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Does awareness and concern for the environment influence the use of detrimental inputs? A study of maize farmers in Ghana

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Abstract

Sustainable food systems are necessary not only as a channel for addressing the food security needs of the world's growing population, but are also crucial in ensuring that the needs of future generations are not compromised. This study examined the influence of environmental awareness and concern about the use of detrimental inputs in crop production. The study involved 400 maize farmers from the Northern Region of Ghana, and made use of multivariate multiple linear regression and the translog profit function for the data analysis. The results show that farmers with characteristics including being male, the head of the household, the decision maker on the farm, receiving frequent extension visits and being the owner of the farm, along with the nature of the farm plot, significantly determine the level of farmers' environmental awareness and concern. Moreover, environmental awareness and concern have a significant effect on the use of detrimental inputs in production. The results contribute to an understanding of the importance of knowledge in facilitating actions towards environmental conservation. Environmental awareness campaigns are thus relevant to the promotion of sustainable agricultural production and should be championed by governments, development agencies and NGOs.

Key words: agriculture, agrochemicals, application rate, sustainability, translog profit function

1. Introduction

Agriculture continues to play a major role in defining ecosystems worldwide (Pretty *et al*. 2008; Luty *et al*. 2021). The need to provide food for the world's ever-growing population is giving rise to the increased use or intensification of land, fertilisers and other agrochemicals. This pattern of production poses serious threats to the environment and is identified as the root cause of the triple planetary crises of climate change, biodiversity loss and pollution. Agriculture has therefore featured greatly and is still a focus in attempts at ensuring sustainable development, with strategies outlined in Sustainable Development Goal (SDG) 12 towards promoting sustainable production (United Nations 2016). Actions directed at natural resource conservation have the potential to increase biodiversity and generally contribute to environmental sustainability. In this regard, the awareness of actors in the agricultural sector, especially producers, is considered a path to ensuring socially desirable levels of conservation (Forsyth *et al*. 2004; Baumgart-Getz *et al*. 2012). According to Baumgart-Getz *et al*.

(2012), the more environmentally aware farmers are, the more the actions they take are aimed at conserving the environment. Even in cases where environmentally unfriendly actions are taken prior to awareness, ex-post awareness of and concern for the environment can lead to a reversal of negative actions taken (Rogan *et al*. 2005; Francis *et al*. 2008).

Therefore, programmes to create awareness about environmental conservation are increasingly being implemented worldwide (Francis *et al*. 2008; Drangert *et al*. 2017; Weiner 2017; Eneji *et al*. 2020). The resultant effect is a change in farmers' behaviour, including decisions on farming and the food system (Eneji *et al*. 2020). In particular, environmental awareness can contribute to efforts aimed at reducing the use of agrochemicals such as fertilisers and pesticides. This is considered a step towards reducing pollution and further towards achieving sustainable agricultural production (Pretty *et al*. 2008; Pogutz & Winn 2016; Weiner 2017). A study by Rahman (2005) in Bangladesh, for instance, found that farmers who are aware of the detrimental effects of conventional technologies and farm practices on the environment use much smaller amounts of such inputs and practices to prevent further degradation.

In Ghana, mono- and continuous cropping systems dominate farm practices and result in lowering soil fertility levels, increasing the incidence of pests and diseases, and leading to continuous declines in crop yield (Boahen *et al*. 2007; Akowuah 2010). In an effort to resolve these problems, farmers use intensive application of chemical fertilisers and other agrochemicals such as pesticides and weedicides (Akowuah 2010; Abdulai *et al*. 2013). Meanwhile, the increased use of agrochemicals has numerous negative effects on both human health and the environment, including habitat and species losses (Nonga *et al*. 2011; Jiang *et al*. 2012; Adiyiah *et al*. 2013; Vidogbena *et al*. 2015), and also leads to an increase in the probability of pest infestation (Tanzubil 2014). Several studies in Ghana have revealed the presence of high levels of persistent bio-accumulative and toxic agrochemicals in water bodies, fish, crops and human fluids (Amoah *et al*. 2006; Essumang *et al*. 2009; Fianko *et al*. 2011; Owusu-Boateng *et al*. 2013). These studies reveal a very high probability of accidents occurring from pesticide exposure in Ghana as a result of a lack of awareness of the safe use of agrochemicals.

Human behaviour is thus seen as a significant contributor to environmental problems in agriculture (Rahman 2005). Besides, the knowledge or awareness of farmers with regard to resource conservation is identified as an important social indicator of agricultural sustainability (Zhen & Routray 2003). Environmental awareness is expected to affect farmers' concern for the environment, and this will further inform the use of detrimental inputs in production. However, environmental sustainability studies, particularly in Ghana, often ignore the cognitive aspects of human action. Rahman (2005) examined the relationship between farmers' environmental awareness and resource allocation decisions in Bangladesh. The current study includes an indicator of 'environmental concern' in determining farmers' resource allocation decisions and makes a significant contribution to the literature, as environmental awareness alone is considered insufficient for promoting actions toward environmental conservation (Pannell 1999). Furthermore, the results reveal useful information for stakeholders who are working tirelessly to promote the adoption of sustainable agricultural practices – not only among Ghanaian farmers, but also in other developing countries worldwide.

