY GOOD		
	Well organised & systematic	4.00				
	Effective communication	4.00				
	Used class time to fully promote teaching and learning	3.83				
	Encouraged independent study	4.00				
	Encouraged students to analyse issues from different perspectives	4.00				
	Accepted other view points	3.83				
	Made room for questions and discussions	4.00				
	Responses to questions were appropriate and informative	3.83				
	Genuinely concerned with students academic progress	4.00				
ASSESSMENTS	Graded assessments	4.00	4.00	VERY GOOD		
	Graded assessments returned in a good time	4.00				
	Graded assessments were subsequently discussed in class	4.00				

NUMBER OF ASSESSMENT(S) GIVEN		2 or more		
MODE OF ASSESSMENTS USED		Assignments, Presentation, Term Paper		
COURSE OUTLINE	% OF STUDENTS HAVING	100.00	% OF STUDENTS NOT HAVING	0.00

The key for interpretation of the ratings:

1.00 - 2.00 - Very Unsatisfactory
2.01 - 2.49 - Unsatisfactory
2.50 - 2.99 - Satisfactory
3.00 - 3.59 - Good
3.60 - 4.00 - Very Good

Course taught by: Lecturer alone

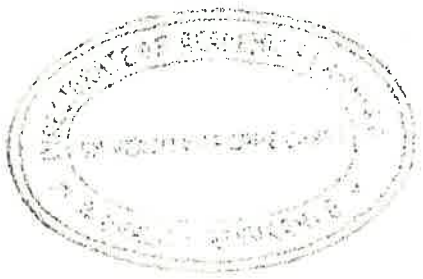
LECTURER'S STRENGTH(S): Used relevant illustrations to enhance understanding

LECTURER'S WEAKNESS(ES): Nil

OFFICE OF ACADEMIC PLANNING & QUALITY ASSURANCE
DIRECTOR

UNIVERSITY OF CAPE COAST						
SUMMARY REPORT ON STUDENTS' APPRAISAL OF COURSES & TEACHING (REGULAR PROGRAMMES)						
NAME OF LECTURER	MOSES KWADZO			YEAR	2017/2018	
COURSE CODE & TITLE	NCD809: TOPICAL ISSUES ON NGOs AND COMMUNITY DEVELOPMENT(GROUP 000)					
NO. OF STUDENTS IN CLASS	7	NO. OF RESPONDENTS	7			
DEPARTMENT THAT MOUNTED THE COURSE	AGRICULTURAL ECON. AND EXT. DEPT.	DATE OF ASSESSMENT	APRIL, 2018			
STATUS	FULL-TIME	NO. OF LECTURERS	1			
CORE AREAS		WEIGHTED AVERAGE RATING	MEAN RATING	REMARK	GRAND MEAN RATING	GRAND MEAN REMARK
COURSE CONTENT	Course content based on outline provided	3.14	3.29	GOOD	3.61	VERY GOOD
	Course content likely to be covered	3.43				
	Detailed course content	3.29				
ATTENDANCE	The lecturer was regular	2.71	3.52	GOOD		
	The lecturer was punctual	3.86				
	Lecturer stayed up to end of class	4				
MODE OF DELIVERY	Knowledge of the subject matter	3.29	3.63	VERY GOOD		
	Well organised and systematic	3.29				
	Effective communication	3.29				
	Fully promote teaching and learning	3.57				
	Encouraged independent study	4				
	Encouraged students to analyse issues from different perspectives	3.86				
	Accepted other view points	3.71				
	Made room for questions and answers	3.86				
	Responses to questions were appropriate and informative	3.71				
	Concerned with academic progress of students	3.71				
ASSESSMENT	Graded assessments	4	4	VERY GOOD		
	Graded assessments returned in good time	4				
	Discussed graded assessments	4				
COURSE OUTLINE	% OF STUDENTS HAVING	100%		% OF STUDENTS NOT HAVING		0%

The key for interpretation of the ratings:
1.00 - 2.00 - Very Unsatisfactory
2.01 - 2.49 - Unsatisfactory
2.50 - 2.99 - Satisfactory
3.00 - 3.59 - Good
3.60 - 4.00 - Very Good



UNIVERSITY OF CAPE COAST

SUMMARY REPORT ON STUDENTS' APPRAISAL OF COURSES & TEACHING (REGULAR PROGRAMMES)

Name of Lecturer	DR. MOSES KWADZO	**Semester**	1
Course Code & Title	NCD 805: HUMAN RESOURCE MANAGEMENT		
No. of Students in Class	4	**No. of Respondents**	4
Department that mounted the course	AGRIC. ECONOMICS AND EXTENSION	**Date of Assessment**	17/11/2016
Status	FULL-TIME	**No. of Lecturers**	1

