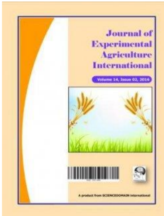

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Assessing Smallholder Farmers' Understanding of Environmental Effects of Modern Agronomic Practices in Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This paper seeks to assess smallholder farmers' level of understanding of the environment effects of modern agriculture.
Study Design: Every second household or homestead was selected from the west to east direction using GPS. Thus, a systematic random sampling technique was employed to solicit the needed information.
Place and Duration of Study: The study was conducted in August 2017 at Dzodze, the District Capital of Ketu North, and its surrounding villages in Ghana.
Methodology: A total of 150 farmers were systematically selected and interviewed using an

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interview schedule guide. Farmers were asked to rank 10 indicator variables on a Likert scale of 1 to 5, with 1 being the least important and 5 being extremely important. To test for the level of agreement and reliability among raters, Cronbach's alpha (α = 0.85) was used. In addition, the Relative Importance Index (RII) was computed for the farmers' ranks of environmental issues associated with modern agriculture. The highest score for all the variables per farmer was 60. This was converted into an index that ranges between 0 and 1. The index was employed in the Tobit regression model to econometrically estimate the effects of the socioeconomic and biophysical attributes on farmers' understanding of environmental issues that are associated with modern agriculture. The Kendall Coefficient of Concordance was used to evaluate the level of agreement for the farmers' rankings of the indicator variables.

Results: The results indicated that individual concordance (W) values were significant at $P < 0.001$. The indicator variables were ranked from the 1^{st} to the 10^{th} positions by the farmers as follows: *Reduce Soil Fertility, Effects Human Health, Reduces Fish Catch, Increases Soil Toxicity, Contaminates Water, Increases Crop Diseases, Causes Soil Compaction, Increase Soil Salinity, Increase Soil Erosion* and *Increases Insect Infestation*; however, the results of the Tobit model indicated that variables such as *Education, Electronic Media, Farm Size and Experienc*e were positive, whereas *Age of Farm Household Head* and *Labour Endowment* were negative and significantly related to smallholders' understanding of the environmental effects of modern agronomic practices.

Conclusion: In conclusion, the study indicates the need for the proactive education of smallholder farmers regarding environmental concerns upon the adoption of modern agriculture technology.

Keywords: Tobit; environmental problems; modern agriculture; agronomic practices.

1. INTRODUCTION

Agriculture in Ghana is primarily dominated by smallholder farming systems. Smallholder agricultural systems (i.e. *Resource-poor farming systems with limited capital, fragmented holdings and limited access to inputs*) produce about 90% of food crops and employ approximately 70% of the labour force in the country [1]. This sector has gradually experienced a shift from traditional agronomic practices to modern scientific agriculture methods. The adoption of modern agriculture increases food crop yields, fibre, and other essential products for industries and has ensured food security and reduced poverty in many rural communities across the globe, particularly in Asia and sub-Saharan African [2,3]. The higher productivity and returns from modern agricultural systems are often achieved at the expense of sustainable agroecological systems. Modern agriculture is characterized by intensification and high input usage. This can lead to negative environmental impacts and social costs [4]. Modern farming systems are suitable for a sociocultural environment with a large proportion of the literate and highly educated farming population along with the adequate provision of extension services [see, 5]. In most developing countries, including Ghana, the farming sector is dominated by smallholder farmers with little or no formal education. This makes it difficult for famers to understanding the science behind the technology packages they have adopted. Modern agriculture requires a high level of calibration in the use of inputs to ensure efficiency. In this regard, formal education is necessary to equip farmers with the skills to access and to process agricultural information as well as to apply this information to enhance on-farm productivity [6,7].

The irony is that modern conventional agriculture meant to improve productivity has more or less displaced traditional agriculture systems and the associated indigenous knowledge that is in harmony with the environment. In addition, modern agriculture has brought about an increase in negative environmental problems, particularly in the tropics. Traditional farming systems have been criticised for contributing to nutrient depletion and deforestation in the tropics [8]; however, these farming systems provide necessary feedback loops that restore the ecosystem balance, unlike conventional agriculture. Traditional agricultural systems in the tropics were the first type of farming systems practiced when early man became sedentary [9,10]. These farming systems had evolved over many millennia to interplay and to converge with ecological, cultural, social, political and economic factors [11,12]. Moreover, the traditional body of ecological knowledge associated with these types of farming systems is adaptive in nature and depicts the beliefs and thought patterns of man's relationship with the environment [13,14]. In Ghana, the indigenous knowledge associated with these farming systems has a direct link with traditional religious philosophy. This philosophy emphasises biophysical resource conservation and sustainable land use [15]. This knowledge is secretly guarded and passed on from generation to generation [16,17]. Many traditional societies in Africa, Latin America and parts of Asia have perceived physical and biological components of the environment and the human populations as being a complex web [14].

In general, agriculture has a direct effect on the environment, and the key difference between traditional and modern farming systems is the factor input-output relationship [18]. Modern (conventional) agriculture stresses input intensification that is primarily not organic in nature. Traditional farming systems' transformation in the tropics should occur within a cultural and economic context that would promote the transition to more sustainable practices. The emergence of environmental consciousness, leading to the creation of a market niche for organically produced plants and animal products, has compelled scientific communities to re-examine the good practices of traditional agricultural systems [19]. This has metamorphosed into current thinking of agro-ecological food systems, which is now the basis of organic farming [19,20].

Over the years, the government of Ghana's agricultural policy had been broad-based, pro-poor agricultural growth [21]. In recent times, the agricultural policy of the current government is captioned "*planting for Food and Jobs, a Campaign for Rapid Growth".* The central premise of this policy is to promote increased growth in food production and to create over 750,000 jobs [22,23]. This policy has five main thrust provisions of subsidised agrochemicals, particularly fertilizer and improved seeds, access to extension services, e-fertilizer and marketing [24]. The focus on the adoption of chemical fertilizer, herbicides and pesticides by smallholder farmers with little or no education needed to understand the environmental effects of the misuse or the over application of agrochemicals is of great concern. The use of inappropriate and unsustainable farming methods for food production as currently envisaged can cause severe soil erosion, pest resistance and resurgences of unknown pests and loss of biodiversity [See 25,26]. This has serious implications for food security and environmental health as well as the poverty reduction strategy and the country's bid to meet Sustainable Development Goals (SDGs). In addition, to ensure socioecological sustainability, there is an urgent need for research to understand farmers' behaviours in relation to the complexity of agricultural systems [27,28,26]. The aim of this study was to investigate farmers' levels of understanding of environmental issues associated with the use of certain modern agronomic practices in lieu of traditional agricultural methods. This information will aid policy-makers and extension professionals in developing appropriate tailored-made training and effective policy instruments to support programmes that encourage a sounder environmental management of agriculture in the country.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in August 2017 at Dzodze, the District Capital of Ketu North, and its surrounding villages. The Ketu North District is located between Latitude 6°03'N and 6°20'N and Longitude 0°49'E and 1°05'E. It shares boundaries with the Akatsi North District to the north, the Keta Municipality to the south-west and the Republic of Togo to the east (Fig. 1).

The study site experiences an average annual temperature of about 30°C with a mean annual rainfall of approximately 1270 mm [29].