2. Data and methods

2.1 Data

The study made us of cross-sectional primary data gathered from the Northern Region of Ghana using a multi-stage sampling procedure. Three districts, namely Karaga, Kumbungu and Gushegu

Municipal, were purposively chosen for the study. In the second stage, five villages (farming communities) were randomly selected from each of the three districts, while the third and last stage involved interviews of 400 randomly chosen maize farmers from the selected communities. Maize is the most important grain crop in Ghana because it is produced in all 10 regions and constitutes 55% of the nation's total grain production (Angelucci 2019). Of this, smallholder farmers account for about 70% of the total maize produced. It is also considered as a very important crop for food security, because 40% of the harvest is consumed by the farm households (Akowuah 2010). Furthermore, maize is present in the diet of the majority of Ghanaians and is also used in the poultry industry (Akowuah 2010; Barimah *et al*. 2014). Due to its importance, maize production is expanding to the drier parts of the Northern Region and virtually replacing sorghum and millet, which used to be traditional food security crops (Martey *et al*. 2013). While agriculture provides a livelihood for over 70% of the Northern Regions' inhabitants (Al-Hassan & Poulton 2009), the region experiences very extreme fluctuations in the annual rainfall pattern, varying between 700 and 1 100 mm (Van der Geest 2011). There is a relatively drier climate in the northern than in the southern parts of the country because of its closeness to the Sahel and the Sahara. It also has a single rainy season that begins in May and ends in October, resulting in high incidences of drought, especially from variability in the intra-seasonal rainfall (Van der Geest 2011). Crop production in the region is therefore very vulnerable to drought due to over-reliance on the natural climate, and to the low adaptive capacity attributed to both the geographic and socioeconomic features of the region (Antwi-Agyei *et al*. 2012).

2.2 Methods

2.2.1 Construction of environmental awareness and concern indices

Two separate sets of seven specific questions on environmental awareness (EA) and environmental concern (EC) were used in the construction of the indices (Appendix 1). Farmers were asked to give their answers to a number of questions (EA_i, EC_i) relating to awareness and concern for the environment. A value of 1 was assigned to each question to which the farmer affirmed awareness or concern for the environment, and 0 otherwise. The total score $(\sum EA_i, \sum EC_i)$ of each farmer was then converted into an index, as follows:

$$EAI_i = \sum EA_i /7, \quad i = 1, \ldots, n, \tag{1}$$

$$ECI_i = \sum EC_i /7 \quad i = 1, \ldots, n, \tag{2}$$

where EAI_i denotes the environmental awareness index constructed for the i^{th} farmer, ECI_i is the environmental concern index constructed for the i^{th} farmer, and n denotes sample size.

2.2.2 Determinants of farmers' environmental awareness and concern

Multivariate multiple linear regression (MMLR) models the linear relationship between more than one dependent (outcome) variable and more than one independent variable. Developed by Bartlett (1938), the MMLR is an extension of the OLS regression model, and is unique in taking on discrete dependent variables. The choice of the MMLR model over other discrete dependent variable models, such as the logit and probit, is a result of the multiple constructs (dependent variables) of environmental awareness and concern. The estimates of the MMLR are unbiased and have minimum variances, just like the OLS estimates (Bartlett 1938). Each dependent variable in a sample of n observations can be expressed as a linear function of a set of explanatory variables and a random error, ε. Representing the number of explanatory variables by q, and β_s as the regression coefficients, the general form of the multivariate model is:

$$
\begin{aligned}
y_1 &= \beta_0 + \beta_1 x_{11} + \beta_2 x_{12} + \cdots + \beta_q x_{1q} + \varepsilon_1 \\
y_2 &= \beta_0 + \beta_1 x_{21} + \beta_2 x_{22} + \cdots + \beta_q x_{2q} + \varepsilon_2 \\
y_n &= \beta_0 + \beta_1 x_{n1} + \beta_2 x_{n2} + \cdots + \beta_q x_{nq} + \varepsilon_n
\end{aligned} \tag{3}
$$

The multivariate model can be re-written in matrix form as

$$
\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix} = \begin{bmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1q} \\ 1 & x_{21} & x_{22} & \cdots & x_{2q} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x_{n1} & x_{n2} & \cdots & x_{nq} \end{bmatrix} \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_q \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix} \tag{4}
$$

Table 1 presents the descriptions of both the dependent and independent variables used in the MMLR model. The dependent variables labelled 'a' denote environmental awareness constructs, while those labelled 'b' represent environmental concern constructs.

2.3 Influence of environmental awareness and concern on resource allocation decisions: the translog (transcendental logarithmic) profit function

The translog functional form (Christensen *et al*. 1973) is widely used in empirical analysis due to its conceptual simplicity. It also imposes no a priori restrictions on elasticities of substitution (technological structure) and returns to scale. Although the Cobb-Douglas production function is popular, it dwells on highly restricted assumptions, such as the unitary elasticity of substitution, constant returns to scale, and the a priori imposition of separability. This functional form (Cobb-Douglas) thus produces invalid elasticities and fails to explain the real relationships between inputs and outputs (Diewert 1971; Christensen *et al*. 1973). There are also other functional forms that are applied to time-series data, such as the constant elasticity of substitution (CES), the variable elasticity of substitution (VES) and the nested constant elasticity of substitution production function. These are superior to the Cobb-Douglas function, but they also dwell on rigid restrictions (Chaudhary *et al*. 1998), making them unattractive for use. The translog functional form is thus ideal in this case. Lau and Yotopoulos (1971) further recommend the profit function over the production function because it is easier to use and has more advantages.

