Environmental Awareness and Probability of Adoption of Ecofriendly Agricultural Practices by Vegetable Farmers: A Case Study from Kalpitiya, Sri Lanka

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ABSTRACT

Agricultural production with excessive amounts of fertilizers and agrochemicals has become a serious concern all over the world. Statistics show that applications of fertilizers have grown over the years and remarkably in Asia. Therefore, this research attempted to study the relationship between the knowledge of farmers on the environmental issues or 'environmental awareness' on environmentally responsible behavior or 'environmental stewardship', by considering a sample of farmers from Kalpitiya, Sri Lanka, where soil and ground water is rapidly degrading due to overuse of fertilizer. Environmental awareness was measured in terms of an index developed using the answers to a set of Likert type statements and was related to stewardship behavior measured in terms of willingness to adopt ecofriendly agricultural practices in a Bayesian framework. A Bayesian probit model was estimated with non-informative priors for model parameters with a post burn-in sample of 80,000 iterations. Results revealed that environmental awareness is strongly linked with the intention to adopt ecofriendly agricultural practices. Human capital available to farmer moderates the impacts positively, while the farm size moderates it negatively.

KEYWORDS: Bayesian, Environmental awareness, Environmental stewardship, Probit, Kalpitiya

Introduction

Modern agriculture with the turnaround during the times of the 'Green Revolution' has improved agricultural yields worldwide. Without doubt, it has helped to increase the food supply, while ensuring food security worldwide. Yet, due to continuous intensive agricultural practices and fertilizations, especially with Nitrogen, soils have become degraded, making it difficult to cultivate further (Bisht and Chauhan, 2020).

Further, modern crop varieties are highly fertilizer dependent and farmers with or without the knowledge of the destructive nature of the modern agriculture use more and more fertilizers. For example, in the period from the year 2000 to 2019, use of Nitrogen fertilizers has increased by 33%, while the use of Phosphorus fertilizers has increased by 34% and the use of Potassium has increased by 74% (FAO, 2022). Thereby, the overall fertilizer usage has increased by around 40% during this period. The application of fertilizers is highest in the Asian region for all the three nutrients. It has been estimated as 58%, 55% and 49%, respectively out of total world usage in Nitrogen, Phosphorus and Potassium. In case of the overall fertilizer usage, Asia accounts for 56% of the total worldwide usage (FAO, 2022). Out of the three main nutrients, Nitrogen is the dominant nutrient used in agricultural production. Sixty percent of total fertilizer usage in Asia, is accounted by Nitrogen fertilizers with a similar high percentages in other areas in the world. Although modern day fertilizers are becoming efficient in terms of absorption to plants, still, most of the Nitrogen fertilizer applied to soil tend to leach away. Depending on the rainfall and soil types, about 15 to 40 kg of Nitrogen per hectare is lost due to leaching (Dybowski et al., 2020). Nitrogen leaching into ground water has become a major issue worldwide. Because of this, ground water contamination due to Nitrogen leaching has been a key research area studied by many (Letey and Vaughan, 2013; Libutti and Monteleone, 2017; Köhler et al., 2006). However, to date, the application of Nitrogen is continuously rising worldwide, and the problem is progressive.

To control this issue, a major scientific breakthrough is in order in terms of increasing absorption efficiency into plants, nano technology or using bio fertilizers. However, none of these are yet economically viable to the vast majority of small farmers, especially to those in Asia where highest rates are applied. Until such a breakthrough emerges, best would be to control the farmer behaviours. Environmental stewardship is such a behaviour of interest, which is related to responsible use and protection of natural environment. The need to promote environmental stewardship is highlighted in many studies (Nagchaudhuri et al., 2006; Schaible et al., 2015; Lobley and Potter, 1998). Therefore, this study evaluates, how environmental awareness, induces environmental stewardship, especially in reducing harmful activities or pollution of the environment in the case of fertilizer application in Kalpitiya peninsula.

Methodology

Conceptual Framework and Variable Definition

Figure 1 depicts the conceptual framework used in this research. It is assumed that environmental awareness of farmers influences the environmental stewardship behaviour. Apart from the environmental awareness, other variables such as human capital and the cultivation extent may play a key role in stewardship behaviour in crop production.