The soils in the study area are predominately savannah Ochrosols (WRB: Lexicons/Luvisols) and Interspersed with Lithosol [30,31,32,33]. One of the major economic activities in the district is farming, which contributes to more than 60% of household incomes [34,35]. In the Ketu North District, approximately 75.8% of its population is also rural. The major ethnic groups found in the district are Ewes, Akans, Ga-Adangbe and Guan. The predominant tribe is Ewe (98.2%) [36].

2.2 Data Collection and Sampling Procedure

A systematic random sampling technique was employed to select 150 households from five suburbs within Dzodze Township. The sampling procedure involved walking from the west to east direction using GPS. The first household encountered in the community was ignored, and the second was sampled in this sequence. Thus, every second household or homestead in the west to east direction was selected for the administration of the test item, or questionnaire. The questionnaire is comprised of structured (based on a Likert format or scale) and semi-structured (open-ended) questions, which were used to interview the respondents and to elicit demographic, biophysical and socioeconomic data. The interviews were limited to de-facto or de-jure household heads. The number of household heads interviewed in each suburb was as follows: *Ablorme* (n=40), *Adegbledu* (n=40), Afetefe (n=20), *Fiagbedu* (n=25) and *Kpordoave* (n=25).

2.3 Statistics and Analytical Framework

Farmers were asked to rank 10 indicator variables (environmental issues) on an ordinal scale of 1 to 5, with 1 being least important and 5 extremely important. Zero (0) was assigned when the respondent (farmer) was not able to attach any importance to the indicator variable. The highest score for each variable per farmer was 50, and this was converted into an index that ranged between 0 and 1.The index was used as an endogenous variable in the Tobit regression model to econometrically estimate the influence of socio-demographic and economic attributes on

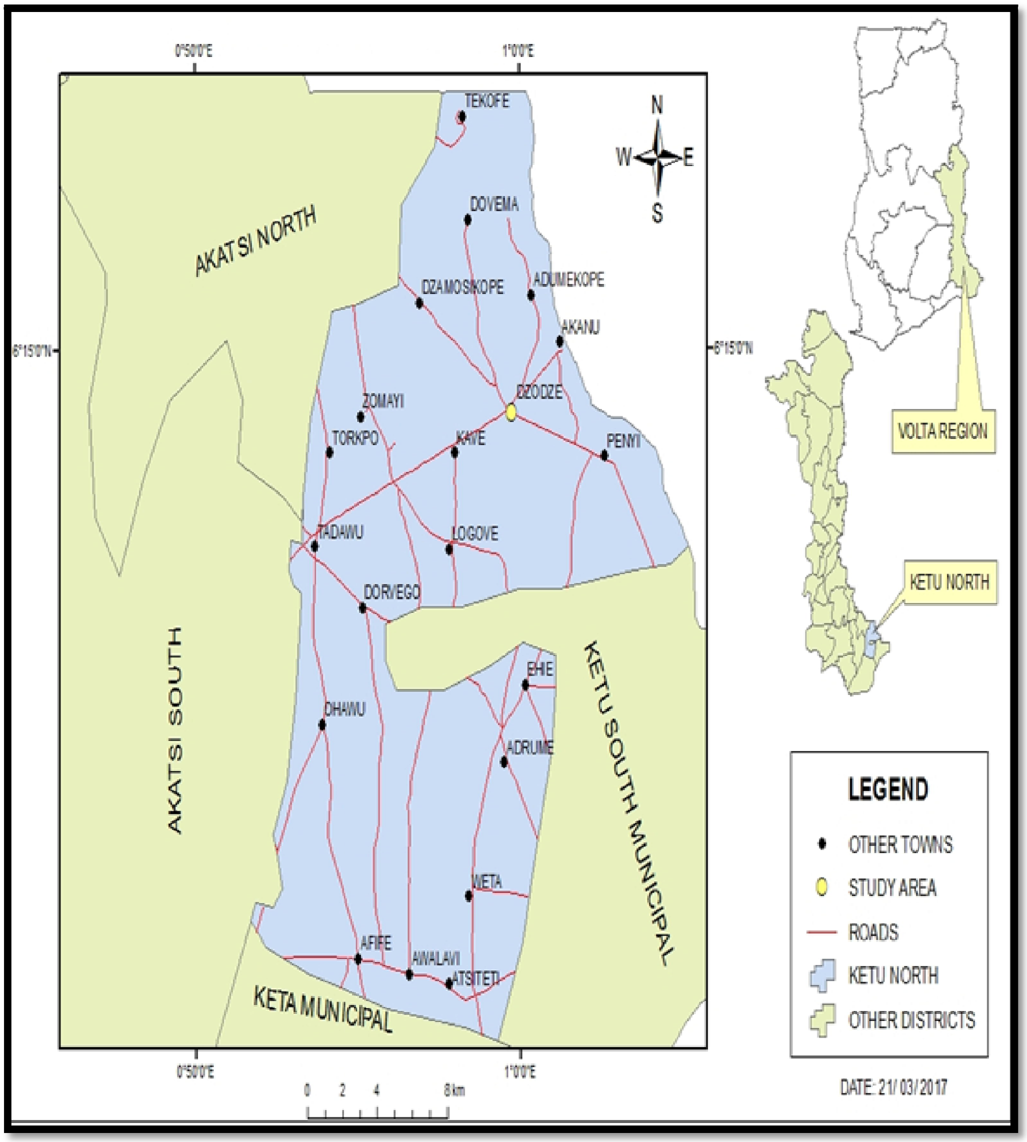

Fig. 1. Map of the study area

farmers' perceptions and understanding of environmental issues associated with modern agriculture. The Kendall Coefficient of Concordance was used to evaluate the level of agreement in the rank scores of the indicator variables ranked by farmers. In addition, Cronbach's alpha was employed to assess the consistency and reliability of the results based on the Likert scale estimation [37]. The relative Importance Index (RII) used was a modified procedure adopted from Enshassi et al. [38] and was computed as follows:

$$RII = (R_0 * 0) + (R_1 * 1) + (R_2 * 2) + (R_3 * 3) + (R_4 * 4) + (R_5 * 5) \quad (1)$$

Where R_0 = number of farmers who answered 'Not Important'

R_1 = number of farmers who answered 'Least Important'

R_2 = number of farmers who answered 'Moderately Important'

R_3 = number of farmers who answered 'Important'

R_4 = number of farmers who answered 'Very Important'

R_5 = number of farmers who answered 'Extremely Important'