Assuming a farmer maximises profit subject to a given state of technology and fixed inputs, and that marginal conditions hold, the normalised restricted profit function for one output (Christensen *et al*. 1973) is specified as:

$$
\ln \pi' \, \alpha_0 + \sum_{i=1}^{4} \alpha_i \ln P_i' + \frac{1}{2} \sum_{i=1}^{4} \sum_{h=1}^{4} \gamma_{ih} \ln P_i' \ln P_h' + \sum_{i=1}^{4} \sum_{m=1}^{3} \delta_{im} \ln P_i' \ln Z_m + \sum_{m=1}^{3} \beta_m \ln Z_m + \frac{1}{2} \sum_{m=1}^{3} \sum_{k=1}^{3} \theta_{mk} \ln Z_m \ln Z_k + v, \tag{5}
$$

where π' is the normalised restricted profit, derived as total revenue minus total variable costs of variable inputs divided by the output price (P_y); P_i' is the price of variable input X_i, normalised by output price (P_y); *i* is the price of inputs (inorganic fertiliser, weedicide, hired labour, family labour); Z_m is the quantity of fixed input *m* (area under maize cultivation, EAI, ECI); v is the random error; and α_0, α_i, γ_{ih}, δ_{im}, β_m and θ_{mk} are the parameters to be estimated.

Table 1: Definition, summary statistics of variables and hypothesised direction of influence

Variable	Definition	Mean	Standard deviation
Dependent variables, y_n			
a. Farmer's health	Are you aware that the excessive application of agrochemicals is detrimental to your health? (1 = Yes; 0 = No)	0.83	
b. Farmer's health	Are you concerned that the excessive application of agrochemicals is detrimental to your health? (1 = Yes; 0 = No)	0.85	
a. Consumers' health	Are you aware that the excessive application of agrochemicals is detrimental to the health of consumers? (1 = Yes; 0 = No)	0.81	
b. Consumers' health	Are you concerned that the excessive application of agrochemicals is detrimental to the health of consumers? (1 = Yes; 0 = No)	0.83	
a. Biodiversity	Are you aware that the excessive application of agrochemicals is detrimental to biodiversity? (1 = Yes; 0 = No)	0.80	
b. Biodiversity	Are you concerned that the excessive application of agrochemicals is detrimental to biodiversity? (1 = Yes; 0 = No)	0.80	
a. Destroys soil structure	Are you aware that conventional tillage destroys soil structure? (1 = Yes; 0 = No)	0.84	
b. Destroys soil structure	Are you concerned that conventional tillage destroys soil structure? (1 = Yes; 0 = No)	0.81	
a. Facilitates soil erosion	Are you aware that conventional tillage facilitates soil erosion? (1 = Yes; 0 = No)	0.84	
b. Facilitates soil erosion	Are you concerned that conventional tillage facilitates soil erosion? (1 = Yes; 0 = No)	0.84	
a. Increases pests and diseases incidence	Are you aware that the non-rotation of cereals with legumes increases the incidence of pests and diseases? (1 = Yes; 0 = No)	0.83	
b. Increases pests and diseases incidence	Are you concerned that the non-rotation of cereals with legumes increases the incidence of pests and diseases? (1 = Yes; 0 = No)	0.82	
Explanatory variables, X_q			
Gender	Gender of respondent (1 = Male; 0 = Female)	0.88	
Mstatus	Marital status of respondent (1 = Married; 0 = Single)	1.92	
Hhhead	Are you the head of your household? (1 = Yes; 0 = No)	0.35	
Age	Age of respondent (years)	40.56	13.34
Experience	Farming experience (years)	20.14	13.42
Educ	Educational level of respondent (years of schooling)	3.40	4.21
DecisionM	Main decision maker of farm (1 = Yes; 0 = No)	0.91	
MainOcc	Farming as main occupation (1 = Yes; 0 = No)	0.83	
Off-farm	Engagement in an off-farm job (1 = Yes; 0 = No)	0.28	
MemFBO	FBO membership (1 = Yes; 0 = No)	0.28	
FreqExtCont	Frequency of extension contacts (number of contacts/ month)	1.42	1.59
Self-owned	Ownership of plot (1 = Yes; 0 = No)	0.59	
Leasehold	Leasehold of plot (1 = Yes; 0 = No)	0.08	
Flatplt	Flat plot slope (1 = Yes; 0 = No)	0.88	

Source: Own survey, 2021

The two main detrimental inputs in maize production are inorganic fertilisers and weedicides. The use of pesticides in maize production in the Northern Region of Ghana is rare, hence it was replaced in this analysis with the rate of weedicide application, which is more popular. The fixed input – total land allocated to maize production – is expected to have a significant positive relationship with the quantities of inputs demanded, while the levels of EAI and ECI are expected to show the direction of resource allocation decisions. Rational expectations posit that environmentally aware and concerned farmers would use relatively lower amounts of agrochemicals (Rahman 2005).

