

# Valuing Pollination as an Ecosystem Services: The Case of Hand Pollination for Cocoa Production in Ghana

Salamatu Jebuni-Dotsey<sup>1</sup>, Bernardin Senadza<sup>2</sup> & Wisdom Akpalu<sup>3</sup>

<sup>1</sup> Research Department, Bank of Ghana, Ghana

<sup>2</sup> Department of Economics, University of Ghana, Ghana

<sup>3</sup> Ghana Institute of Management and Public Administration, Ghana

Correspondence: Salamatu Jebuni-Dotsey, Research Department, Bank of Ghana, Ghana. E-mail: [sjdotsey@gmail.com](mailto:sjdotsey@gmail.com)

Received: June 5, 2023

Accepted: July 2, 2023

Online Published: July 15, 2023

doi:10.5539/jas.v15n8p48

URL: <https://doi.org/10.5539/jas.v15n8p48>

## Abstract

The promotion of cocoa farm productivity has necessitated the intensification of input use with ensuing loss of natural pollinators. Ghana Cocoa Board's (COCOBOD) remedy to declining pollinator population is addressed in the rolling out of hand pollination in the 2016/17 crop year. Applying contingent valuation on field data covering 608 farmers in five cocoa growing regions, we estimate the value of pollinator services to the cocoa industry in Ghana and farmers willingness to pay for the service. We find that cocoa farmers in Ghana are willing to pay for hand pollination to improve on their farm yields. Farmers averagely value pollinator services at \$1.3 per acre of land. Extrapolated to cover all cultivated cocoa lands for 2017/18 crop year, the value of pollinator services to Ghana's cocoa industry is averagely \$6.1 million per annum. Hand pollination can improve cocoa farms yields given the statistically significant mean difference in yields between hand-pollinated and non-hand-pollinated farms. Having established the loss to the cocoa industry from pollinator decline and the need for effective pollination to support crop productivity, it is imperative for COCOBOD to ramp up strategies at preserving cocoa farm ecology to safe guard the industry.

**Keywords:** productivity, pollination, hand pollination, cocoa, contingent valuation, willingness to pay

## 1. Introduction

Cocoa cultivation thrives on extensive land use that leads to the loss of forest cover with its diverse ecology more especially cocoa pollinators such as ceratopogonids midge. Also, the increasing use of agrochemicals to control pests and diseases in addition to the promotion of monoculture agriculture exacerbates such losses (Claus, Vanhove, Van Damme, & Smagghe, 2018). Insect pollinators require diversity of plant life to thrive; however, changing landscape ambience caused by global warming, population growth, intensification in agricultural land use and inappropriate use of agro-chemicals reduces the conduciveness of their dwelling and their population (Ali, Sajjad, Farooqi, Bashir, Aslam, Nafees, & Khan, 2020; Hanley, Awbi, & Franco, 2014). The cocoa tree bears many flowers on its trunk, but on average only 5 percent of such flowers results into matured cocoa pods as many flowers get aborted due to low pollination (Vaissière, Freitas, & Gemmill-Herren, 2011). Improving productivity in cocoa is highly dependent on effective pollination of cocoa tree flowers which is supported by the population density of midges' pollinators (Toledo-Hernandez et al., 2017). There is reported global decline of pollinators, largely driven by human activity reflected in falling yields of crops dependent on their input with dire consequences for crop production, food security and livelihoods of small-scale farmers (Sawe, Nielsen, & Eldegard, 2020; Rhodes, 2018).

The cocoa industry in Ghana has been particularly hit with years of reported low yields despite intensification in input use. Poor pollination has been identified by COCOBOD (Note 1) as one of the key challenges to improving industry productivity for which reason the hand pollination programme was launched in 2016/17 crop year to supplement natural pollination. Hand pollination is proven to remarkably increase the number of cocoa pods per tree (Forbes et al., 2019). This notwithstanding, for more sustainable cocoa production, the propagation of natural pollinators such as as the *ceratopogonids* midges through landscape perseveration is essential for addressing the problem of low yields (Vanhove, Yao, Toussaint, Kaminski, Smagghe, & Van Damme, 2020;

Claus et al., 2018; Frimpong, Gordon, Kwabong, & Gemmill-Herren, 2009). This is because cocoa is highly dependent on insect pollination with a dependency ratio of 0.95 (Chaudhary & Chand, 2017). According to Claus et al. (2018), intensification of input use may be necessary to maintain and increase cocoa output, however, gains in productivity is enhanced by facilitating pollination intensity on cocoa farms. This is further supported by Aizen, Garibaldi, Cunningham, and Klein (2008) who asserts that the need for pollinators is not offset by agricultural intensification, selective breeding or genetic modification of the crop. Rather, these modified crops' productivity is enhanced by pollination. The drive for productivity increase can effectively be achieved in conjunction with preservation of cocoa forest vegetation to facilitate pollination.

Ecosystem valuation allows for value to be ascribed to nature's resources by offering the opportunity for demonstrating the benefits of conserving this service (Hanley et al., 2014). It also facilitates the process of examining the cost and benefits associated with different policy options that has direct bearing on the environment (Himes-Cornell, Pendleton, & Atiyah, 2018). The ecosystem provides diverse direct and indirect services that supports all life forms and classified by the Millennium Ecosystem Assessment (2005) into four distinct categories, namely, support, regulatory, provisioning and cultural. Pollination performs both regulatory and provisioning functions. It supports the functioning of a range of Eco services such as crop production, pest control, biodiversity maintenance and nutrient recycling (Popak & Markwith, 2019; Breeze, Bailey, Potts, & Balcombe, 2015).