The RII was assessed based on how the individual farmer perceived or understood the environmental problems associated with conventional agronomics practices from a set of questions. The Tobit stochastic modelling framework assumes that for an individual level of the understanding of environmental problems associated with modern agriculture, there is an index in the form of a linear function with sets of explanatory variables [39,40,41,42]:

$$Y_i = \beta X_i + \phi_i \quad (i = 1,2,3,4..........\,...N) \quad (2)$$

where Y_i denotes the index of understanding of environmental problems associated with modern agronomic practices. In addition, Y_i captures the latent unobserved component of the index with the $(1x1)$ vector, and β is the $(Kx1)$ vector of the unknown parameter estimates and X_i is the $(Kx1)$ vector of the independent variables constituting technology attributes, farm biophysical and farmer-specific socio-economic characteristics of the household [41,42]. ϕ is the error term considered to be a random variable with a mean of zero and a constant variance of σ^2 distributed normally over the population of farming households [39,40]. N is the number of observations representing individual farming households interviewed within the community. The conditional terms of farmers' levels of understanding of environmental problems are defined as follows [43]:

$$Y_i = \begin{cases} 0 & if \quad Y^{\#} \leq 0 \\ Y^{\#} & if \quad 0 < Y^{\#} < 1 \\ 1 & if \quad Y^{\#} \geq 1 \end{cases} \qquad (1 = 1.2....N) \quad (3)$$

Based on the conditional terms or the probability of farmers' levels of understanding of environmental issues, the highest rating or observation of an environmental problem associated with modern agriculture occurs when the index Y_i falls within $0 < Y^{\#} \leq 1$, and the lowest rating or no noticeable environment impact is observed on the part of the farmer when $Y^{\#} \leq 0$ [7]. The upper limit of the index Y is 1, and the lower limit is 0.The operationalised Tobit model is specified as follows:

$$Y_i = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + ...\beta_n X_n \quad (4)$$

where X(s) are the socioeconomic and biophysical characteristics (variables) of farm households and β(s) are the parameter estimates of the variables.

2.4 The Empirical Model

The empirical model within the Tobit framework used to determine the factors that influence farmers' understanding of environmental problems associated with conventional (modern) agriculture is specified as:

$$\begin{aligned} Perception\ /Unders\tan ding &= \beta_0 + \beta_1 Education + \beta_2 Eclectroni\ cMedia + \beta_3 FarmSize + \\ &\beta_4 Age + \beta_5 TypeOfCrop\ Cultivated + \beta_6 Experience + \beta_7 SocialCapi\ tal + \\ &\beta_8 LabourEndo\ wment + \beta_9 HouseholdS\ ize + \beta_{10} Gender + \varepsilon \end{aligned} \quad (5)$$

The estimated empirical Tobit model used sets of biophysical and socioeconomic characteristics as explanatory variables that were assumed to influence farmers' levels of understanding of environmental problems associated with conventional agriculture's agronomic practices. Detailed descriptions of the characteristics of the explanatory variables and their hypothesised signs are given in Table 1. The dependent variable measures farmers' levels of understanding of environmental problems associated with conventional farming practices. This was estimated from ten sets of questions with their corresponding responses measured using a five-point Likert scale. All the parameters in model (5) were estimated using the EViews-10 software package for Windows with the Tobit link function using the Maximum Likelihood Estimator within the framework of the Newton-Raphson optimisation algorithm [44]. For instance, a farmer who scored 50 is equivalent to 1(50/50 = 1), and 40 is equivalent to 0.8 (40/50 = 0.8) on the scale of the index. Education is one behavioural factor that influences decision-making and thought processes. Education reinforces positive environmental behaviours and sound judgements [45]. In addition, it promotes compliance and voluntary action and removes barriers associated with cultural norms that are inimical to good environmental management practices [46,45]. Moreover, the use of on-farm conventional agronomic practices includes a set of rules or instructions to aid in the deployment of such technology. Education therefore provides insights into the workings and technical ramifications of such technologies [47,48,49,50]. Hence, it is hypothesised to be positively related to the level of understanding of problems associated with conventional agriculture and sound environmental management practices.

Electronic media is a variable used to measure whether a farm household had television or a radio set as the household asserted. Electronic media is a proxy of access to information on agriculture and the environment from television and radio broadcasts [51]. Currently, there are several documentaries on the radio and on television that educate the populace regarding environmental management in both local dialects and English [see e.g. 52]. These documentaries invariably increase farmers' awareness of environmental management [53]. Hence, electronic media is hypothesised to be positively related to increased levels of understanding or perceptions of problems associated with modern agronomic practices, or conventional agriculture.

Farm size is a biophysical characteristic that influences farmers' decisions to use agriculture inputs, particularly herbicides, fertilizers and insecticide, as well as the adoption of other farm practices [54,55,56,57]. Farm size influences farmers' decisions related to environmental management practices and values [57]. As the farm size increases, the use of these agrochemicals increases with a corresponding impact on the environment. In the absence of training and education, the use of these agrochemicals may be subjected to abuse or misapplication; however, some studies have maintained that small-scale farmers may have greater concern and values for the environment than large-scale farmers [58,59]. Thus, there is no a priori direction between the variable farm size and farmers' perceptions or understanding of environmental problems associated with modern agronomic practices.

Age can be either positively or negatively related to environmental awareness and the use of modern agriculture technology. The age of the household head has a strong influence on the level of the use of agriculture technology [60,61]. The type of crop cultivated by a farmer determines the choice and the level of agrochemical inputs usage [62,57]. In Ghana, crop farmers practice relatively low input agriculture apart from the usage of herbicides and fertilizers, unlike vegetable crop production, which requires a wide range of agriculture inputs. In general, vegetable production creates a wide range of environment problems [see, 45,63,64]. It is therefore expected that farmers engaged in vegetable production are well-informed of environmental problems associated with their farming practices. Experience was measured as the number of years the household head had been engaged in farming and related activities. Experience was found to strengthen an individual's understanding of the technical and practical ramifications of certain agronomic practices. It was expected that experience would positively influence the farmers' understanding and environmental awareness of problems associated with modern agronomic practices.
Social capital is a function of a social network. In this study, it was captured as a membership to a farming organisation, group or society. Farmers learn environmental management behaviours through social networking with other farmers and the informal sharing of knowledge and know-how [65,66,45]. Social capital strengthens farmers' access to information related to environmental management practices. It is a common practice

for farmers in cooperative societies and agriculture commodities organisations to be provided with education or training on the deployment of novel technology, particularly the application of farming inputs. Social network learning is important in creating awareness and spreading new novel information amongst farmers [67,68]. Labour endowments and household size are functions of household labour availability. Labour endowment was measured as the number of individuals in the household with an age equal to or greater than eighteen years (age ≥18 years). Labour availability influences farmers' decisions to use various agronomic practices. In agrarian societies, households depend on their own labour endowment for farm activities, particularly under conditions in which labour markets do not function effectively [69]. Households with a large family size and more available labour endowments use or adopt labour intensive agronomic practices [70].

In the absence of available labour, there is a likelihood that farmers will substitute labour with capital intensive agronomic practices, such as using herbicide to control weeds instead of cutlass and applying conversional fertilizers instead of farm yard manure. Alternatively, farm households may decide not to use technologies or agronomic methods that would require more labour at any specific time, such as land preparation or weeding, than the household can provide [69]. Hence, the relationship between labour availability and farmers' levels of environmental awareness is inconclusive.