The Environmental Awareness Index (EAI) and the Environmental Concern Index (ECI) are both treated as a given level or stock of knowledge. In ensuring the existence of duality between the profit function and its corresponding production possibility set, it is sufficient for the profit function ($\pi(P, Z)$) to be (i) a non-negative real-value function defined for all $P > 0$ and any Z, (ii) homogenous of degree one in P, (iii) convex and continuous in P for every fixed Z, (iv) non-decreasing in Z for every fixed P, and non-decreasing (non-increasing) in P_i if i is an output (variable input) for every Z. The profit function contains sufficient information to fully describe the production technology and the production possibility set if the conditions described above hold and producers maximise profits (Diewert 1974).

Differentiating the translog profit function (Equation 5) with respect to P_i' and to the price of output generates a system of variable input/profit and an output/profit ratio. Using Hotelling's lemma, the corresponding share equations of the translog profit function (Equation 5) are expressed as

$$S_i = -\frac{P_i X_i}{\pi} = \frac{\partial \ln \pi'}{\partial \ln P_i'} = \alpha_i + \sum_{h=1}^{4} \gamma_{ih} \ln P_h' + \sum_{m=1}^{3} \delta_{im} \ln Z_m, \tag{6}$$

$$S_y = \frac{P_y X_y}{\pi} = 1 + \frac{\partial \ln \pi'}{\partial \ln P_y} = 1 + \sum_{i=1}^{4} \alpha_i + \sum_{i=1}^{4} \sum_{h=1}^{4} \gamma_{ih} \ln P_i' + \sum_{i=1}^{4} \sum_{m=1}^{3} \delta_{im} \ln Z_m, \tag{7}$$

where S_i is the share of the ith input, S_y is the share of output, X_i denotes the quantity of input i, and y is the level of maize output. Since S_i and S_y sum to unity, one of the equations can be ignored in the estimation (Christensen *et al*. 1971). The output share equation is thus ignored in this analysis. This approach enables the simultaneous estimation of both the profit and variable inputs share equations as functions of the normalised input prices, and quantities of fixed factors as exogenous variables. Share equations are estimated for fertiliser (S_F), weedicide (S_W), hired labour (S_H), and family labour[1] (S_M). The share equations are expressed as

$$s_F = \beta_F + \alpha_{FF} \ln P'_F + \alpha_{FW} \ln P'_W + \alpha_{FH} \ln P'_H + \alpha_{FM} \ln P'_M + \gamma_{FL} \ln Z_L + \gamma_{FA} \ln Z_A + \gamma_{FC} \ln Z_C, \tag{8}$$

$$s_W = \beta_W + \alpha_{WW} \ln P'_W + \alpha_{WF} \ln P'_F + \alpha_{WH} \ln P'_H + \alpha_{WM} \ln P'_M + \gamma_{WL} \ln Z_L + \gamma_{WA} \ln Z_A + \gamma_{WC} \ln Z_C, \tag{9}$$

$$s_H = \beta_H + \alpha_{HH} \ln P'_H + \alpha_{HF} \ln P'_F + \alpha_{HW} \ln P'_W + \alpha_{HM} \ln P'_M + \gamma_{HL} \ln Z_L + \gamma_{HA} \ln Z_A + \gamma_{HC} \ln Z_C, \tag{10}$$

$$s_M = \beta_M + \alpha_{MM} \ln P'_M + \alpha_{MF} \ln P'_F + \alpha_{MW} \ln P'_W + \alpha_{MH} \ln P'_H + \gamma_{ML} \ln Z_L + \gamma_{MA} \ln Z_A + \gamma_{MC} \ln Z_C, \tag{11}$$

where β_i, α_{ij} and γ_{im} are coefficients to be estimated, P'_F, P'_W, P'_H and P'_M are the normalised prices of fertiliser, weedicide, hired labour and family labour respectively, Z_L, Z_A and Z_C are fixed

[1] Man-days are calculated for family labour based on the rule that one adult male and one adult female working for one day (eight hours) equal one man-day and 0.75 man-days respectively (Battese & Malik 1996; Coelli & Battese 1996; Onumah *et al*. 2010).

factors – farm size, level of environmental awareness (EAI), and level of environmental concern (ECI) respectively. The following restrictions were imposed on the profit function to ensure homogeneity in input prices and fixed factors:

1. The symmetry property:
   $\alpha_{ij} = \alpha_{ji}$, where i, j = 1, 2, 3, 4

2. Homogeneity in prices:
   $\sum \beta_i = 1$

3. Row sum is zero:
   $\sum_j \alpha_{ij} = 0$

4. Column sum is zero:
   $\sum_i \alpha_{ij} = 0$

5. Homogeneity in fixed factors:
   $\gamma_{im} = 0$

Once the parameter estimates of equations (5) and (8) to (11) had been obtained, the elasticities of demand for variable input with respect to the mth fixed factor were calculated at averages of the S_y and at given levels of the relevant variable input prices (Sidhu & Baanante 1979), expressed as:

$$\eta_{im} = \beta_m + \delta_{im} \ln P_i' + \sum_{k=1}^{3} \theta_{mk} \ln Z_k - \frac{\delta_{im}}{S_y} \tag{12}$$

3. Results and discussion

3.1 Determinants of farmers' environmental awareness and concern

Each of the univariate models (for both awareness and concern constructs) was statistically significant (i.e. all the *p*-values were less than 0.0001). The standard R^2 values of the models for both awareness and concern show that the independent variables explain over 80% of the variance in all the outcome (viz. dependent) variables (see Appendix 2(a) and 2(b)).