CORE AREAS		WEIGHTED AVERAGE RATING	MEAN RATING	REMARK	GRAND MEAN RATING	GRAND MEAN REMARK
COURSE CONTENT	Course content based on outline provided	3.75	3.67	VERY GOOD	3.75	VERY GOOD
	Course content likely to be covered	4.00				
	Detailed course content	3.25				
ATTENDANCE	The Lecturer was regular	3.50	3.83	VERY GOOD		
	The Lecturer was punctual	4.00				
	The Lecturer stayed up to the end of class	4.00				
MODE OF DELIVERY	Knowledge of the subject matter	3.50	3.50	GOOD		
	Well organised & systematic	3.50				
	Effective communication	3.50				
	Used class time to fully promote teaching and learning	3.75				
	Encouraged independent study	3.75				
	Encouraged students to analyse issues from different perspectives	4.00				
	Accepted other view points	4.00				
	Made room for questions and discussions	3.25				
	Responses to questions were appropriate and informative	3.00				
	Genuinely concerned with students academic progress	2.75				
ASSESSMENTS	Graded assessments	4.00	4.00	VERY GOOD		
	Graded assessments returned in a good time	4.00				
	Graded assessments were subsequently discussed in class	4.00				

NUMBER OF ASSESSMENT(S) GIVEN		2 or more	
MODE OF ASSESSMENTS USED		Assignments and Presentation	
COURSE OUTLINE	**% OF STUDENTS HAVING**	**100.00**	**% OF STUDENTS NOT HAVING** **0.00**

The key for interpretation of the ratings:
1.00 - 2.00 - Very Unsatisfactory
2.01 - 2.49 - Unsatisfactory
2.50 - 2.99 - Satisfactory
3.00 - 3.59 - Good
3.60 - 4.00 - Very Good

Course taught by: Lecturer Alone

LECTURER'S STRENGTH(S): Good communication skills

LECTURER'S WEAKNESS(ES): Nil

DIRECTORATE OF ACADEMIC PLANNING & QUALITY ASSURANCE
DIRECTOR

UNIVERSITY OF CAPE COAST

SUMMARY REPORT ON STUDENTS' APPRAISAL OF COURSES & TEACHING (REGULAR PROGRAMMES)

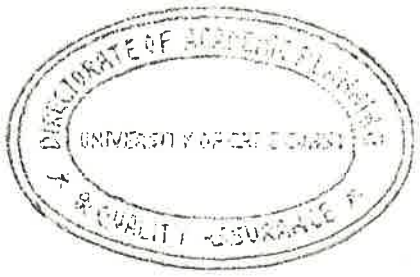
NAME OF LECTURER	DR. MOSES KWADZO	YEAR	2018/2019
COURSE CODE & TITLE	AEX201A: RURAL SOCIOLOGY AND AGRICULTURAL EXTENSION(GROUP 000)		
NO. OF STUDENTS IN CLASS	57	NO. OF RESPONDENTS	50
DEPARTMENT THAT MOUNTED THE COURSE	AGRICULTURAL ECON. AND EXT. DEPT.	DATE OF ASSESSMENT	NOVEMBER, 2018
STATUS	FULL-TIME	NO. OF LECTURERS	1

CORE AREAS		WEIGHTED AVERAGE RATING	MEAN RATING	REMARK	GRAND MEAN RATING	GRAND MEAN REMARK
COURSE CONTENT	Course content based on outline provided	3.7	3.69	VERY GOOD	3.73	VERY GOOD
	Course content likely to be covered	3.84				
	Detailed course content	3.54				
ATTENDANCE	The lecturer was regular	3.82	3.82	VERY GOOD		
	The lecturer was punctual	3.84				
	Lecturer stayed up to end of class	3.8				
MODE OF DELIVERY	Knowledge of the subject matter	3.62	3.61	VERY GOOD		
	Well organised and systematic	3.56				
	Effective communication	3.58				
	Fully promote teaching and learning	3.6				
	Encouraged independent study	3.62				
	Encouraged students to analyse issues from different perspectives	3.62				
	Accepted other view points	3.64				
	Made room for questions and answers	3.6				
	Responses to questions were appropriate and informative	3.64				
	Concerned with academic progress of students	3.64				
ASSESSMENT	Graded assessments	3.92	3.79	VERY GOOD		
	Graded assessments returned in good time	3.84				
	Discussed graded assessments	3.6				
COURSE OUTLINE	% OF STUDENTS HAVING	98%		% OF STUDENTS NOT HAVING		2%

The key for interpretation of the ratings:
1.00 - 2.00 - Very Unsatisfactory
2.01 - 2.49 - Unsatisfactory
2.50 - 2.99 - Satisfactory
3.00 - 3.59 - Good
3.60 - 4.00 - Very Good