Gender is a dummy variable that indexes a social role rather than the sex of the household head. Male was coded 1 and female 0 in the study [71]. In sub-Saharan Africa, male smallholder farmers are more resource-endowed than their female counterparts. This stems from cultural and traditional barriers. Hence, most female farmers are more or less marginalised [72]. The social roles played by males and females in agricultural production in Ghana varies from one tribe to another. This also manifests in the body of indigenous knowledge possessed by women. Rural female farmers' environmental and gender-specific knowledge is dictated by the males [73]. This places pressure on the females, subjecting them to the behavioural and thought patterns of their male counterparts. Due to differences in social roles in the agrarian society, most female subsistence farmers have different technological needs [74]. In Ghana, the processing, handling and marketing of agricultural products are viewed as the females' responsibilities. The on-farm division of labour and food crop production specialisation are the areas the gender role affects the most. For instance, among the Brongs

Table 1. Socioeconomic factors hypothesised to influence farmers' understanding of environmental problems

Variable	Description of household characteristics	Value	Hypothesised sign
Education	Years of schooling	Years	(+)
Electronic media	The ownership of either a radio or a television set as a household asset	Yes = 1 No = 0	(+)
Farm size	Total farm area under crop cultivation or animal husbandry	Acre (1 acre = 0.41 hectare)	(-)(+)
Age	Age of the farm household head (either de facto or de jury)	Years	(+)(-)
Type of crop cultivated	Dummy variable	Vegetables =1 Otherwise = 0	**(+)**
Experience	Number of years of farming experience for the household head	Years	(+)
Social capital	Membership to social group/cooperative organization /social group	Yes= 1 No = 0	(+)
Labour endowment	Total number of household members of an age greater than or equal to 18 years	Number	(+)
Household size	Total number of household members: individuals eating from common cooking pot	Number	(-)(+)
Gender	Social roles in the community	Male =1 Female=0	(+)

ethnic group and some tribes in the northern regions of Ghana, vegetable production is the domain of the females [75]. Thus, the specific social roles played by an individual household head, either de-facto or de-jury household head, in the on-farm production process invariably influences his or her understanding of environmental problems associated with certain on-farm agronomic practices.

3. RESULTS AND DISCUSSION

3.1 The Results of Farmers' Rating on an Ordinal Scale

The results showed a high level of agreement in the rating or ranking among the household heads with respect to indicator questions and their corresponding responses according to the Kendall Coefficient of Concordance (W) of 0.86 (Chi-square 128.96; DF = 9; $P < 0.001$). In addition, the results revealed a high degree of consistency and reliability of the Likert ordinal scale instrument used in the analysis. The Cronbach's Alpha (**α**) was 0.85 (see Table 2). The ten questions aimed to determine the farm household heads' understanding of environmental problems, and the indicator that recorded the highest responses was 'reduce soil fertility'. Reduced soil fertility is viewed as a major problem associated with modern agronomic practices. For reduce soil fertility, the recorded Relative Importance Index (RII) was 504, and the mean ranking was 7.5 based on the analysis of the Kendall Coefficient of Concordance. This was followed by 'Effects on human health'. Effects on human health had an RII value of 498 and a mean rank of 7.33, and it was second on the list of indicators. Many farm household heads associated ill-health and their general well-being with modern agriculture. The majority of the house heads maintained that modern agricultural methods or agronomics practices have contributed to a reduction in fish catches in major river bodies. This response, or indicator, had a recorded RII of 423 and a mean rank of 6.35; however, the result revealed that 'increase insect infestation' was least associated with modern agronomic practices by farm household heads interviewed. This indicator variable recorded a mean rank of 4.89 from the Kendall Coefficient of Concordance analysis and an RII value of 290, and it was tenth on the list of environmental problems associated with modern agronomic practices; however, most respondents gave relatively low ratings or low priority to environmental problems such as soil compaction, increase soil salinity, increase soil and erosion.

3.2 The Results of the Empirical Model

The empirical results of the Tobit model revealed that education significantly ($P < 0.0001$) increased the farmers' levels of understanding environmental problems (Table 3). The parameter estimate of education was positively related to farmers or household heads' levels of understanding and perceptions of environmental issues. Interestingly, electronic media was positive and statistically significant ($P < 0.0001$) as hypothesised (Table 1). One of the variables that strongly influenced farmers' level of understanding of environmental problems associated with conventional agricultures was farm size. This variable was positive and significant ($P = 0.0006$). The age of the household heads was negative and significantly ($P< 0.0001$) related to understanding associated with modern agriculture; however, there was a positive relationship between 'types of crop cultivated' by the farmers and their worldview of environmental problems associated with agronomic practices of modern agriculture. This was significant ($P= 0.0739$) at the 10% level of probability. Similarly, social capital was positive and significantly related to farmers' perceptions and understanding at the 10% level of probability ($P = 0.0558$); however, it was revealed that labour endowment decreased farmers' level of understanding or perceptions. This variable was negative and statistically significant ($P < 0.0016$). One of the interesting determinants of farmers' level of understanding of environmental issues related to modern agriculture was experience. This predicator was positive and statistically significant ($P < 0.0001$); however, household size and gender were variables identified as not significant.

3.3 Farmers' Ratings of Environmental Problems

This paper examines smallholder farmers' understanding of environmental problems associated with modern agronomic practices. In addition, the study assessed socioeconomic and on-farm biophysical factors that are likely to influence smallholder farmers' level of understanding through the Tobit model econometric estimation. Modern agriculture is input-dependent and relies on many types of agrochemicals, such as fertilizers, pesticides and herbicides. Inappropriate application or a failure to adhere to the strictly recommended dosage guidelines by the manufacturer can lead to environmental pollution and serious consequences for non-target species and the general ecological stability of agroecosystem [76,77]. In this study, the smallholder farmers ranked 'decline soil fertility' as the number one environmental problem associated with modern agriculture. Reduce soil fertility was viewed as a major problem associated with modern agriculture. This result is in line with the work of Rahman [42]. Moreover, it has been documented that traditional farming systems like shifting cultivation and bush fallow can replenish lost nutrients in the soil during inter-fallow breaks [78, 79,80].

This mechanism is absent in modern agriculture, which promotes intensification and increases in agrochemical usage, particularly fertilizers [81,4]. The inability of smallholder farmers to augment lost soil nutrients through artificial fertilizer applications exacerbates the problem. The farmers often resort to nutrient mining, which leads to a further reduction in soil fertility in the long-term [see, 82,83]. One of the underlying causes is the removal subsidy on fertilizers, which makes it exorbitant to smallholder farmers [84] and leads to a reduction in artificial fertilizer usage. Traditional farming systems rely on ecological principles that sustain the balance between nutrient losses and recycling in the environment [77]; however, the link between modern tillage methods and nutrients lost through soil erosion and leaching have been documented, particularly in the tropics [see e.g., 85,8,43]. These numerous factors over a period of time affect the viewpoint of smallholder farmers regarding the negative impacts of modern or conventional agriculture on the environment [86].

The effects of modern agriculture on human health were ranked second on the list of indicator variables used to assess smallholder farmers' level of understanding of environmental problems associated with modern agriculture. Nevertheless, within the community where the study was conducted, the farmers attributed low life expectancy, impotency [87] and certain ailments to modern agriculture and exposure to agrochemicals as well as the quality of nutritional value of food crops, particularly grains and vegetables [e.g. 88]. The consensus view of the farmers was that pesticides pose health risks and environmental hazards. This finding is consistent with the comprehensive review work of Onder et al. [76]. Rahman [42] reported similar findings in a related study on farmers' perceptions of the environmental impacts of modern agricultural technology.