With the exception of the *Age*, *Educ*, *Off-farm* and *Leasehold* variables, all the other explanatory variables included in the model influenced farmers' awareness of the effect of conventional technologies and practices on the environment (Table 2). The variables *Gender*, *Hhhead*, *DecisionM*, *MemFBO*, *Extenfreq*, *Self-owned* and *Flatplt* exerted a significant influence on the environmental awareness constructs. The coefficients of *Gender*, *Hhhead*, *DecisionM*, *Extenfreq* and *Flatplt* were positive, indicating that (i) males, (ii) household heads, (iii) decision makers at the farm level, (iv) those who had frequent access to extension education, and (v) those who had flat topographical farm plots were more aware of the negative effect of conventional farming activities on the environment, and vice versa. Studies such as those of Liu *et al*. (2018) and Despotović *et al*. (2021) have likewise demonstrated the significant influence of environmental knowledge on environmental awareness. In these two studies, the authors observed that extension information influences environmental awareness. Male farmers are more aware of the effect of conventional farming practices than their female counterparts. Women have additional responsibilities in the household, including cooking and caring for the family, and this could possibly hinder their access to technical advisory and information services. The significance of flat plot (*Flatplt*) indicates that the flatter a farmer's plot is, the more aware that farmer is of the potential harm conventional practices can cause to his farmland, in particular the influence of conventional tillage on the destruction of soil structure, and erosion (Table 2). It is interesting to note that producers who belong to farmer-based organisations (*MemFBO*) are less aware of the detrimental effects of conventional practices on the environment compared to those who do not belong to any such groups. Farmer-based organisations (FBOs) are nonetheless seen as channels for the dissemination of agricultural information in Ghana (Quaye *et al*. 2022). The variables *Mstatus* (married) and *Experience* (farming experience) are significant and have a positive influence on only one awareness construct (dependent variable) respectively, viz. conventional tillage facilitates soil erosion and conventional tillage destroys soil structure. This shows that experienced farmers have more knowledge of the negative effects of conventional tillage.

Gender, *Mstatus*, *Hhhead*, *Age*, *Experience*, *DecisionM*, *MainOcc*, *MemFBO*, *Extenfreq*, *Self-owned* and *Flatplt* had a significant influence on the concern for the environment, but not with all the constructs (Table 3). The coefficients of *Gender*, *Hhhead*, *Age*, *Experience*, *DecisionM*, *Extenfreq*, *Self-owned* and *Flatplt* exerted a positive influence on the environmental concern constructs. This means that (i) males, (ii) household heads, (iii) older farmers, (iv) experienced farmers, (v) decision-makers, (vi) farmers who receive frequent extension visits, (vii) farmers who own their plots, and (viii) those whose plots are flat are more concerned about the negative environmental consequences of conventional agricultural practices. The coefficient of FBO membership (*MemFBO*) is negative, indicating that FBO members are less concerned about the effects of conventional farming on the environment. Technical advisory information shared by agricultural extension agents at the household level seems to be more valuable in contributing to farmers' awareness and concern for the environment compared to being a member of an FBO. This reveals the ineffectiveness of farmer-based organisations in Ghana. In actual fact, these groups are functional only during the implementation of development programmes and projects. Older and experienced farmers seem to be more concerned about the environment, which could possibly be due to their depth of knowledge of farming and the consequences of conventional practices on human health and the environment. This observation is similar to the results obtained by Rana *et al*. (2012).

Table 2: Factors influencing environmental awareness: Results of the multivariate multiple linear regression model

Independent/explanatory variables	Dependent variables Environmental awareness constructs					
	Excessive agrochemical use is detrimental to …			*Conventional tillage …*		*Monocropping …*
	Farmer's health	**Consumers' health**	**Biodiversity**	**Destroys soil structure**	**Facilitates soil erosion**	**Increases incidence of pests and diseases**
Socio-economic characteristics Gender	0.172 (0.059)**	0.122 (0.061)*	0.110 (0.062)*	0.214 (0.057)***	0.108 (0.059)*	0.165 (0.058)**
Mstatus	0.059 (0.051)	0.069 (0.053)	0.050 (0.054)	0.070 (0.049)	0.149 (0.051)**	0.039 (0.050)
Hhhead	0.145 (0.042)**	0.119 (0.044)**	0.117 (0.044)**	0.082 (0.040)*	0.025 (0.042)	0.123 (0.042)**
Age	0.003 (0.002)	-0.001 (0.002)	-0.003 (0.002)	-0.003 (0.002)	0.001 (0.002)	-0.001 (0.002)
Experience	-0.001 (0.002)	0.002 (0.002)	0.001 (0.002)	0.004 (0.002)*	0.001 (0.002)	0.002 (0.002)
Educ	-0.017 (0.019)	-0.009 (0.020)	-0.005 (0.021)	-0.008 (0.019)	0.026 (0.019)	-0.001 (0.019)
DecisionM	0.226 (0.064)***	0.290 (0.066)***	0.3190 (0.067)***	0.262 (0.061)***	0.208 (0.064)**	0.345 (0.063)***
MainOcc	-0.009 (0.049)	0.101 (0.051)*	0.112 (0.052)*	0.087 (0.047)*	0.063 (0.049)	0.065 (0.049)
Off-farm	-0.025 (0.042)	-0.026 (0.043)	-0.021 (0.044)	-0.012 (0.039)	0.018 (0.042)	0.042 (0.041)
Institutional characteristics MemFBO	-0.061 (0.043)	-0.135 (0.045)**	-0.161 (0.046)***	-0.071 (0.041)*	0.011 (0.043)	-0.068 (0.043)
Extenfreq	0.047 (0.013)***	0.046 (0.013)***	0.048 (0.013)***	0.043 (0.012)***	0.016 (0.013)	0.039 (0.012)**
Plot characteristics Self-owned	0.078 (0.039)*	0.832 (0.041)*	0.092 (0.042)*	0.053 (0.038)	0.041 (0.039)	0.100 (0.039)*
Leasehold	-0.116 (0.074)	-0.091 (0.077)	-0.080 (0.078)	-0.059 (0.071)	-0.048 (0.074)	0.016 (0.073)
Flatplt	0.158 (0.056)**	0.142 (0.058)*	0.125 (0.059)*	0.174 (0.053)**	0.106 (0.056)*	0.094 (0.055)*