Hand pollination is undertaken by COCOBOD to support farm productivity at no cost to the farmers as part of the input support programmes, which currently has no market. Cocoa pollinator losses persist because the industry has no information of the value of such losses to drive its conservation. Also, the critical role of such information lies in the fact that input support programmes by government are better sustained with the adequate participation of the stakeholders, in this case the farmers. To address cost sharing as in the case of hand pollination, key information on farmers' willingness to bear some cost on the project, which also points to their acceptance of such initiative, is needed to facilitate this process. This paper seeks to provide both the value of pollinators and farmers willingness to pay (WTP) using cross-sectional survey data from five cocoa growing regions as demarcated by COCOBOD, namely Ashanti, Brong-Ahafo, Western North, Western South and Volta regions. The paper adopts contingent valuation method to value pollination services to the cocoa industry of Ghana, information which to the best of our knowledge is currently not available. Secondly, the mean willingness to pay estimates will serve as a benchmark price for COCOBOD should they opt to continue the programme at a fee to the farmer, also being indicative of farmers' willingness and ability to pay for the hand pollination.

The rest of the paper is structured as follows. Section 2 reviews the related literature. The methodology, discussed in section 3, highlights the study design and the empirical approach. Section 4 presents and discusses the results, while section 5 concludes with policy implications.

## 2. Review of Literature

The enthusiasm for environmental service valuation comes out of the understanding that the services of nature are exhaustible. To galvanize efforts towards their protection and preservation, it is necessary to impute monetary value to such public goods (Gowdy, Krall, & Chen, 2013). However, the absence of markets for ecosystem services limits the effective use of price for valuation. Moreover, though market price in a competitive environment can reflect the true value of a commodity, in certain cases the market value of a commodity may be a weak approximation of its true value (Fisher, Bateman, & Turner, 2013). This is typical of environmental or public goods in which services extend to cover both present and future generations. Value under such conditions may be far more than that revealed by markets. The divergence between market price and the value of a good to the consumer is a surplus which is the basis for welfare evaluation of public goods.

The fact that ecosystem service offers both direct and indirect benefits to humans, coupled with their diversity of service and function makes it challenging to develop one universal method of valuation (Hanley et al., 2014). The complexity of estimating the value of environmental services is overcome using surrogate measures compatible with the individual decision-making processes. According to the Food and Agriculture Organization (FAO, 2006), public environmental goods can be valued either directly or indirectly under the umbrella of revealed preference or stated preference methods. Direct valuations or stated preference methods are used when there is no existing consumer behaviour to infer individual preferences (Loomis, Huber, & Richardson, 2019), instead, researchers construct or stimulate a market to which preferences are stated, referred to as the stated preferences methods of valuation. Stated preference methods are categorized into contingent valuation methods (CVM) and choice modelling (CM). Choice modelling is applied to valuation in which the policy maker does not

have a single defined scenario. The solution to solving one environmental challenge lies in devising several different resource management options (Loomis et al., 2019). In choice experiments participants are presented with varied attributes of the environmental good and are allowed to select an array of attributes of the hypothetical good that appeal to them. Some applications of this technique are given by the works of Syuhada, Mahirah, and Roseliza (2020), and Buckell and Hess (2019).

Contingent valuation is a valuation method contingent on the information offered to the respondent in a survey (Oerlemans, Chan, & Volschenk, 2016; Hoyos & Mariel, 2010). The analysis is operationalized with the setting up of a hypothetical market scenario and depending on the eliciting technique, participants are requested to state the maximum amount they are willing to pay for incremental value of a given environmental/public good (Johnston, Boyle, Adamowicz, Bennett, Brouwer, Cameron, & Tourangeau, 2017). Contingent valuation methods have extensively been used in applied works with Carson and Hanemann (2005) identifying the use of CVM for over six thousand papers covering more than a hundred countries. The advantage of CVM is that it allows for the gathering of valuable information on consumer behaviour which prior had not existed. Also, it allows for the presentation of new goods that maybe outside the experience of the consumer (Oerlemans et al., 2016). There have been some initial reservations to the use of the method in the 1960s when it gained empirical application because of criticism of hypothetical bias, scenarios where the individual may indicate a WTP that may exceed the amount of money they are willing to commit (Loomis et al., 2019; Boyle, 2017). Likewise, if the respondent does not have fair knowledge of the good in question, they may undervalue the product. The solution prescribed is to provide enough information to the respondent of the nature of the public good (Mwebaze, 2018; Boyle, 2017).

Contingent valuation is computationally much easier to implement than CM, more especially when the research respondents are not literate (Arshad, Amjath-Babu, Kächele, & Müller, 2016). The estimate of WTP is similar for both techniques since both formulations require a respondent-stated WTP. This paper adopts CVM as opposed to CM based on two considerations. The first consideration is that the valuation is set on a single managerial scenario which is increasing pollination services to cocoa farms using hand pollination. Secondly the respondent population is made up of rural cocoa farmers with little or no education; hence the computationally less complex CVM will be better fitted for the population.