It is becoming a common practice in Ghana for some fishermen to use pesticides and toxic chemicals in illegal fishing [89,90]. This has been a major concern to policy makers in the fishing industry [91]. In this regard, considerable public education and publicity efforts through the media have focused on creating awareness of environmental hazards and health risk implications of using chemicals in fishing [90]. It is not surprising that most farmers linked the reduction in fish stocks in major rivers and streams within the community to modern agriculture and the indiscriminate use of agrochemicals [see, 92]. The farmers ranked reduced fish catch in the third position of the list of indicator variables. In addition, they expressed that run-off from modern or conventional agriculture lands can lead to reductions in the fish population in rivers [see 2,93,94].

The general principle from the perspective of plant protection in agronomy is that the prolonged usage of agrochemicals could lead to pest resurgence and resistance to pesticides as well as to the destruction of beneficial insects [88]; however, in this study, the results revealed that 'increase insect infestation' was rated the lowest on the list of indicator variables of environmental problems associated with modern agronomic practices. In fact, it was tenth on the list. This is contrary to a similar study on the same subject [42]. The possible explanation is that smallholder farmers may find it difficult to establish interlinkages between current pest status, resurgence and the emergence of secondary pests as well the general population dynamics of pests in an agroecosystem due to the usage of agrochemicals, particularly pesticides. Nevertheless, smallholder farmers' indigenous knowledge of the environment and the management of traditional farming systems can play a complementary role in the scientific approach to managing agroecosystems [95].

3.4 Determinants of Farmers' Understanding of Environmental Issues

The parameter estimate of education was positive, indicating that this indicator variable strongly influences smallholder farmers' understanding of environmental issues associated with modern agronomic practices. In fact, education increases farmers' environmental awareness of contemporary issues related to modern agriculture [42]. This result is in line with the initial hypothesis and with the results of other authors on the subject of the adoption of agriculture technology and perception studies [47,48,49,50,96].

Electronic media provides a means for the dissemination of information and educates rural smallholder farmers on current novel agriculture technology. Electronic media and education play complementary roles or act in tandem to improve individual levels of understanding and awareness of agriculture and the environment [51]. Currently, there are several programmes and documentaries on environmental management in both local dialects and English [see e.g. 52]. Thus, it is not surprising that electronic media is positively related to farmers' level of understanding of environmental problems associated with modern agriculture. This result corroborates the study of Ali [53].

In this study, it was observed that as farm size increased, farmers' levels of understanding also increased. There was a positive relationship between farm size and the environmental awareness of the farmers. This finding is in conformity with the result of Welsh and Rebecca [57]. Moreover, the adoption of many agriculture technologies, particularly inputs, depend on farm scale [53,54,56,57]. As farm size increases, the usage of these agrochemicals increases with a corresponding impact on the environment. Nevertheless, other authors have maintained that smallholders have a greater concern for the environment [58,59].

Table 2. Farmers' prioritisation of problems associated with modern agronomic practices

Indicators	♣Responses							Ranking	Mean rank*
	NI	LM	MI	I	VM	EI	RII		
	0	1	2	3	4	5			
Reduces soil fertility	15	13	20	19	21	62	504	**1**	**7.50**
Effects human health	16	8	25	13	39	49	498	**2**	**7.33**
Reduces fish catch	26	9	22	30	35	28	423	**3**	**6.35**
Soil toxicity	40	9	13	17	39	32	402	**4**	**6.23**
Water contamination	39	7	20	26	24	34	391	**5**	**6.20**
Increases crop diseases	39	7	28	19	32	25	373	**6**	**6.06**
Soil compaction	40	10	25	31	26	18	347	**7**	**5.97**
Increases soil salinity	45	12	19	31	23	20	335	**8**	**5.53**
Increases soil erosion	51	9	20	30	26	14	313	**9**	**5.24**
Increase insect infestation	51	16	26	21	21	15	290	**10**	**4.89**

**Kendall Coefficient of Concordance (W^a) = 0.86; Chi-square 128.96; DF = 9; P < 0.001); ♣Cronbach's Alpha (α) = 0.85: The ranking above environmental problems in terms of relative importance on an ordinal scale of 0 (not important/lest) to 5 (extremely important). A zero weight is assigned to a response in which the impact is not recognised. RII denotes Relative Importance Index.5=Extremely Important: EI; 4= Very Important: VM; 3= Important: I; 2= Moderately Important: MI; 1= Least Important: LM; 0= Not Important: NI*

Table 3. Results of the tobit model estimation factors influencing farmers' level of understanding of environmental problems associated with modern agronomic practices

Variable	Coefficient	Standard error	Z-statistic	Prob.
Education	0.016165	0.004046	3.994985***	0.0001
Electronic Media	0.049109	0.008498	5.778709***	0.0001
Farm Size	0.002359	0.000877	3.447742***	0.0006
Age	-0.002359	0.000398	-5.961184***	0.0001
Type of Crop Cultivated	0.037187	0.020809	1.787087*	0.0739
Experience	0.009812	0.000628	15.62621***	0.0001
Social Capital	0.020687	0.010817	1.9112514*	0.0558
Labour Endowment	-0.001816	0.000577	-3.148811***	0.0016
Household Size	0.001187	0.000731	1.622609^{NS}	0.1047
Gender	0.016702	0.011402	1.464919^{NS}	0.1420

*Log likelihood function = 311.03; Average log likelihood= 1.244, LR Chi^2 (11) = 22.361***; Pseudo R^2= 0.6128; Note: ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. NS: not significant*

In this study, it was observed that the variable age of the farm household heads decreased their level of understanding by a factor of 0.2% per unit change in age, which means that younger farmers are more enlightened regarding environmental problems related to agriculture than their older counterparts. Young farmers are more progressive and less conservative in accepting novel technology [60,61]. Hence, younger farmers are predisposed to access information. This attribute improves their level of understanding of environmental issues. Nonetheless, experience and age are two variables that sometimes move together in the same direction. Experience and age in principle should have positive synergetic effects on environmental awareness and the understanding of agronomic problems associated with modern agriculture; however, the direction on the coefficient of age is heuristic. It can be either positive or negative, and in some cases, inconclusive [97,61,13]. In this study, experience was positively related to farmers' levels of understanding of environmental issues related to modern agriculture. This suggests that engaging in farming for several years enables smallholder farmers to accumulate a body of knowledge related to their environment. Experience enables individual farmers to understand the technical ramifications of their day-to-day on-farm operations. In addition, it helps farmers to solve practical problems emanating from modern agronomic principles [75]. This result corroborates the work of Zhang et al. [61] on the use of the fold system for raising sheep in China. Moreover, farmers learn more about the workings of farm technology through experience, which affects their scope of reference [See, 98].

Because gender and household size were insignificant and type of crop cultivated and social capital had low significance levels (probability level of 10%), these indicator variables are not discussed in detail; however, one interesting finding is that labour endowment decreased farmers' level of understanding of issues related to modern agriculture. This suggests that in the absence of available labour farmers, households substitute labour with capital. Capital goods, such as weedicide, replace manual weeding implements (e.g. hoes and cutlass), and animal manure substitutes for inorganic fertilizers [69]. Based on the results, low labour endowment increased smallholder farmers' understanding of environmental issues related to modern agriculture. Rural households with excess labour usually cultivate labour intensive crops, and during the off-seasons, labour is sold in the off-farm labour market to generate income for households [70].