Source: Survey data, 2021. Standard errors in parenthesis; single, double and triple asterisks (*, ** and ***) indicate [statistical] significance at the 10%, 5% and 1% level.

Table 3: Multivariate multiple linear regression model results of factors influencing environmental concern

Independent variables	Dependent variables Environmental concern constructs					
	Excessive agrochemical use is detrimental to…			*Conventional tillage…*		*Monocropping…*
	Farmer's health	**Consumers' health**	**Biodiversity**	**Destroys soil structure**	**Facilitates soil erosion**	**Increases incidence of pests and diseases**
Socio-economic characteristics Gender	0.129 (0.058)*	0.155 (0.061)*	0.180 (0.067)**	0.209 (0.065)**	0.129 (0.059)*	0.224 (0.062)***
Mstatus	0.144 (0.049)**	0.155 (0.053)**	0.051 (0.057)	0.050 (0.056)	0.169 (0.052)**	0.106 (0.053)*
Hhhead	0.047 (0.041)	0.103 (0.044)*	0.091 (0.048)*	0.091 (0.046)*	0.119 (0.043)**	0.083 (0.044)*
Age	0.004 (0.002)*	0.002 (0.002)	0.006 (0.003)*	0.007 (0.003)*	0.002 (0.002)	0.002 (0.002)
Experience	0.001 (0.002)	0.002 (0.002)	0.003 (0.003)	0.004 (0.003)*	0.001 (0.002)	0.002 (0.002)
Educ	0.022 (0.019)	-0.005 (0.020)	0.002 (0.022)	-0.001 (0.022)	0.044 (0.019)*	0.031 (0.021)
DecisionM	0.139 (0.063)*	0.187 (0.066)**	0.127 (0.072)*	0.112 (0.070)	0.095 (0.065)	0.103 (0.067)
MainOcc	-0.002 (0.048)	0.0934 (0.051)*	0.135 (0.055)*	0.104 (0.054)*	0.026 (0.049)	0.058 (0.052)
Off-farm	-0.025 (0.041)	-0.064 (0.043)	0.053 (0.047)	0.053 (0.046)	-0.059 (0.042)	0.016 (0.044)
Institutional characteristics MemFBO	-0.048 (0.042)	-0.094 (0.045)*	-0.081 (0.049)*	-0.066 (0.048)	-0.039 (0.044)	-0.103 (0.045)*
Extenfreq	0.029 (0.012)*	0.027 (0.013)*	0.036 (0.014)*	0.037 (0.014)**	0.025 (0.013)*	0.041 (0.013)**
Plot characteristics Self-owned	0.050 (0.039)	0.024 (0.041)	0.091 (0.044)*	0.091 (0.043)*	0.046 (0.039)	0.073 (0.041)*
Leasehold	-0.024 (0.073)	-0.114 (0.077)	0.062 (0.084)	0.053 (0.082)	-0.046 (0.075)	0.058 (0.078)
Flatplt	0.119 (0.055)*	0.084 (0.058)	0.024 (0.063)	0.024 (0.061)	0.135 (0.057)*	0.108 (0.059)*

Source: Survey data, 2021. Standard errors in parenthesis; Single, double and triple asterisks (*, ** and ***) indicate [statistical] significance at the 10%, 5% and 1% level.

3.2 Influence of environmental awareness and concern on the use of detrimental inputs in production

The descriptive statistics of variables included in the profit function are presented in Table 4, while the output from the profit function estimated jointly with four input demand equations is presented in Table 5. The R-squared value of the profit function from the OLS is 0.313, which shows that 31.3% of the parameters explain variations in profit, while 14 of the 35 parameters are significantly different from zero (at the 10%, 5% and 1% levels of significance). The cross elasticities (variable-fixed input) were computed based on parameter estimates of the profit function. The two potential detrimental inputs used for maize production in the Northern Region of Ghana are inorganic (chemical) fertilisers and weedicides. Pesticides, on the other hand, are used minimally and are rare.