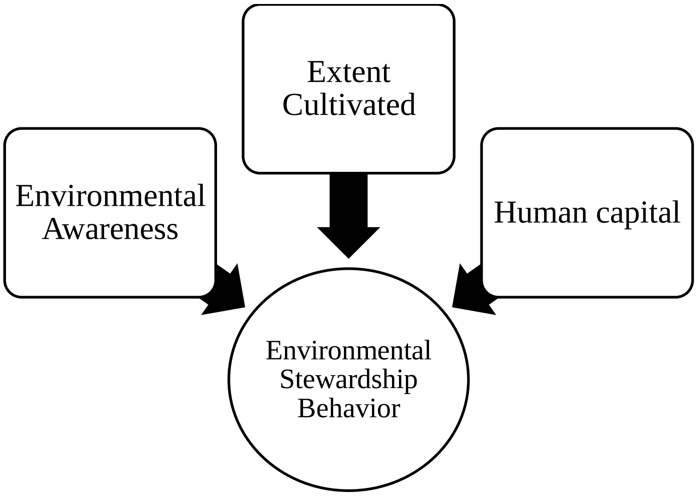

Figure 1: Conceptual Framework

Environmental awareness is the understanding of the environment, the impacts of human behaviours on it, and the importance of its protection. To operationalize this concept, an index was prepared in this study using five statements measured in a 5-point Likert scale given to each farmer. Two of the statements were related to the awareness of overuse of fertilizer and pesticides in the area studied. The third statement was used to understand whether the farmer is aware that the ground water is already highly polluted in the study area. The fourth statement examined whether the farmer is aware that the excessive applications of fertilizer/chemical lead to ground water pollution in the area. The fifth and the final statement assessed the farmers' awareness on the significance of Nitrogen fertilizer in the pollution of ground water in the Kalpitiya peninsula. In creating the awareness index, the following formula was used. This created an index for each statement, which ranged from 0 to 1.

$$\text{Awareness Index}_i = \frac{X - \min}{\max - \min} \qquad [1]$$

Then all these five indexes were added to formulate a grand index. As the sum of individual indexes does not create an index that is distributed between 0 and 1, above equation was used again for the resulting sum to achieve the final 'Awareness Index'.

The environmental stewardship behaviour was operationalized in the data analysis process using the responses to the question "If an ecofriendly practice is introduced, would you follow it?" in the questionnaire. This recorded a dichotomous answer, a 'yes' or a 'no.' Thus, by estimating this relationship, the probability of adoption of ecofriendly fertilizer practices can be estimated when the environmental awareness increases. This is important because extension efforts can be directed towards increasing the awareness, if predicted probability is high. However, it is also hypothesized that the intended behaviour may also be influenced by farm and economic features that must be encountered by a farmer (Figure 1).

Two such important variables were assumed to characterize the intention to adopt ecofriendly fertilizer practices: the extent cultivated and human capital of the farm family. A variable, capturing the human capital, was created by formulating an education index, following the same procedure as outlined in developing the awareness index, taking education levels achieved by all members of the household. These are therefore included in the model. All the variables in the estimated model are given in Table 1.

Table 1: Variables in the Model

Variable	Description	Expected Sign
Adopt [Dependent]	Willingness to adopt ecofriendly fertilizer practices Yes=1, 0=otherwise	-
Awareness Index	Index created using five statements measured using a 5-point Likert scale	Positive
Extent	Extent cultivated in Ha	Ambiguous
Human Capital Index	Index which lies between 0 and 1 capturing education levels of the household	Positive

Estimation Strategy

The dependent variable of the model was of dichotomous nature (Table 1). There were two main possibilities of modeling a dichotomous variable: using a probit or a logit model. Here a probit model was used. In the probit model, an underlying latent distribution ("z" _"i") of utility differences of choices is assumed, which follows a normal linear regression model with characteristics that can be observed contained in a covariate matrix ("x" _"i") and a normally distributed error (ε_i) (Koop 2003). This can be specified as.