4. CONCLUSION

The combination of indigenous knowledge and a modern scientific farming system could be helpful in achieving food security and a sustainable environment. If policy direction focuses on strengthened, tailor-made educational outreach programmes to disseminate information to smallholder farmers regarding how to deploy on-farm technologies, environmental health could be improved. The use of electronic media has the potential to positively change how information is transferred to farming communities. This paper emphasises the use of electronic media to reach out to rural smallholder farmers and to educate them regarding environmental problems associated with the use of certain agriculture inputs as well as how to deploy such inputs and their associated technology packages. There is a need for a conscientious effort from policy makers to strengthen the capacity of the almost defunct extension services and agricultural education institutions in the country. The disaggregation of farmers based on farm scale will be helpful in designing appropriate tailor-made environmental education packages because farmers with large holdings are more informed about environmental issues related to modern agriculture than farmers with small holdings. In addition, age and experience must be considered as determinants that influence smallholders' environmental awareness. Hence, any policy intervention used to reinforce learning and to improve competencies and skills should be developed in consideration of these policy variables. Educated smallholder farmers can serve as a conduit for the transfer of environmental management information and can act as agents of change through social networks within rural communities. Comprehensive research must be conducted to understand the link between labour endowment and the environmental management strategies of smallholder farmers in agrarian rural communities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chamberlin J. Defining smallholder agriculture in Ghana: Who are smallholders, what do they do and how are they linked with markets? International Food Policy Research Institute (IFPRI) Discussion Paper, GSSP Background Paper 6; 2007.
2. Pereira JL, Antunes CC, Castro BB, Marques CR, Gonçalves AMM, Gonçalves F, Pereira R. Toxicity evaluation of three pesticides on non-target aquatic and soil organisms: Commercial formulation versus active ingredient. Ecotoxicology. 2009;18: 455-463.
3. Gollin D. Smallholder agriculture in Africa: An overview and implications for policy .IIED Working Paper. IIED, London; 2014.
4. Gliessman S. Transforming food systems with agroecology. Agroecol. Sustainable Food Syst. 2006;40(3):187-189.
5. Ashooria D, Bagheria A, Allahyarib MS, Michailidisc A. Understanding the attitudes and practices of paddy farmers for enhancing soil and water conservation in Northern Iran. Inter Soil Water Conserv. Res. 2016;4:260–266.
6. Huffman WE. Human capital: Education and agriculture, in: G.L. Gardner and G.C Rausser. Eds Handbook of Agricultural Economics, Amsterdam, the Netherlands: Elsevier Science. 2001;1B,
7. Baffoe-Asare R, Danquah JA, Annor-Frempong F. Socioeconomic factors influencing adoption of codapec and cocoa high tech technologies among small holder farmers in Central Region of Ghana. Am. J. Exp. Agric. 2013;3(2):277-292.
8. Brown S, Lugo A. Rehabilitation of tropical lands: A key to sustaining development. Restor. Ecol. 1994;2(2):97-111.
9. McTavish EJ, Decker JE, Schnabel RD, Taylor JF, Hillis M. New World cattle show ancestry from multiple independent domestication events. Proc. Natl. Acad. Sci. U.S.A. 2013;110: E1398–406.
10. Katherine H. Humans feasting on grains for at least 100,000 years. Scientific American; 2009.
    Available:https://blogs.Scientificamerican.com/observations/humans-feast ing-on-grains-for-at-least-100000-years/
    (Accessed April 28, 2018)
11. Ofori BD, Ayivor JS. Pabi, Gordon C. Agroecological niches as ecosystem-based adaptive option to environmental change in the forest-savanna transition zone of Ghana. J. Sustainable Dev. 2015; 8(9):281-292.
12. Eileen SJ. Ecological systems and complexity theory: Toward an alternative model of accountability in education. Complicity: Int. J. Complexity Edu. 2008; 5(1):1-10.
13. Berkes F, Colding J, Folke C. Rediscovery of traditional ecological knowledge as adaptive management. Ecol. Appl. 2000; 10(5):1251-1262.
14. Gadgil M, Berkes F. Traditional resource management systems. Resour. Manage. Opt. 1991;8(3-4):127-145.
15. Oteng-Yeboah AA. Philosophical foundations of biophysical resource use with special reference to Ghana: In: Gyasi EA, et. al. (Eds) Managing agrodiversity the traditional way: Lesson from West Africa in sustainable use of biodiversity and related natural resources. United Nation University Press. 2004;8-11.
16. Sarfo-Mensah P, Oduro W. Traditional natural resources management practices and biodiversity conservation in Ghana. A Review of Local Concepts and Issues on Change and Sustainability NOTA DI LAVORO 90; 2007.
17. Busia KA. The ashanti of the gold coast in Africa world studies: In. D, Forde, ed. The Cosmological Ideas and the social values of African people, London: Oxford University; 1957.
18. Stoate C, Boatman N, Borralho R, Carvalho CR, De Snoo G, Eden P. Ecological impacts of arable intensification in Europe. J. Environ. Manag. 2001;63(4): 337–365.
19. Upton J. Turns out those old-fashioned ways of farming were actually pretty smart. Climate and Energy. GRIST; 2013.
    Available:http://grist.org/article/ turns-out-those-old-fashioned-ways-of-farm ing-were-actually-pretty-smart/
    (Retrieved, on 24th August, 2017)
20. Sofia PK, Prasad R, Vijay VK. Organic farming-tradition reinvented. Ind. J. Trad. Knowledge. 2006;5(1):139-142.
21. GOG. Ghana poverty reduction strategy 2003-2005: An agenda for growth and prosperity. Volume I: Analysis and Policy Statement. Government of Ghana; 2003.
22. GOG. Ghana's agric policy since 1960: Planting for food and jobs the new baby; 2018.