The major source of error in contingent valuation comes from the technique used in eliciting bids as estimates of valuation are sensitive to the elicitation format (Vossler & Zawojnska, 2020). The National Oceanic and Atmospheric Administration (NOAA) panel on contingent valuation recommends the use of dichotomous choice formulation that simply requests the individual to decide if they are willing to pay a certain price for a good (Boyle, 2017). This formulation is like general consumption decision made by consumers and is believed to produce more reliable welfare estimates. The simplicity of this formulation lies in the reduced cognitive engagement of the respondent and reduction in the incentive to give strategic decisions.

Double bounded dichotomous (DBD) choice elicitation format is an extension of the single bound, designed to gain more statistical efficiency in CV estimates. The formulation allows for a second referendum bid after response to the first bid has been given, in which the value of the second bid is conditioned on the response to the first. DBD choice format is more likely to produce efficient welfare estimates than the single bound. It has also been proven to reduce the variance of the estimated parameters significantly because it defines precise boundaries for WTP (Vossler & Zawojnska, 2020).

The driving incentive behind pollination valuation in the 1940s was conservation rather than crop yields. With this objective in focus, economic value of pollinators was estimated based on the production function approach. The argument being that pollinator services is an input to production of crops as most crops fail to produce seed without pollination (Breeze et al., 2015). The challenge with this approach is that it ascribes the market value of the entire crop, as the full value of pollination services, even for crops that required only minimal pollination. Ensuing work have sought to overcome some of the challenges with the economic value method leading to the formulation of the insect pollinated economic value or the bio-economic method (Barfield, 2012). The model isolates the contribution of pollination as one of the inputs to crop production by discounting total crop value by the level of dependency ( $D$ ) of a given crop on pollination (Knapp & Osborne, 2017). The value of pollinators is then given by the market value of the crop times the dependency level of the crop on pollination:

$$BEV_{it} = P_{it} \times Q_{it} \times D \quad (1)$$

where,  $BEV_{it}$  is the bio-economic value of a crop at time  $t$ ,  $D$  is the dependency ratio and  $P$ ,  $Q$  are the market price and quantity of the crop. Nevertheless, the bio-economic approach has also been criticized for failing to

account for production cost and other alternatives to natural pollination and secondly for treating the dependency ratio as a constant.

Knapp and Osborne (2017) estimates the economic value of pollinators to courgettes production in United Kingdom at £2.74 million using the production function approach, while Garratt et al. (2014) estimates the value of insect pollinators to cox and gala apple production in UK at £37 million. Winfree et al. (2011) similarly value native bees in New Jersey and Pennsylvania at \$2.25 million per year. In the African context, Toni and Djossa (2015) also using the production function approach, values cocoa pollinator services in Benin at \$107,837 based on a crop value of \$113,513 and a 95% dependency ratio.

A second major method of valuing pollination services is the replacement cost method. With this method value is approximated with the cost of substituting technologies to pollination; either the rental cost of hired bees, labour cost for hand pollination or machine plus labour cost for pollen dusting (Magrach, Champetier, Krishnan, Boreux, & Ghazoul, 2019). The criticism of this technique lies in the fact that it is based on cost of substitute methods rather than willingness to pay. Moreover, the replacement cost method fails to account for changing cost of the replacement alternatives.

Recent valuation of pollination services makes use of stated preference method given by either contingent valuation (CV) or choice modelling techniques. Stated preference method allows for the estimation of both the use and non-use value of pollinators, which is believed to produce values that are close to the real value for the services of nature to humankind. Application of CV techniques for valuing pollinations can be found in the work of Mwebaze, Marris, Brown, MacLeod, Jones, and Budge (2018) who estimates U.K. households' mean WTP to conserve bee at £43. Breeze et al. (2015) earlier on using choice modelling also elicits willingness to pay for bee conservation at £13.4 per household for the same country.

Some studies have attempted to use a combination of available valuation techniques in order to compare outcomes. Breeze et al. (2016) finds many of such attempts have produced estimates that are heterogeneous even for the same crop in similar locations. Valuation estimates will differ depending on the valuation technique. To facilitate the computation of both the use and non-use value of cocoa pollinators we adopt CVM to value pollinator services to the cocoa industry.

### **3. Methodology**

#### *3.1 Research Design*

Data for this research is obtained through a field survey comprising of 989 cocoa farmers using a cross sectional design. Given that in contingent valuation a hypothetical market situation is created, it is essential to ensure that the respondents understand and know the product being valued to facilitate the estimation of realistic welfare values of the ecological service in question. To this end a structured questionnaire was prepared consisting of both demographic and farm information in the first two sections. Subsequent sections fielded questions related to pollination and hand pollination. Specifically, to ensure that the respondents undertaking the valuation are farmers with an understanding of the product to be valued, the starting line-up of questions were structured to evaluate farmers' understanding of the pollination process and hand pollination services. Respondents who indicated knowledge about hand pollination and were also willing to hand pollinate their farms were then allowed to answer the valuation questions.