$$z_i = x_i'\beta + \varepsilon_i \quad [2]$$

$$y_i = 1 \text{ if } z_i > 0 \quad [3]$$

$$y_i = 0 \text{ if } z_i \leq 0 \quad [4]$$

Only two outcomes are possible in the probit model. Hence, when outcome ("y" _"i") is not observed, the latent utility difference is assumed to be less than or equal to zero, while it is more than zero when it is observed. To estimate this model using the Bayesian approach, a prior pdf of parameters of the model, and the likelihood of the data based on the parameters, are formed. Then the resulting posterior distribution of parameters is studied with the usual Bayesian relationship as shown below.

$$\pi(\boldsymbol{\theta} \mid \mathbf{y}) \propto f(\mathbf{y} \mid \boldsymbol{\theta})\, \pi(\boldsymbol{\theta}) \quad [5]$$

The data generating density is normal in the probit regression. The likelihood for the probit model is $f^N(\mathbf{y}\,|\,\boldsymbol{\theta}) = \prod_{i=1}^{N} (\Phi(-x_I'\beta))^{1-y_j}(\Phi(x_I'\beta))^{y_j}$. Here, the notation, Φ (.) denotes the cumulative distribution function of the normal distribution. The parameters of interest in the probit model are $\theta \equiv (\beta)$. In the absence of prior information, sufficiently diffused conjugate priors were used in the estimation.

Study Area and the Sample

Kalpitya is situated in the Puttalam District in the Northwestern Province of Sri Lanka, which is a low-lying sandy peninsula. It is located between 8° 20'' - 8° 90'' Northern latitude and 79° 40'' - 79° 50'' Eastern longitude and covers a total land extent of about 160 square kilometers. This area is known for its agricultural activities, fisheries, prawn farming and the main coal power plant in the country (Aheeyar et al., 2016). It is situated in the low country, dry zone of Sri Lanka falling into DL_3 Agroecological region (Punyawardena, 2008). Kalpitiya is one of the most productive areas of commercial agriculture in Sri Lanka, which generates job opportunities and ensure livelihoods of many. Large amounts of vegetable and fruit cultivation areas are found in the Kalpitiya peninsula.

As the Kalpitiya peninsula consists of shallow aquifers with sandy soil, the Nitrogenous fertilizers applied to these soils leach down quickly and therefore, the ground water become highly concentrated with Nitrogen (Jayasingha et al., 2011) and is rapidly degrading. According to a study by De Silva et al. (2020), only 30% of farmers apply the recommended dosage of fertilizers. In the intensively cultivated areas of the peninsula, ground water levels of nitrates are beyond the permissible limits (Lawrence and Kuruppuarachchi, 1986; Kuruppuarachchi and Fernando, 1990; Villholth and Rajasooriyar, 2010; Matharaarachchi et al., 2014). It has been reported that many crops grown in this area contain elevated levels of Nitrate (Liyanage et al., 2000), causing long term health effects such as methemoglobinemia in infants and gastro-intestinal cancers are reported in this area (Jayasekera et al., 2008).

Eight hundred vegetable growers were interviewed through a structured questionnaire to collect primary data. Kalpitiya divisional secretariat has been divided into 31 Grama Niladhari (GN) Divisions and 121 villages. A two-stage sampling method was used in selecting 800 farmers for this study. In the first stage, seven Grama Niladhari (GN) divisions were selected randomly to reflect the groundwater pollution levels in the area. Farmers were randomly selected probability proportionately from these GN divisions in the second stage, optimizing the cost and time functions

Results and Discussion

The Awareness Index

As discussed previously, an awareness index was constructed using five statements that carry responses in a 5-point Likert scale (Figure 2). Majority of the farmers in the sample are aware of the severity of the issue in the area they farm as most agree or strongly agree to all the statements.

It should be especially noted that the agreement to the statement 3, "Ground water in Kalpitiya peninsula is highly polluted" is high compared to others indicating that the environmental awareness of farmers is quite high.