Available:http://www.ghana.gov.gh/index.php/media-center/features/38_02-ghana-s-agric-policy-since-1960-plant ing-for-food-and-jobs-the-new-baby; 2018.
23. Institute of statistical, Social and Economic Research (ISSER). Sowing the seeds for growth and jobs Budget: ISSER 2017 Post-budget analysis. Policy Brief. 2017;5.
24. Vercillo S. Ghana's new agricultural policy is leaving behind smallholders. AgriIn Ghana; 2007.
Available:https://agricnghana. com /2017/02/1 4/ghanas-new-agriculture-policy-is-leaving-behind-its-smallholder (Accessed July17th, 2017)
25. Ruttan VW. The transition to agricultural sustainability. Proc. Natl. Acad. Sci. 1999; 96:5960–5967.
26. Feola G, Binder CR. Towards an improved understanding of farmers' behaviour: The integrative agent-centered (IAC) framework. Ecol. Econ. 2010;69: 2323–2333.
27. Janssen MA, Ostrom E. Governing social–ecological systems. In: Tesfatsion L. Judd KL. (Eds.), Handbook of Computational Economics, Elsevier, Amsterdam. 2006;2: 1465–1509.
28. Darnhofer I, Bellon S, Dedieu B, Milestad R. Adaptive farming systems — a position paper. Proceedings of the 8th European IFSA Symposium, Clermont-Ferrand, France; 2008.
29. Oppong-Anane K. Country pasture/forage resource profiles: Ghana. Food and Agriculture Organization of the United Nations (FAO). Publishing Policy and Support Branch, Office of Knowledge Exchange, Research and Extension, FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy; 2006.
30. Brammer H. Soils*:* In agriculture and land use in Ghana. Wills JB, ed. Oxford; 1962.
31. ISSS/ISRIC/FAO. World reference base for soil resources. World Soil Resource Report 84, FAO, Rome; 1998.
32. Adjei-Gyapong T, Asiamah RD. The interim Ghana soil classification system and its relation with the World Reference Base for Soil Resources. FAO Report on Soil Resources No. 98; 2000.
33. Issaka RN, Buri MM, Tobita S, Nakamura S, Owusu-Adjei. E. Indigenous fertilizing materials to enhance soil productivity in Ghana. In "Soil Fertility Improvement and integrated Nutrient Management-Global Perspective (Joann W. Ed.). In Tech Press, Rijeka, Croatia. 2011;119-134.
34. Ghana Statistical Services. Population and housing Census. Ghana Statistical Service; 2010.
35. Acquah HD, Annor-Frempong KF. Farmers' perception of impact of climate change on food crop production in Ketu North District in the Volta Region of Ghana. 1st World Sustainability Forum; 2011.
Available:www.wsforum.org
(Accessed September 27th, 2017)
36. Ghana Statistical Services. 2010 population and housing census: District analytical report Ketu North. Ghana Statistical Service; 2014.
37. Cronbach LJ. Coefficient alpha and the internal structure of tests. Psychometrika. 1951;16(3):297–334.
38. Enshassi A, Mohamed Mustafa ZA, Mayer PE. Factors affecting labour productivity in building projects in the Gaza strip. J. Civ. Eng. Manag. 2007;13(4):245-254.
39. Tobin J. Estimation of relationships for limited dependent variables. Econometrica. 1958;26(1):24-36*.*
40. McDonald JF, Moffit RA. The uses of tobit analysis. Rev. Econs. Stat. 1980;61:318–321.
41. Fraser C, Wind Y. Why and when to use tobit analysis. University of Pennsylvania Working Paper 86-2; 1986.
42. Rahman S. Environmental impacts of modern agricultural technology diffusion in Bangladesh: An analysis of farmers' perceptions and their determinants. J. Environ. Manage. 2003;68:183–191*.*
43. Gould BW, Saupe WE, Klemme RM. Conservation tillage: The role of farm and operator characteristics and perception of soil erosion. Land Econ. 1989;65(2):167-182.
44. Eviews-10. Eviews 10: Innovative solutions for econometric analysis, forecasting and simulation. HIS Global Inc; 2018.
Available:www .eviews.com
(Accessed April 29th, 2018)
45. Mills J, Gaskell P, Ingram J. Dwyer J, Reed M, Short C. Engaging farmers in environmental management through a better understanding of behaviour. Agric. Human Values; 2016.
DOI: 10.1007/s10460-016-9705-4
46. Burton RJF. Reconceptualising the 'behavioural approach' in agricultural

studies: A socio-psychological perspective. J. Rural Studies. 2004;20(3):359–371.
47. Asafu-Adjaye J. Factors affecting the adoption of soil conservation measures: A case study of Fijian cane farmers. J. Agr. Resour. Econ. 2008;33(1): 99-117.
48. Asiedu-Darko E. Farmers' perception on agricultural technologies a case of some improved crop varieties in Ghana. Agric. Forest. Fisheries. 2014;3(1):13-16.
49. Waller BE, Hoy CW, Henderson JL, Stinner B, Welty C. Matching innovations with potential users: A case study of potato IPM practices. Agric. Ecosyst. Environ. 1998;70:203-215.
50. Caswell M, Fuglie K, Ingram C, Jans S, Kascak C. Adoption of agricultural production practices: Lessons learned from the US. Department of Agriculture Area Studies Project. US Department of Agriculture, Resource Economics Division, Economic Research Service, Agriculture Economic Report No. 792. Washington DC University Press London, Accra, New York. 2001;88-126.
51. Abbas M, Sheikh AD, Muhammad S, Ashfaq M. Role of electronic media in the adoption of agricultural technologies by farmers in the central Punjab–Pakistan. Int. J. Agric. Biol. 2013;(5)1:22-25.
52. Muhammad S, Butt SA, Ashraf I. Role of television in agricultural technology transfer. Pak. J. Agr. Sci. 2004;41:158-161.
53. Ali J. Adoption of mass media Information for decision-making among vegetable growers in Uttar Pradesh. Indian J. Agric. Econ. 2011;66(2):241-254.
54. Lambert DM, Sullivan P, Claassen R, Foreman L. Profiles of US farm households adopting conservation-compatible practices. Land Use Policy. 2007;24:72–88.
55. Breustedt G, Muller-Scheeßel J, Latacz-Lohmann U. Forecasting the adoption of GM oilseed rape: Evidence from a discrete choice experiment in Germany. J. Agric. Econs. 2008;59:237–256.
56. Wilson TA, Rice ME, Tollefson JJ, Pilcher CD. Transgenic corn for control of the European corn borer and corn rootworms: A survey of Midwestern farmer's practices and perceptions. J. Econ. Entomol. 2005; 98(2):237–247.
57. Welsh R, Rebecca RY. Rivers environmental management strategies in agriculture. Agric. Human Val; 2010. DOI: 10.1007/s10460-010-9285-7
58. Schneider ML, Francis CA. Ethics of land use in Nebraska: Farmer and consumer opinions in Washington County. J. Sustainable Agric. 2006;28:81–104.
59. D'Souza G, Ikerd J. Small farms and sustainable development: Is small more sustainable? J Agric. Appl. Econs. 1996; 28:73–83.
60. Adesina AA, Mbila D, Nkemleu GB, Endamana D. Econometric analysis of the determinants of adoption of alley farming by farmers in the forest zone of Southwest Cameroon. Agr. Ecosyst. Enviro. 2000; 80:255-265.
61. Zhang W, Li F, Xiong YQ, Xia Q. Economic analysis of the determinant of adoption of raising sheep in folds by farmers in the semiarid Loess Plateau. Ecol. Econ. 2012;74:145-152.
62. Stringer R. Environmental policy and Australia's horticulture sector. University of Adelaide, Australia, CIES Policy Discussion Paper 98/02; 1998.
63. St. Martin C, Isaac WA, Brathwaite RAI Open field vegetable production: Practices and systems. Editors: Wendy-Ann P. Isaac, Wayne G. Ganpat Sustainable Food Production Practices in the Caribbean. 2012;56-77.
64. Padilla-Bernal LE, Lara-Herrerab A, Reyes-Rivasc AE, González-Hernández JR. Assessing environmental management of tomato production under protected agriculture. Int. Food Agribus. Manag. Rev. 2015;18(3):193-210.
65. Sligo FX, Massey C. Risk, trust and knowledge networks in farmers' learning. J. Rural Stud. 2007;23:170–182.
66. Oreszczyn S, Lane A, Carr S. The role of networks of practice and webs of influencers on farmers' engagement with and learning about agricultural innovations. J. Rural Studies. 2010;26(4):404–417.
67. Conley TG, Udry CR. Learning about a new technology: Pineapple in Ghana. Unpublished Paper. Yale University, Economic Growth Center, Center Discussion Papers. 2000;49.
68. Bandiera O, Rasul I. Social networks and technology adoption in Northern Mozambique. CEPR Discussion Paper no. 3341. London, Centre for Economic Policy Research; 2002.
Available:http://www.cepr.org/pubs/dps/DP3341.asp
(Accessed December, 23rd 2017)