#### *3.2 Bid Design and Process*

To design effective bids for this valuation study, a pre-test was carried out with open ended questions asking farmers to state how much they are willing to pay for hand pollination. This was undertaken in October 2018 in four cocoa growing communities of the New Tafo district of Eastern region of Ghana, namely, Nobi, Tontro, Obodanso and Sansakwa. The highest and lowest bids were identified from the range of monetary values stated in the responses. Following which, some extra information gleaned from sections of the questionnaire on farm maintenance cost was used to facilitate the setting of valuation bids. For instance, the cost of hiring a single farm labourer to weed a plot of land in a day at the time of the survey was Gh¢ 25 (\$5.5). Since this value represented the lowest labour cost, this amount was used as the starting point for bid structuring. In addition to this the open-ended questionnaire from the pre-test produced Gh¢400 (\$87) as the farmers highest WTP. This value was also used as the upper bound for the range of bids. The bids were then structured to range from a lower bound of GH¢25 with 100% percent incremental jumps ending at an upper bound of GH¢400. Bids were administered to farmers in the survey using a double bounded elicitation technique. For instance, if a randomly selected bid is offered and the farmer response yes to the offer, a second higher offer of either Gh¢ 50 (\$10.9) or Gh¢100 (\$21.8) is offered to find out if the farmer is willing to pay more. On the other hand, if a bid such as Gh¢200 (\$43.6) is

initially offered and it is rejected by the farmer, a lower bid such as Gh¢ 100 is offered to the farmer to express a WTP. Kim, Petrolia, and Interis (2011) believes this iterative process facilitates the estimation of maximum willingness to pay, while the interval range between a yes and no response produces the mean WTP.

### 3.3 Ethical Considerations

Informed consent is the basic requirement of human subject studies which mandates the researcher to explain fully the purpose of the research, issues regarding confidentiality and appropriate use of information. Consent should be given freely devoid of any element of coercion and the individual should comprehend the risk and benefit associated with the exercise. Compensation package should not be of high monetary volume in order to reduce the effect of monetary coercion (Badu-Nyarko, 2013; Marczyk, DeMatteo, & Festinger, 2005).

The data for this study was collected under the institutional ethical guidelines for Cocoa Research Institute. The institution being a research centre has standing researcher/regulator collaborations with cocoa farmers. Farmers evaluate the effect of their supply interventions and CRIG on the other hand process such information, and transmit findings through research papers and memos which acts as the foundations for future research and support to the farmers.

The ethical standard observed on the field included first explaining the objective of the study to the respondents. This was done through group debriefing exercises at each community. Farmers were informed that their participation is voluntary and given the opportunity to opt out. Verbal consents were taken as questionnaires were administered with electronic tabulates. The compensation to farmers who were willing to participate comprised of one cake of cocoa soap produced by CRIG worth GH¢4 (\$0.87). This value was not excessive, satisfying the requirement that the compensation should not cause coercion.

### 3.4 Empirical Model

We value the services of cocoa pollinators using survey responses from a contingent valuation exercise in which bids were randomly assigned to each farmer. Following (Hynes, Ravagnan, & Gjerstad, 2019; Mueller, Soder, & Springer, 2019) let a single bound WTP ( $W$ ) be a function of  $Z$  covariates,

$$W_k = z_k' B + u_k \quad (2)$$

where,  $B$  is the vector of parameters for the model,  $z_k$  vector of explanatory variables and  $u_k$  the random error which follows the standard normal distribution assumptions. Since farmers are presented with a randomly selected bid, their true valuation is greater than/equal to the bid. If the farmer accepts the bid  $W_k > d_k$  and if they reject the bid  $W_k < d_k$ , where,  $d_k$  is the bid value.

Let  $Y_k = 1$  if the bid is accepted and  $Y_k = 0$  if the bid is rejected, the probability of acceptance is a function of covariates.

$$\begin{aligned} P(Y_k = 1 | z_k) &= P(z_k' B + u_k > d_k) \quad \text{or,} \\ P(Y_k = 1 | z_k) &= P(u_k > d_k - z_k' B) \end{aligned} \quad (3)$$

A standard probit model is used to estimate parameters of the model given as,

$$P(Y_k = 1 | z_k) = P\left(u_k > \frac{d_k - z_k' B_k}{\sigma}\right) \quad (4)$$

$\Phi(z)$ , is the standard normal cumulative density for  $n$  sample observations and  $\sigma$  is the standard deviation of  $z_k' B$ . The joint density function of the data is interpreted as a likelihood function  $L = f(B, \sigma | Y, d, z)$ , expressed in log transformation as:

$$\ln L = \sum \left\{ Y_k \ln \left[ 1 - \Phi \left( (d_k - z_k' B) / \sigma \right) \right] + (1 - Y_k) \ln \left[ \Phi \left( (d_k - z_k' B) / \sigma \right) \right] \right\} \quad (5)$$

The bivariate probit model extends on the single probit function to estimate a single function with two related probit equations (Hynes et al., 2019). The WTP for bids one and two are given as:

$$W_1 = z_1' B + u_1 \quad (6)$$

$$W_2 = z_2' B + u_2 \quad (7)$$

where,

$$\begin{bmatrix} u_1 \\ u_2 \end{bmatrix} \sim \left( \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \sigma^2 \begin{bmatrix} 1, \rho \\ \rho, 1 \end{bmatrix} \right)$$

The model assumes the errors are standard bivariate normal  $\Phi(2)$  with correlation  $\rho$ , if  $\rho = 0$  the two errors are not related and the density function reduces to two separate probit models. However, if  $\rho \neq 0$  the errors are correlated, thus the probability of one error depends on the probability of the other, which captures the unobserved characteristics that correlate the farmer's probability of being willing to pay for hand pollination.