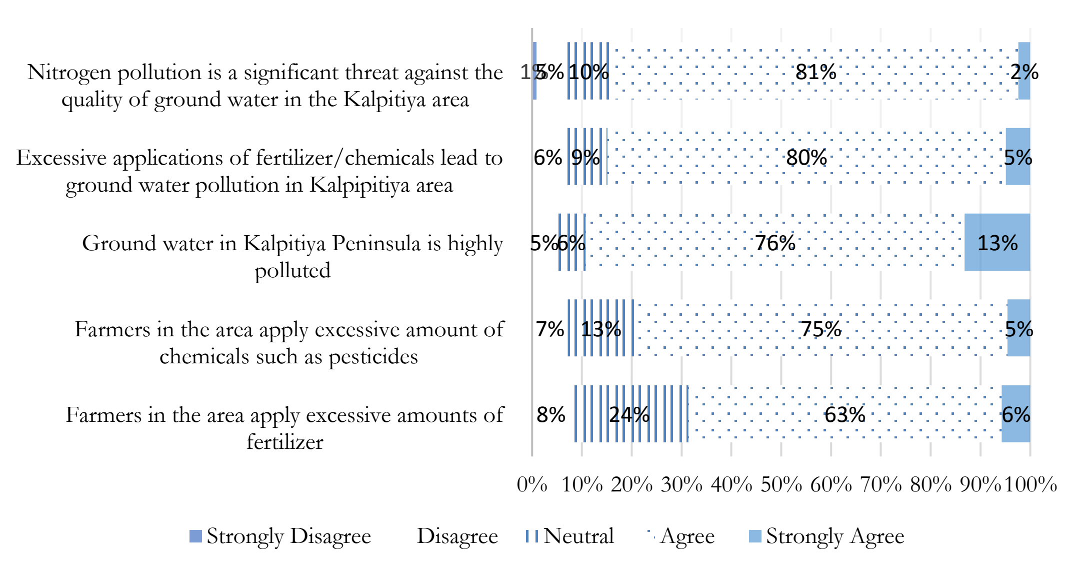

Figure 2: Responses for Statements Measuring the Awareness of Pollution Due to Agricultural Activities

Table 2 shows the distribution of the calculated environmental awareness index. About 94% of the sample falls above 0.75 of the index value showing a high awareness about the pollution in the area. Employing a normal noninformative prior distributed as, $awareness\ index \sim (0,\ 10^2)$, the simulated population distribution of the index is given in Figure 3, which is distributed around a posterior mean value of 0.68.

Table 2: Distribution of Values of the Awareness Index

Awareness index value	Frequency	Percent	Cum.
0.00< Awareness Index <=0.25	24	2,92	2.92
0.25< Awareness Index <=0.50	11	1.34	4.26
0.50< Awareness Index <=0.75	17	2.07	6.33
0.75< Awareness Index <=1.00	770	93.67	100.00

The Environmental Stewardship Behavior

The environmental stewardship behaviour was assessed using probable investments, such as the use of ecofriendly agricultural practices, if one was introduced.

Close to 98% of the farmers agreed that they would adopt such a practice, if it were introduced to them (Figure 3).