Table 4: Description and summary statistics of variables used in the profit function

Variable name	Description	Unit of measurement	Mean	Standard deviation
Π	Profit from maize production	Gh¢	1 284.34	1 244.64
P_F	Price of fertiliser	Gh¢/kg	75.49	31.86
P_W	Price of weedicide	Gh¢/litre	19.66	11.42
P_H	Wage of hired labour	Gh¢/man-day	7.29	4.47
P_M	Wage of family labour	Gh¢/man-day	5.53	2.32
Z_L	Area under maize cultivation	Hectare	1.39	1.27
Z_A	Environmental awareness index		0.831	0.291
Z_C	Environmental concern index		0.832	0.288

Source: Survey data, 2021

Table 5: Parameter estimates of the translog profit function

Variables	Parameters	Estimates	Variables	Parameters	Estimates
Constant	α_0	8.134 (1.064) ***	$InP_F \times Z_L$	δ_{FL}	0.023 (0.043)**
InP_F	α_F	-0.888 (0.333) ***	$InP_F \times InZ_A$	δ_{FA}	0.525 (0.302)*
InP_W	α_W	-0.062 (0.242)	$InP_F \times InZ_C$	δ_{FC}	-0.520 (0.324)
InP_H	α_H	-0.244 (0.204)*	$InP_W \times InZ_L$	δ_{WL}	-0.022 (0.059)
InP_M	α_M	-0.118 (0.096)	$InP_W \times InZ_A$	δ_{WA}	0.552 (0.381)
InZ_L	β_L	-0.592 (0.672)	$InP_W \times InZ_C$	δ_{WC}	0.069 (0.393)
InZ_A	β_A	-2.604 (4.679)	$InP_H \times InZ_L$	δ_{HL}	-0.081 (0.151)
InZ_C	β_C	1.294 (0.623)	$InP_H \times InZ_A$	δ_{HA}	0.348 (0.898)
$1/2InP_F \times InP_F$	γ_{FF}	0.151 (0.084)*	$InP_H \times InZ_C$	δ_{HC}	-0.578 (0.647)
$1/2InP_W \times InP_W$	γ_{WW}	0.063 (0.044)	$InP_M \times InZ_L$	δ_{ML}	0.575 (0.327)*
$1/2InP_H \times InP_H$	γ_{HH}	0.065 (0.036)*	$InP_M \times InZ_A$	δ_{MA}	-0.579 (2.085)
$1/2InP_M \times InP_M$	γ_{MM}	0.013 (0.039)	$InP_M \times InZ_C$	δ_{MC}	-0.210 (2.087)
$1/2InP_F \times InP_W$	γ_{FW}	0.010 (0.045)*	$1/2InZ_L \times InZ_L$	θ_{LL}	0.091 (0.131)
$1/2InP_F \times InP_H$	γ_{FH}	0.057 (0.103)*	$1/2InZ_A \times InZ_A$	θ_{AA}	-2.254 (3.736)
$1/2InP_F \times InP_M$	γ_{FM}	0.493 (0.287)*	$1/2InZ_C \times InZ_C$	θ_{CC}	7.235 (0.162)*
$1/2InP_W \times InP_H$	γ_{WH}	-0.101 (0.155)**	$1/2InZ_L \times InZ_A$	θ_{LA}	1.840 (0.893)**
$1/2InP_W \times InP_M$	γ_{WM}	-0.508 (0.357)	$1/2InZ_L \times InZ_C$	θ_{LC}	-1.153 (0.995)
$1/2InP_H \times InP_M$	γ_{HM}	0.540 (0.504)	$1/2InZ_A \times InZ_C$	θ_{AC}	-1.986 (3.537)

Source: Survey data, 2021. F = fertiliser price, W = weedicide price, H = hired labour wage, M = family labour wage, L = land size, A = environmental awareness, C = environmental concern. Single, double and triple asterisks (*, ** and ***) indicate [statistical] significance at the 10%, 5% and 1% level.

From Table 6 we can see that fertiliser demand is unresponsive to an increase in environmental awareness, with an elasticity value of 0.06. In other words, a 1% increase in the level of environmental awareness leads to a 0.06% increase in fertiliser demand. The a priori expectation posits that an increase in the level of awareness of farmers would lead to a decline in the demand for inorganic fertilisers (i.e. negative and elastic). While the positive figure violates the a priori expectation, however, it is inelastic, meaning that although fertiliser demand increases with an increase in the level of environmental awareness, this increase is marginal (insignificant). Moreover, the results imply that farmers with lower levels or no form of awareness apply higher rates of fertiliser compared to their colleagues who have full knowledge of the negative consequences of intensified use of chemical fertilisers. Similar studies, such as those of Veleva and Ellenbecker (2001), Yaghoubi Farani *et al*. (2019) and Despotović *et al*. (2021), also identify awareness as an important indicator that positively influences farmers' behaviour, thus contributing to sustainable production. Nevertheless, fertiliser demand is highly responsive (elastic) to a change in environmental concern (-1.49), in accordance with the a priori expectation. This shows that an increase in the level of concern for the environment leads to a drastic fall in the demand for inorganic fertilisers, by 1.49 units.

Table 6: Estimated cross elasticities (variable input-fixed input) of the translog profit function

	Land size	Environmental awareness	Environmental concern
Fertiliser demand	0.23	0.06	-1.49
Weedicide demand	0.32	-1.12	-2.19
Hired labour demand	1.03	-2.76	3.49
Family labour demand	-4.31	5.16	-0.36

Source: Survey data, 2021. Elasticity estimates computed at mean values.