UNIVERSITY OF CAPE COAST						
SUMMARY REPORT ON STUDENTS' APPRAISAL OF COURSES & TEACHING (REGULAR PROGRAMMES)						
NAME OF LECTURER	MOSES KWADZO				YEAR	2017/2018
COURSE CODE & TITLE	ABU207. ORGANISATIONAL BEHAVIOUR(GROUP 000)					
NO. OF STUDENTS IN CLASS	37	NO. OF RESPONDENTS		37		
DEPARTMENT THAT MOUNTED THE COURSE	AGRICULTURAL ECON. AND EXT. DEPT	DATE OF ASSESSMENT		APRIL, 2018		
STATUS	FULL-TIME	NO. OF LECTURERS		1		
CORE AREAS		WEIGHTED AVERAGE RATING	MEAN RATING	REMARK	GRAND MEAN RATING	GRAND MEAN REMARK
COURSE CONTENT	Course content based on outline provided	3.76	3.73	VERY GOOD	3.78	VERY GOOD
	Course content likely to be covered	3.81				
	Detailed course content	3.62				
ATTENDANCE	The lecturer was regular	3.76	3.83	VERY GOOD		
	The lecturer was punctual	3.86				
	Lecturer stayed up to end of class	3.86				
MODE OF DELIVERY	Knowledge of the subject matter	3.7	3.62	VERY GOOD		
	Well organised and systematic	3.59				
	Effective communication	3.68				
	Fully promote teaching and learning	3.57				
	Encouraged independent study	3.59				
	Encouraged students to analyse issues from different perspectives	3.62				
	Accepted other view points	3.62				
	Made room for questions and answers	3.65				
	Responses to questions were appropriate and informative	3.57				
	Concerned with academic progress of students	3.59				
ASSESSMENT	Graded assessments	4	3.93	VERY GOOD		
	Graded assessments returned in good time	3.89				
	Discussed graded assessments	3.89				
COURSE OUTLINE	% OF STUDENTS HAVING	100%		% OF STUDENTS NOT HAVING		0%

The key for interpretation of the ratings:
1.00 - 2.00 - Very Unsatisfactory
2.01 - 2.49 - Unsatisfactory
2.50 - 2.99 - Satisfactory
3.00 - 3.59 - Good
3.60 - 4.00 - Very Good



UNIVERSITY OF CAPE COAST

SUMMARY REPORT ON STUDENTS' APPRAISAL OF COURSES & TEACHING

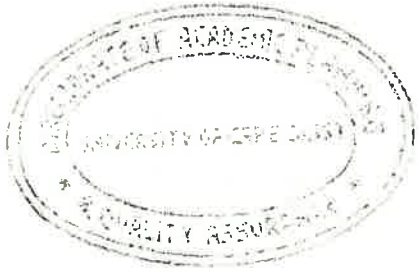
NAME OF LECTURER	MOSES KWADZO	YEAR	2017/2018
COURSE CODE & TITLE	ALX404N: MANAGEMENT OF EXTENSION ORGANISATIONS(GROUP 000)		
NO. OF STUDENTS IN CLASS	20	NO. OF RESPONDENTS	17
DEPARTMENT THAT MOUNTED THE COURSE	AGRICULTURAL ECON. AND EXT. DEPT.	DATE OF ASSESSMENT	APRIL, 2018
STATUS	FULL-TIME	NO. OF LECTURERS	1

CORE AREAS		WEIGHTED AVERAGE RATING	MEAN RATING	REMARK	GRAND MEAN RATING	GRAND MEAN REMARK
COURSE CONTENT	Course content based on outline provided	3.65	3.74	VERY GOOD	3.83	VERY GOOD
	Course content likely to be covered	3.82				
	Detailed course content	3.76				
ATTENDANCE	The lecturer was regular	3.65	3.86	VERY GOOD		
	The lecturer was punctual	3.94				
	Lecturer stayed up to end of class	4				
MODE OF DELIVERY	Knowledge of the subject matter	3.65	3.72	VERY GOOD		
	Well organised and systematic	3.76				
	Effective communication	3.82				
	Fully promote teaching and learning	3.82				
	Encouraged independent study	3.82				
	Encouraged students to analyse issues from different perspectives	3.65				
	Accepted other view points	3.65				
	Made room for questions and answers	3.71				
	Responses to questions were appropriate and informative	3.59				
	Concerned with academic progress of students	3.71				
ASSESSMENT	Graded assessments	4	4	VERY GOOD		
	Graded assessments returned in good time	4				
	Discussed graded assessments	4				
COURSE OUTLINE	% OF STUDENTS HAVING	100%		% OF STUDENTS NOT HAVING		0%