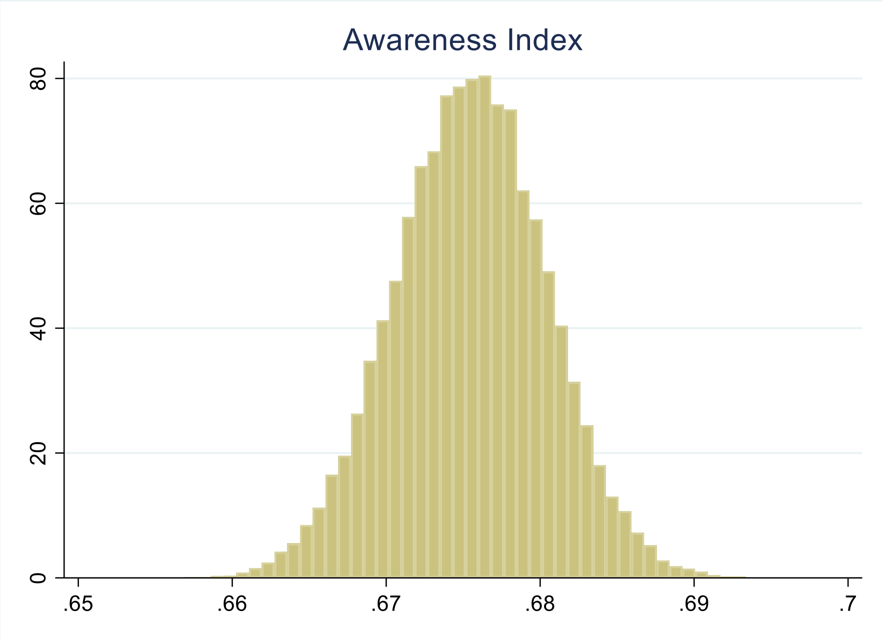

Figure 3: Simulated Population Distribution of the Awareness Index

Impact of Environmental Awareness on Probability of Ecofriendly Behavior

As indicated under methodology, a Bayesian probit model was used to assess the impact of environmental awareness on the probability of adoption of ecofriendly fertilizer practices. A non-informative normal prior, $\beta \sim N(0, 10^2)$, was used for all regression coefficients as there were no previous information about these parameters. Before the results are assessed, it is vital in Bayesian estimation to assess whether the convergence of the Markov Chain is achieved. This was done by using trace plots as given in Figure 4. The Markov Chain was executed for 100,000 iterations with 20,000 disregarded as burn-in to remove the effect of starting values. Figure 4 shows that all trace plots have converged to the mean value of the respective coefficient and therefore, the coefficients are amenable for interpretation.

Summary statistics of the estimated coefficients are given in Table 3, which report the mean of the posterior distribution, Markov chain standard error (MCSE), the posterior standard deviation (Std. dev.) and the posterior median. The 95% credible interval shows the parameter range, suggesting that the probability of the parameter lying in that range is 95%. According to Table 3, the awareness index has a positive mean value of 0.464, which falls between the 95% credible interval, indicating that higher the value of the awareness index, higher is the probability of willingness to adopt ecofriendly fertilizer practices, or environmental stewardship behaviour. Similar findings have been reported by Despotović et al. (2021).

They have reported that environmental awareness was high in farmers who adopted ecofriendly agricultural practices such as biological pest control, mulching and use of green manure. Poltimäe and Peterson (2021) have concluded that general environmental awareness amongst farmers play an important role in adoption of farmland conservation measures.