Response categories are “yes, yes”, “yes, no”, “no, yes” and “no, no”, with the probability of responses for each category given respectively as,

$$P(Y, Y) = P(WTP > d^1, WTP \geq d^2)$$

$$P(Y, N) = P(d^1 \leq WTP < d^2)$$

$$P(N, Y) = P(d^2 \leq WTP < d^1)$$

$$P(N, N) = P(WTP < d^1, WTP < d^2)$$

Molina, Letson, McNoldy, Mozumder, and Varkony (2020) have demonstrated that using Bayes rule, the response functions are

$$P(Y_k = \{1, 1 | z_k\}) = \left( \Phi(z_k' B - d_k^2) / \sigma \right) \quad (8)$$

$$P(Y_k = \{1, 0 | z_k\}) = \left( \Phi(z_k' B - d_k^1) / \sigma \right) - \left( \Phi(z_k' B - d_k^2) / \sigma \right) \quad (9)$$

$$P(Y_k = \{0, 1 | z_k\}) = \left( \Phi(z_k' B - d_k^2) / \sigma \right) - \left( \Phi(z_k' B - d_k^1) / \sigma \right) \quad (10)$$

$$P(Y_k = \{0, 0 | z_k\}) = 1 - \Phi(d_k^2 - z_k' B) / \sigma \quad (11)$$

The log-likelihood function for parameters of the four responses is given by Equation 12:

$$\begin{aligned} \ln L(B, \sigma | z_k, d_k, I_k) = \sum_{k=1}^n \left\{ I_k^{YY} \ln \left( \Phi(z_k' B - d_k^2) / \sigma \right) + I_k^{YN} \ln \left( \Phi(z_k' B - d_k^1) / \sigma \right) - \left( \Phi(z_k' B - d_k^2) / \sigma \right) \right. \\ \left. + I_k^{NY} \ln \left( \Phi(z_k' B - d_k^2) / \sigma \right) - \left( \Phi(z_k' B - d_k^1) / \sigma \right) + I_k^{NN} \ln \left( 1 - \Phi(d_k^2 - z_k' B) / \sigma \right) \right\} \end{aligned} \quad (12)$$

where,  $I_k^{NN}$ ,  $I_k^{NY}$ ,  $I_k^{YN}$ ,  $I_k^{YY}$ , are indicator variables for each response category, with mean willingness to pay given as:

$$\bar{W} = \bar{z}' \hat{B} \quad (13)$$

The key factors influencing farmers' willingness to pay for innovative products are generally categorized into farmer and farm characteristics, socio-economic, and institutional factors in previous studies (Ahiale et al., 2019; Danso-Abbeam, Addai, & Ehiakpor, 2014). The choice of variables selected as covariates for this study was first to test for positive income and negative price signals in contingent valuation. Secondly, we control for knowledge of pollination because in valuation, the knowledge of the product is important to producing reliable mean WTP estimates. Also, we control for farm characteristics such as age of farm, size of farm and farm output as they remain key to explaining the willingness to pay. Specifically, the age of the farm determines if a particular farm will be hand pollinated or not (the age of a cocoa farm benefiting from hand pollination is 3-25 years). Then also the yield levels on a farm determine whether a farmer will be willing to pay for yields improving technology.

## 4. Results and Discussions

### 4.1 Summary Statistics

In discussing the findings of this study, we begin by examining some summary statistics from the survey presented in figure 1 and 2. Figure 1 captures information on farmers knowledge of pollination and their WTP. In chart 1, we show over 60% of 989 cocoa farmers had some knowledge of pollination, with about 90% of the farmers pointing out they facilitated natural pollination with the farming practices observed on farms (chart 2). In terms of farmer's knowledge of COCOBOD hand pollination exercise, respondents appeared to have some good knowledge of the instrument of valuation with 77.3% (764 farmers out of 989) having heard about hand pollination (chart 3). Continuing with farmers who had heard of about hand pollination, chart 4 reveals over 90% of these respondents believed hand pollination could improve yields on their farms, with more than 80% understanding to varying degree the benefits of hand pollination for farm productivity (chart 5). Eighty percent of the farmers were willing to pay for the services (chart 6).