69. Doss CIR. Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. Agric. Econ. 2006;34:207–219.
70. Croppenstedts A, Demek M, Meschi MM. Technology adoption in the presence of constraints: The case of fertilizer demand in Ethiopia. Rev. Dev. Econ. Review. 2003;7(1):58-70.
71. Danquah JA, Kuwornu JKM, Baffoe-Asare R, Annor-Frempong F, Zhang C. Smallholder farmers' preferences for improved cocoa technologies in Ghana. British J. Appl. Sci. Tech. 2015;5(2):150-165.
72. FAO. Indigenous, gender and sustainable community livelihood. Rome: Food and Agriculture Organization; 2005.
73. Mofokeng R. Gender issues in African subsistence farming: A case for developing appropriate technology for rural women in South Africa. J. Farm. Syst. Res. Extension; 2008;4(1):35-43.
74. Peega S. Women as indigenous farmers in Rural South Africa: Cases from Limpopo Province. Unpublished research paper. Indigenous Knowledge Systems (IKS) Programme, University of North-West, Mmabatho, South Africa; 2012.
75. Danquah JA. Analysis of factors influencing farmers' voluntary participation in reforestation programme in Ghana. For. Trees Livelihoods; 2015.
DIO: 10.1080 /1472 88028.2015.1025862
76. Onder M, Ceyhan E, Kahrama A. Effects of agricultural practices on environment. International Conference on Biology, Environment and Chemistry, IACSIT Press, Singapoore. IPCBEE. 2011;24.
77. Magdoff F. Ecological agriculture: Principles, practices, and constraints. Renewable Agric. Food Syst. 2007;22(2):109–117.
78. Buckles D, Triomphe B, Sain G. Cover crops in hillside agriculture: Farmer innovation with mucuna; International Development Research Center: Ottawa, ON, Canada; 1998.
79. Benneh G. Indigenous African farming system: Their significance for sustainable environmental use; In. E.A. Gyasi and J.I. Uitto (eds.): Environment, biodiversity and agricultural change in West Africa. Tokyo, United Nations University Press. 1997;13-18;
80. Wood TN. Agricultural Development in the Northern Savannah of Ghana. Doctoral documents from doctor of plant health program. University of Nebraska Lincoln Digital Commons@ University of Nebraska – Lincoln; 2013.
Available:http: //digitalcommons.unledu/planthealthdoc
(Accessed, March 14th, 2018)
81. Lambin EF, Turnerb BL, Geista HJ, Agbolac SB, Angelsend A, Bruce JW, Coomes OT, Dirzog R, Fischerh G, Folkei C, Georgej PS, Homewoodk K, Imbernonl J, Leemansm R, Lin X, Morano EF, Mortimorep M, Ramakrishnanq PS, Richardsr JF, Skaness H, Steffent W, Stoneu GD, Svedinv U, Veldkampw TA, Vogelx C, Xu J. The causes of land-use and land-cover change: Moving beyond the myths. Glob. Environ. Chang. 2001; 11:261–269.
82. Rengel Z. Cycling of micronutrients in terrestrial ecosystems. In nutrient cycling in terrestrial ecosystems. P. Marschner, Z. Rengel (Eds.) .Soil Biology, Springer-Verlag Berlin Heidelberg. 2007;10.
83. FAO. Fertilizer use by crop in Ghana. Food and Agriculture Organization of the United Nations. Rome, Italy; 2005.
84. von Reppert-Bismark J. How trade barriers keep Africans adrift: West's farm subsidies drive Ghanaians out of rice market fueling poverty and migration. The Wall Street J; 2006.
85. Baumhardt RL, Stewart BA, Sainju UM. North American soil degradation: Processes, practices, and mitigating strategies. Sustainability. 2015;7:2936-2960.
86. Walder P, Kantelhardt J. The environmental behaviour of farmers – Capturing the diversity of perspectives with a q methodological approach. Ecol. Econ. 2018;143:55–63.
87. Sharpe RM, Irvine DS how strong is the evidence of a link between environmental chemicals and adverse effects on human reproductive health? BMJ. 2004;328:447-451.
88. Horrigan L, Lawrence SR, Walker P. How sustainable agriculture can address the environmental and human health harms of industrial agriculture. Environ. Health Persp. 2002;110 (5):445-456.
89. Okrah M. Economic dimensions of inland fisheries of the upper east region of Ghana. A Master of Science Thesis submitted to the Department of Planning,

Kwame Nkrumah University of Science and Technology; 2010.
90. Ghana Web. Fishermen resort to illegal fishing methods just as their Chinese counterparts. 2017;35.
Available:https://www.Ghana webcom/GhanaHome_Page/NewsArchive /Fishermen-resort-to-illegal-fishingmethods-just-as-their-Chinese-counterparts-5421
(Accessed March 9th,2018)
91. GOG. Republic of Ghana fisheries and fishing regulation. Assembly Press, Accra. Ghana; 2009.
92. Sapkota A, Sapkota AR, Kucharski M, Burke J, McKenzie S, Walker P, Lawrence R. Aquaculture practices and potential human health risks: Current knowledge and future priorities. Environ. Int. 2008;34: 1215–1226.
93. Kyei-Baffour N, Mensah E. Water pollution potential from agrochemicals. Proceedings of the 19th WEDC Conference. Edited by John Pickford, et al. for the Water, Engineering and Development Centre. Accra. Ghana; 1993.
94. Gerken A, Suglo JV, Braun M. Pesticides use and policies in Ghana: An economic and institutional analysis of current practice and factors influencing pesticide use. Publication of the Pesticide Policy Project Handover May 2001 Publication Series, No. 10; 2001.
95. Shapi M, Cheikhyoussef A, Mumbengegwi DR, Matengu K, Kent AV, Sifani J. Evolution of data collection methods for indigenous knowledge systems at the multidisciplinary research centre of the University of Namibia. Knowledge Manag. Dev. J. 2011;7(3):308-316.
96. Neupane RP, Sharma KR, Thapa GP. Adoption of agroforestry in the hills of Nepal: A logistic regression analysis. Agric. Syst. 2002;72:177–196.
97. Bayard Jolly CM, Shannon DA. The economics of adoption and management of alley cropping in Haiti. J. Environ. Manag. 2007;84:62-70.
98. Teklewold HT, Dadi L, Yami A, Dana N. Determinants of adoption of poultry technology: A double-hurdle approach. Livestock Res. Rural Devel. 2006; 818(3).
Available:www.lrrd.org/lrrd18/3/tekl18040.htm
(Accessed 10 March 2018)

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