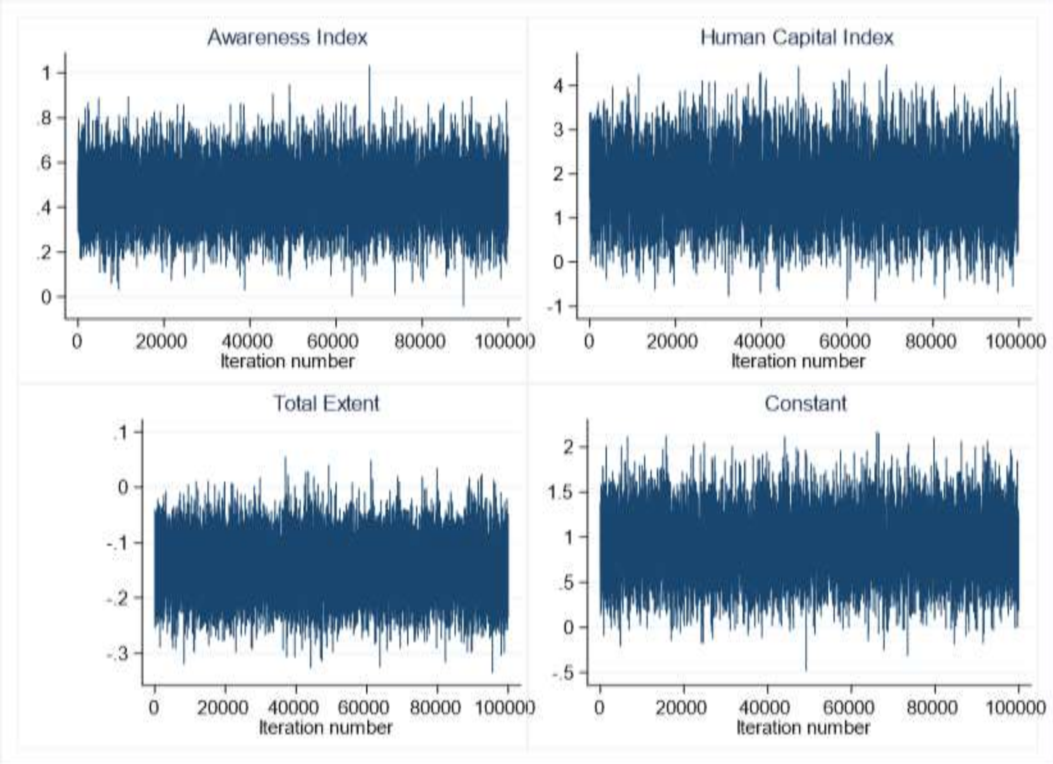

Figure 4: Trace Plots of Estimated Parameters of the Model

Apart from the awareness index, the human capital index also plays an important role in improving environmental stewardship behaviour or probability of adoption of ecofriendly practices because it is positive and significant. The extent returned a negative sign indicating that probability of adopting ecofriendly practices is low in the case of larger farmers. This may be related to farmer perception on the cost of using such practices in larger extents of lands.

Farmer's understanding of ecofriendly practices mainly emanate from the use of organic fertilizers, which is bulky in comparison to inorganic fertilizers and chemicals they are used to. Therefore, they may have perceived that application cost and transportation costs could to be high when the farm size increases and hence the negative sign.

Ajewole (2010) has reported that in the case of adoption of commercially available organic fertilizer, farmers in Nigeria show an inverse relationship between farm size and adoption. Thapa and Rattanasuteerakul (2011) have shows a similar finding in the case of organic vegetable farming in Thailand.

Table 3: Results of the Probit Model Estimation

	Mean	Std. dev.	MCSE*	Median	Equal-tailed [95% cred. interval]	
Awareness Index [AI]	0.464	0.115	0.001	0.462	0.240	0.694
Human Capital Index [HCI]	1.695	0.709	0.011	1.686	0.328	3.133
Extent [Ext]	-0.146	0.045	0.001	-0.147	-0.232	-0.056
Constant	0.912	0.317	0.004	0.910	0.299	1.545

MCSE denotes Markov Chain standard error

To verify whether the two variables, human capital and extent play a moderating role on the impact of environmental awareness on environmental stewardship behaviour, interactions of these variables with the awareness index were introduced into the model. The parameters β_4 and β_5 captures the moderation effect (Baron and Kenny, 1986).

$$Y_i^* = \beta_0 + \beta_1 AI_i + \beta_2 HCI_i + \beta_3 Ext_i + \beta_4 (AI_i \times HCI_i) + \beta_5 (AI_i \times Ext_i) + \varepsilon_i \quad [6]$$

The model was estimated with a non-informative normal prior, $\beta \sim N(0, 10^2)$ as before with a post burn-in a sample of 80,000 iterations. Convergence was assessed using trace plots. The posterior means and other summary statistics are given in Table 4.

Table 4: Posterior Summary Statistics of the Estimated Coefficients of Interaction Model

	Mean	Std. dev.	MCSE	Median	Equal-tailed [95% cred. interval]	
AI	0.426	0.226	0.004	0.421	-0.010	0.873
HCI	0.870	1.134	0.016	0.842	-1.252	3.198
Ext	-0.068	0.119	0.003	-0.069	-0.293	0.173
AI × HCI	0.600	0.662	0.011	0.597	-0.709	1.905
AI × Ext	-0.041	0.057	0.001	-0.040	-0.155	0.070
Constant	0.922	0.447	0.007	0.924	0.054	1.808

The 95% credible interval includes zero in all variables indicating non-significance as shown in Table 4. However, Bayesian estimation generates the population distribution of the coefficients of all variables. Taking advantage of these distributions, one can verify various probabilities regarding the coefficient of interest. Figure 5 shows the simulated posterior distributions of all coefficients, along with the summary statistics in Table 4.

Accordingly, although zero is included in the credible intervals of all distributions of coefficients, a considerable mass lies to the right of the AI, HCI and AI × HCI interaction and there are high probabilities of these coefficients being positive. Similarly, for the variables Ext and AI × Ext interaction, a considerable mass lies to the left of zero indicating a negative impact on the dependent.