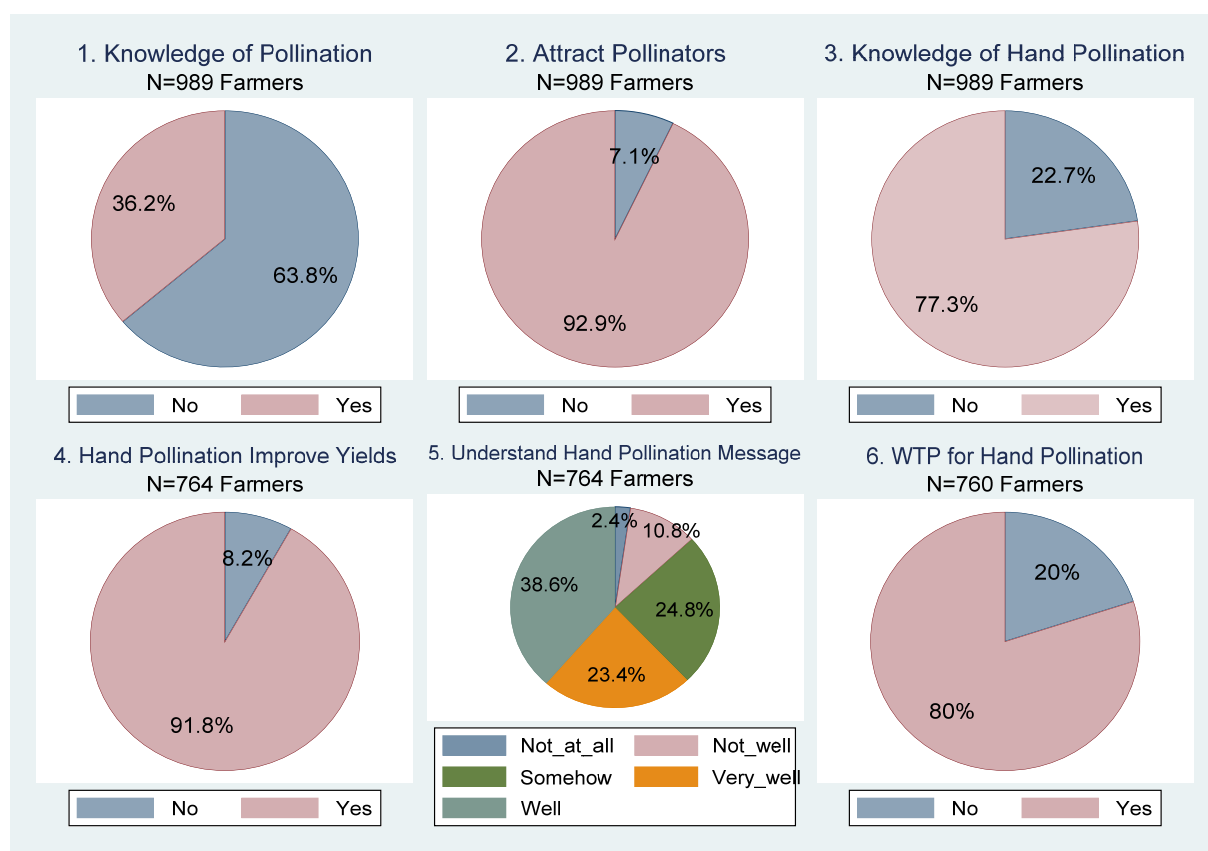


Figure 1. Knowledge of pollination and hand pollination

Source: Field data, 2019.

Having assessed the farmers knowledge on hand pollination, we zero down to evaluate their engagement with the product, findings are given in figure 2. This section is categorized into panels A to D. Panel A reveal out of the 764 cocoa farmers that had heard about this product, less than 40% (254 farmers) had their farms hand pollinated. For farmers with hand pollinated farms, more than 80% observed significant changes on their farm plots (Panel B). The key changes observed on cocoa trees were the appearance of more pods as compared to other sections of the farm that were not hand pollinated (Panel C). For the 510 farmers who had not received hand pollination 70% indicated they were not selected for the programme, 12.2% mentioned that their farms were either too old or young to participate in the exercise, with just 4% pointing out some disinterest in the programme, hence their decision not to participate (Panel D).