The key for interpretation of the ratings:
1.00 - 2.00 - Very Unsatisfactory
2.01 - 2.49 - Unsatisfactory
2.50 - 2.99 - Satisfactory
3.00 - 3.59 - Good
3.60 - 4.00 - Very Good

UNIVERSITY OF CAPE COAST						
SUMMARY REPORT ON STUDENTS' APPRAISAL OF COURSES & TEACHING (REGULAR PROGRAMMES)						
NAME OF LECTURER	MOSES KWADZO				YEAR	2017/2018
COURSE CODE & TITLE	AEX426: SOCIAL CHANGE AND COMMUNITY DEVELOPMENT(GROUP 000)					
NO. OF STUDENTS IN CLASS	20	NO. OF RESPONDENTS		17		
DEPARTMENT THAT MOUNTED THE COURSE	AGRICULTURAL ECON AND EXT DEPT.	DATE OF ASSESSMENT		APRIL, 2018		
STATUS	FULL-TIME	NO. OF LECTURERS		1		
CORE AREAS		WEIGHTED AVERAGE RATING	MEAN RATING	REMARK	GRAND MEAN RATING	GRAND MEAN REMARK
COURSE CONTENT	Course content based on outline provided	3.76	3.82	VERY GOOD	3.87	VERY GOOD
	Course content likely to be covered	3.82				
	Detailed course content	3.88				
ATTENDANCE	The lecturer was regular	3.71	3.9	VERY GOOD		
	The lecturer was punctual	4				
	Lecturer stayed up to end of class	4				
MODE OF DELIVERY	Knowledge of the subject matter	3.88	3.77	VERY GOOD		
	Well organised and systematic	3.82				
	Effective communication	3.59				
	Fully promote teaching and learning	3.82				
	Encouraged independent study	3.76				
	Encouraged students to analyse issues from different perspectives	3.82				
	Accepted other view points	3.76				
	Made room for questions and answers	3.82				
	Responses to questions were appropriate and informative	3.71				
	Concerned with academic progress of students	3.71				
ASSESSMENT	Graded assessments	4	4	VERY GOOD		
	Graded assessments returned in good time	4				
	Discussed graded assessments	4				
COURSE OUTLINE	% OF STUDENTS HAVING	100%		% OF STUDENTS NOT HAVING		0%

The key for interpretation of the ratings:
1.00 - 2.00 - Very Unsatisfactory
2.01 - 2.49 - Unsatisfactory
2.50 - 2.99 - Satisfactory
3.00 - 3.59 - Good
3.60 - 4.00 - Very Good



UNIVERSITY OF CAPE COAST						
SUMMARY REPORT ON STUDENTS' APPRAISAL OF COURSES & TEACHING (REGULAR PROGRAMMES)						
NAME OF LECTURER	MOSES KWADZO			YEAR	2017/2018	
COURSE CODE & TITLE	ACD309 MANAGEMENT OF COMMUNITY DEVELOPMENT ORGANIZATIONS(GROUP 000)					
NO. OF STUDENTS IN CLASS	35	NO. OF RESPONDENTS		29		
DEPARTMENT THAT MOUNTED THE COURSE	AGRICULTURAL ECON AND EXT DEPT	DATE OF ASSESSMENT		APRIL, 2018		
STATUS	FULL-TIME	NO. OF LECTURERS		1		
CORE AREAS		WEIGHTED AVERAGE RATING	MEAN RATING	REMARK	GRAND MEAN RATING	GRAND MEAN REMARK
COURSE CONTENT	Course content based on outline provided	3.07	3.01	GOOD	3.18	GOOD
	Course content likely to be covered	3.17				
	Detailed course content	2.79				
ATTENDANCE	The lecturer was regular	3.41	3.5	GOOD		
	The lecturer was punctual	3.34				
	Lecturer stayed up to end of class	3.76				
MODE OF DELIVERY	Knowledge of the subject matter	2.97	3.03	GOOD		
	Well organised and systematic	2.76				
	Effective communication	2.83				
	Fully promote teaching and learning	3.03				
	Encouraged independent study	3.24				
	Encouraged students to analyse issues from different perspectives	3.07				
	Accepted other view points	3.1				
	Made room for questions and answers	3.17				
	Responses to questions were appropriate and informative	3				
	Concerned with academic progress of students	3.14				
ASSESSMENT	Graded assessments	3.59	3.17	GOOD		
	Graded assessments returned in good time	3.17				
	Discussed graded assessments	2.76				
COURSE OUTLINE	% OF STUDENTS HAVING	97%		% OF STUDENTS NOT HAVING		3%

The key for interpretation of the ratings:
1.00 - 2.00 - Very Unsatisfactory
2.01 - 2.49 - Unsatisfactory
2.50 - 2.99 - Satisfactory
3.00 - 3.59 - Good
3.60 - 4.00 - Very Good