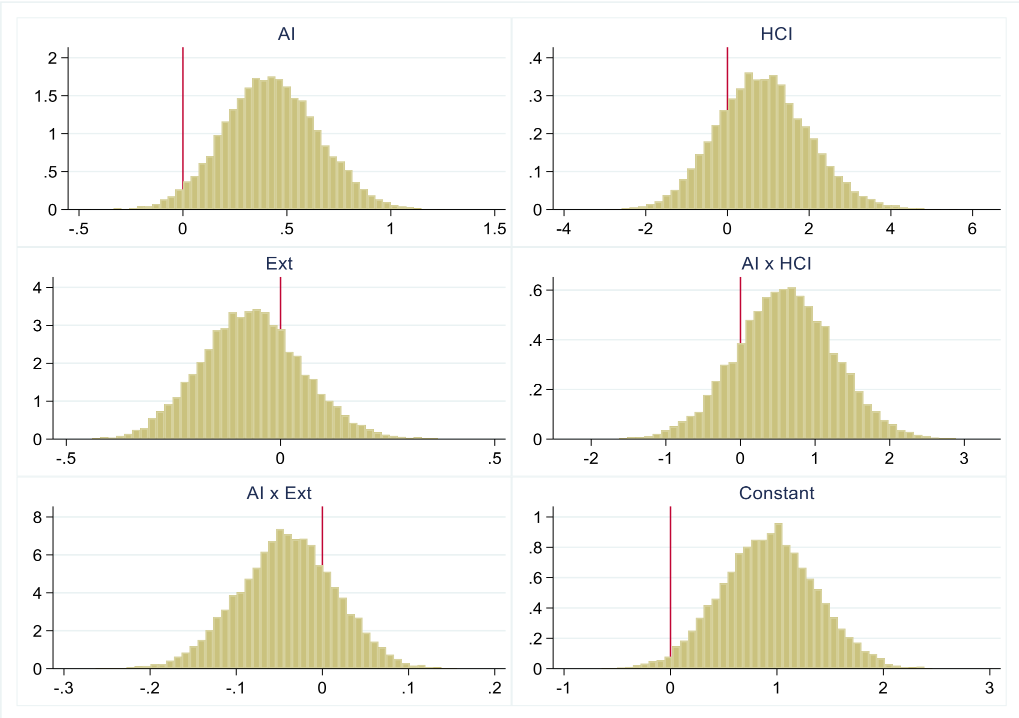

Figure 5: Simulated Posterior Distributions of Regression Coefficients with Reference Lines at Zero

The corresponding probabilities of above variables are calculated and shown in Table 5. The two interaction terms, which capture the moderating effects are AI × HCI and AI × Ext. The moderating effect of human capital (AI × HCI) on the effect of environmental awareness on environmental stewardship is positive. Thus, education amplifies the awareness impacts on adoption of ecofriendly practices. However, the coefficient of AI × Ext shows around 77% chance of being negative and hence can be treated as reducing the effect of awareness on ecofriendly practices. Therefore, larger farm sizes tend to discourage farmers from adoption of ecofriendly practices. The extension efforts and the research on ecofriendly agricultural practices should take this into consideration, when such practices are designed and introduced to farmers.

Table 5: Probabilities of Regression Coefficients being Positive or Negative

	Mean	Std. dev.	MCSE
Probability of AI>0	0.972	0.165	0.0019
Probability of HCI>0	0.775	0.418	0.0049
Probability of AI × HCI>0	0.820	0.384	0.0055
Probability of Ext<0	0.723	0.448	0.0084
Probability of AI × Ext<0	0.766	0.424	0.0075

Conclusions

Continuous rise in application of inorganic fertilizers and agrochemicals and associated groundwater pollution in Kalpitiya depicts a growing environmental concern problem in the world. Therefore, this research attempted to investigate the possibilities of circumventing this issue from a behavioural perspective. The main hypothesis tested was the impact of environmental awareness in environmental stewardship behaviour, in terms of probability of adoption of ecofriendly agricultural practices. The findings strongly support the hypothesis that the knowledge of environmental degradation is related to the possibility of adoption of ecofriendly agricultural practices. In addition, there are factors that moderate this effect. Human capital or the knowledge stock at the household, strengthens this impact while the farm size reduces this impact. These findings shed light not only on the study area of this research study, but all areas where environmental stewardship behaviour is needed and promoted. More importantly, the understanding of the moderating factors of impacts is vital in promoting environmental stewardship behaviour. Additionally, future research may further extend this study by considering mediating factors between awareness and behaviour.

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