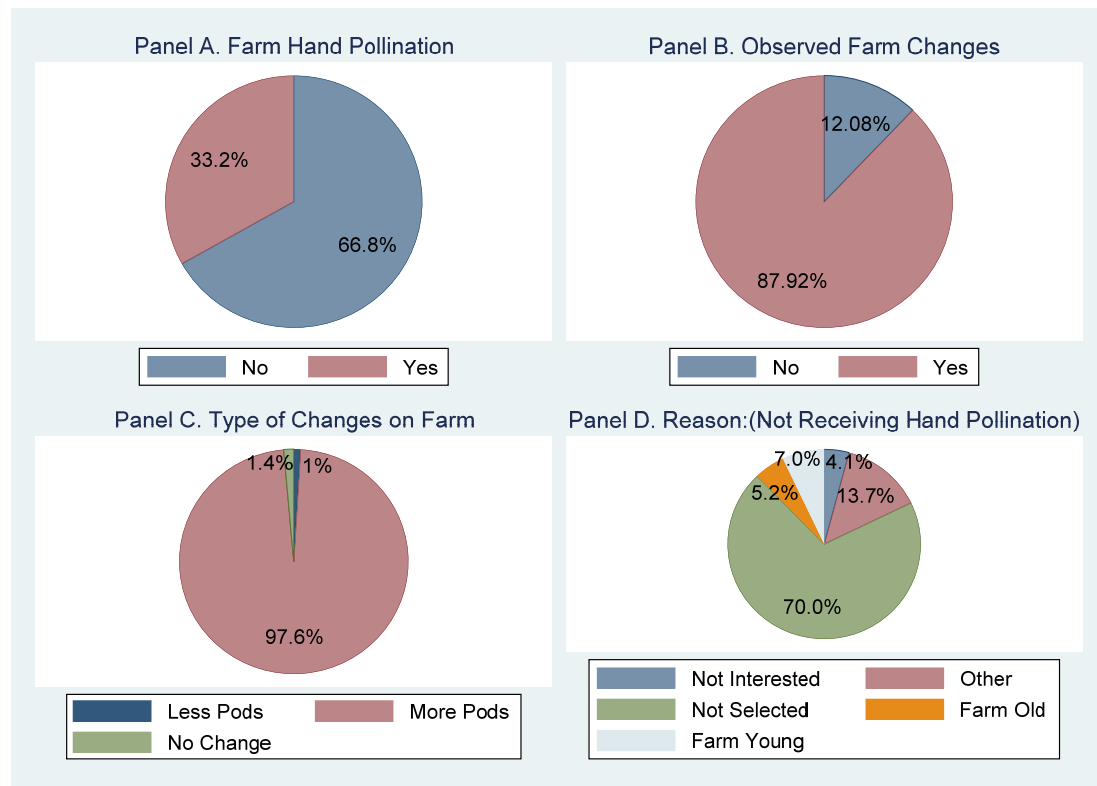


Figure 2. Response on hand pollination

Source: Field data, 2019.

The effect of hand pollination on the productivity of the 254 farms that benefited from the programme was analyzed for 100 farms. This is because most farmers failed to separate produce of hand pollinated plots from non-pollinated sections of the farm. Table 1 presents a t-test of the mean yields (kilograms per acre of farm land) of hand pollinated plots vis-à-vis same plot yields a year earlier. Hand pollination was carried out in 2016/2017 and first yields realized in 2017/18. The results revealed a mean output of 477.8 kg as compared to 361.7 kg a year earlier. The t-test confirmed that this yield difference was significant at 1%, indicating that hand pollination could potentially improve cocoa farm yields and therefore should be added to the existing innovative technologies for boosting productivity in cocoa.

Table 1. Yield analysis: pollinated versus non-pollinated farms (test of means)

Variable	Mean	Standard Error	STD. Deviation	95% confidence Interval
Yields (kg) 2017/18	477.76	37.84	378.42	402.67-552.84
Yields (kg) 2016/17	361.70	38.33	383.30	285.65-437.76
Difference	116.06	33.96	339.63	48.67-183.45
Mean (diff) = Mean (Yields2 – Yields1)			t = 3.4172	

Source: Field data, 2019.

Respondents who indicated their WTP (608 respondents) were followed up with five randomly assigned bids and asked to express how much they are willing to pay. A 'yes' response for the first bid offer stood at 445 farmers, representing 73.19% (Table 2). Farmers willing to pay for the follow-up bids was 389 (63.98%) with those unwilling to pay being 219 (36.02%). The results are consistent with economic theory of consumer demand, as bid price increased the number of rejections of the stated bid also increased.



Table 2. Willingness to pay (initial and follow-up bids)

WTP1	WTP 2		Total
	No	Yes	
No	0	163	163
Yes	219	226	445
Total	219	389	608

Source: Field data, 2019.

The demographic statistics of respondents willing to pay for hand pollination are presented in Table 3. The average years of education for respondents was 9 years with a maximum of 21 years. Average household size was 6 persons rising to 22 persons. The age of cocoa farms was averagely 16 years, with a minimum age of 3 years and a maximum of 60 years. Also, the age of farmers was on average 51 years, with some farmers being as young as 23 years and others as old as 85 years. Annual household total income and annual cocoa income averaged between Gh¢9,990 (\$2,178) and Gh¢8,167(\$1,781) respectively. Majority of respondents were male, with less than 60% of the participants belonging to a farmer association.

Table 3. Summary statistics

Variable	Observations	Mean	St. Dev.	Minimum	Maximum
Education (Years)	608	9	4	0	21
Household Size (person unit)	608	6	3	1	22
Size of Farm (acres)	603	9	8	0.5	70
Age of Farm (years)	584	16	9	3	60
Age farmer (years)	608	51	12	23	85
Farm Experience (years)	608	18	10	1	54
Annual Household Income (Gh¢)	604	9,990	10,407	370	86,450
Annual Cocoa Income (Gh¢)	595	8,167	9,926	237.5	119,700
Cocoa Output (kgs)	595	959.7	796.9	32	4800
Gender	Indicator	Frequency	Percent	Cumulative	
Male	1	510	83.88	83.88	
Female	0	98	16.12	100	
Farm Association Membership					
Yes	1	433	56.58	56.58	
No	0	264	43.42	100	

Source: Fields data, 2019.

#### 4.2 Bivariate Probit Estimates of WTP

A bivariate probit model was selected to evaluate the bid response on farmers' willingness to pay. We first ascertain the feasibility of using a bivariate probit rather than single probit models for the two response categories. Beginning with Table 4, which models only the bid responses, the athrho estimate was significant at 1% with a rho of 0.962, pointing to a close correlation between the errors of the two estimates. This is confirmed by the Wald test of the null that rho is equal to zero, which is rejected at 1% with a chi (1) of 159.49. The model estimated was thereby adequate for the data. Following from this, the regression results revealed a significant and negative response of WTP to the first and second bid at 1% level. Increasing initial bid by Gh¢1 reduced the probability of acceptance by 0.046, whereas increasing the follow-up bid reduced the probability of acceptance by 0.176. This seemingly confirms negative price sensitivity, that is, as bid values increased the number of rejections also increased.