The demand for weedicides is highly responsive (i.e. elastic) to farmers' level of environmental awareness (-1.12) and meets the a priori expectation. This shows that the demand for weedicides declines significantly as farmers' level of awareness of the detrimental effects of weedicides on the environment increases. Also, the demand for weedicides falls as the level of concern for the environment increases, and is indicated by the elasticity value of -2.19 (highly elastic), revealing a positive effect of environmental awareness and concern on the environment. Agrochemicals, especially weedicides, have a high tendency to pollute the environment through the emission of toxic gases and have a high potential to pollute water bodies and destroy biodiversity. Also, the health of the applicator/farmer is at risk from the use of weedicides, which could expose them to skin and eye irritations (Bajwa 2014; Al-Samarai *et al.* 2018). Although awareness in itself is not sufficient to explain the sustainable behaviour of farmers, it produces a concern for the environment, and the resulting effect includes actions that reduce environmental pollution. Bijani *et al*. (2017), Cishahayo *et al*. (2022) and Zhu *et al*. (2022) also found an influence of farmers' environmental awareness and concern on management behaviour.

4. Conclusions

This study has examined the relationship between environmental awareness and concern and detrimental resource allocation decisions by maize farmers in the Northern Region of Ghana. The study is a contribution to the literature on the influence of environmental awareness and concern on agrochemical use by farmers. In the production of maize, chemical fertilisers and weedicides were identified as inputs that pose a threat to the natural environment, including a loss of biodiversity, especially when misapplied.

Three main findings were established that are of relevance to policy makers. First, the frequency of contacts with agricultural extension agents (AEAs) increases farmers' level of awareness of and concern for the environment. This reinforces the importance of technical advisory information as a relevant input required by farmers in production. Second, farmers' awareness and concern regarding the negative environmental consequences of weedicide use result in a decline in the demand for weedicides. This implies that farmers' awareness and concern for the environment contribute to the achievement of sustainable food production. Meeting the SDGs for agricultural production therefore will depend not only on the promotion and dissemination of climate-smart technologies and practices, but will also require dedicated efforts by the government, development agencies and NGOs to improve and increase the provision of technical and advisory information to farmers. This is particularly necessary in developing countries, where the majority of farmers are illiterate (i.e. have no formal education), and where AEA-to-farmer ratios are very low, coupled with dwindling government and donor funding. All these elements make service delivery inadequate and leave large areas of farming communities uncovered. Third, the findings from the study provide a basis for the formulation of laws on the use of agrochemicals, particularly in Ghana. In addition, the results point to the need for promoting already existing technologies and practices, such as integrated fertiliser, pest and weed management, which contribute to conserving the environment. These environmentally friendly approaches to production are well known to give rise to notable improvements in social welfare. Furthermore, there is a need for the development of new innovations that boost agricultural productivity and reduce negative effects on the environment.

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Appendix 1: Assessment of awareness and concern about the detrimental effects of conventional practices

Please provide answers to the following questions:			
No.	***Statement***	***Are you aware that?***	***If you are aware, are you concerned?***
	using agrochemicals excessively is detrimental to …		
1a.	*your health*	Yes [ ] No [ ]	Yes [ ] No [ ]
1b.	*the health of consumers*	Yes [ ] No [ ]	Yes [ ] No [ ]
1c.	*the environment/ecosystem*	Yes [ ] No [ ]	Yes [ ] No [ ]
	conventional tillage …		
2a.	*destroys soil structure*	Yes [ ] No [ ]	Yes [ ] No [ ]
2b.	*facilitates soil erosion*	Yes [ ] No [ ]	Yes [ ] No [ ]
	continuous cropping leads to …		
3a.	*Soil fertility loss*	Yes [ ] No [ ]	Yes [ ] No [ ]
	non-rotation of crops…		
4a.	*increases the incidence of pests and diseases*	Yes [ ] No [ ]	Yes [ ] No [ ]

Appendix 2(a): Models of environmental awareness

Equation	Obs	Parms	RMSE	R-squared	F	P
Farmer's health	400	14	.3625254	0.8470	156.9744	0.0000
Consumers' health	400	14	.3703881	0.8360	144.5034	0.0000
Biodiversity	400	14	.3471665	0.8613	176.1062	0.0000
Destroys soil structure	400	14	.3589653	0.8526	163.9948	0.0000
Facilitates erosion	400	14	.3558742	0.8563	169.0428	0.0000
Increased incidence of diseases and pests	400	14	.3551735	0.8540	165.8589	0.0000

Notes: Obs = observations; Parms = parameters; RMSE = root mean square error; F = test statistics for F-test; P = statistical significance

Appendix 2(b): Models of environmental concern

Equation	Obs	Parms	RMSE	R-squared	F	P
Farmer's health	400	14	.3505005	0.8610	175.7235	0.0000
Consumers' health	400	14	.3706193	0.8401	148.9680	0.0000
Biodiversity	400	14	.3943919	0.8151	125.0206	0.0000
Destroys soil structure	400	14	.3647867	0.8473	157.3678	0.0000
Facilitates erosion	400	14	.3601145	0.8521	163.3199	0.0000
Increased incidence of diseases and pests	400	14	.3799087	0.8310	139.4124	0.0000

Notes: Obs = observations; Parms = parameters; RMSE = root mean square error; F = test statistics for F-test; P = statistical significance