Progressing from this first estimates, other covariates were incorporated into the model to identify the factors influencing individual farmers' WTP and facilitate the testing of construct validity under this valuation exercise (Table 5). We begin by testing for the fitness of this second model. The results established the desirability of using a bivariate probit model rather than using two single probit models for the two dependent variables. The arthrho was statistically significant and the Wald test for the null of rho being zero was rejected. Also, the

correlation between the errors given by rho was 0.987 pointing to close correlation between the two responses. Then also, the log likelihood for this model was -492.074 with a likelihood ratio test of chi2 (14) being 145.23 supporting model fitness.

Interpretation of results in Table 5 is undertaken with reference to the two response categories given that they are modelled as related outcomes. In this regard the marginal effects are computed as joint effect of the first and second responses. The results revealed that increasing bid value by Gh¢1 reduced the probability of acceptances by 0.035 whereas increasing income raised the probability of WTP by 0.055.

The knowledge of hand pollination on WTP was not significant, this could be explained by the fact that farmers probability had some confidence in COCOBOD and as such were ready to partake in new initiatives by the board without much personal knowledge. Oerlemans et al. (2016) posits the effect of extra knowledge on WTP depends on the existing knowledge held by the valuer. The size of the farm increased the probability of acceptance perhaps because size could be related to revenue. Those with larger farms will likely have higher farm output affording them the opportunity to pay for pollination services. Secondly the possibility of increasing farm yields maybe more attractive to those with larger farms given higher investment in farming, hence their WTP. These results are in sync with other studies such as Poudel and Johnsen (2009) who also find that Nepal rice farmers with more resources and larger landholdings were more willing to maintain agricultural biodiversity. Also, Fahad and Jing (2018) find that farm produce influenced Pakistani farmers WTP for crop insurance. Moving from here, the study also found that increasing cocoa yields reduced farmer's probability of paying for hand pollination by 0.067. This is expected if the product of valuation is to improve yields, then a farmer already enjoying improved yields may not be willing to pay for the same outcome. The age of a cocoa farm increased the probability of acceptance, albeit at the 10% level. This is explained by the fact that cocoa yields fall with age, as such farmers with aging farms already facing lower yields will be more open to this new opportunity for improving yields. The study however, found that the gender of the farmer did not influence the choice to pay or otherwise for hand pollination. Other studies such as Chatterjee (2019), Ramli, Samdin, and Ghani (2017) also find gender not significant in WTP estimations.

Table 4. Bivariate probit estimates with constant

Variables	Coefficients	dy/dx
WTP 1: Initial bid	-0.146*** (0.048)	-0.046 (0.015)
Constant	0.872*** (0.098)	
WTP 2: Follow-up Bid	-0.464*** (0.054)	-0.176 (0.021)
Constant	0.366*** (0.094)	
athrho	1.972*** (0.156)	
rho	0.962 -0.0193	
Wald test of rho = 0	chi2(1) 159.49	Prob chi2 > 0 = 0.000
LR test of chi2 (2)	97.69	Prob chi2 > 0 = 0.000
Observations	608	

Note. Robust standard errors in Parenthesis \*\*\*p < 0.01, \*\*P < 0.05, \*P < 0.1.

Table 5. Bivariate probit estimates with covariates

Variables	Marginal Effects	
Initial Bid	-0.035**	
	(0.018)	
Household Income	0.055**	
	(0.028)	
Knowledge of Pollination	-0.047	
	(0.058)	
Size of Farm	0.077***	
	(0.028)	
Age of Farm	0.025*	
	(0.014)	
Cocoa Yields	-0.067**	
	(0.028)	
Gender (Male = 1)	-0.023	
	(0.044)	
athrho	-2.497***	
	(0.463)	
rho	0.987	
Wald Test of Rho = 0	chi2 (1) = 29.062	Prob chi2 > 0 = 0.000
log Likelihood	-492.074	
Wald chi2(14)	145.23	Prob chi2 > 0 = 0.000
Observations	415	

Note. Robust standard errors in parenthesis \*\*\*  $p < 0.01$ , \*\*  $P < 0.05$ , \*  $P < 0.1$ .

#### 4.3 Estimation of Mean Willingness to Pay

Tables 6 and 7 presents the mean estimates of farmers willingness to pay for hand pollination, which are constructed from the probit and bivariate probit regression results. The probit estimates are not presented because results from Table 5 show that a bivariate probit model best fits the elicitation method of WTP. However, for comparison we present the mean WTP outcomes for both models. In Table 6, the mean WTP estimates are presented without any covariates, whereas Table 7 controls for covariates. All mean WTP estimates are computed with a 95% confidence interval around the mean using Krinsky & Robb procedure (Jeanty, 2007), with a user written command in STATA “wtpcikr” and using 5,000 replications.

Beginning from the estimates with no covariate, the single bounded probit estimates produced a mean WTP of Gh¢4.86 (\$1.06). This increased slightly to Gh¢5.12 (\$1.12) using the double bounded bivariate probit estimates, with a maximum WTP of Gh¢9.00 (\$1.96) and minimum of Gh¢3.7 (\$0.81) (Table 6). The estimated WTP from the double bounded model exhibits lower confidence interval around the mean as compared to the single bound estimates, and hence is the preferred estimate of mean WTP.

To further investigate the preference of the double bounded estimate to a single bound, some covariates were controlled for in the model. Results given in Table 7 revealed a higher mean WTP of Gh¢5.94 (\$1.30), with a maximum WTP of Gh¢13.59 (\$2.96) and a minimum of Gh¢3.9 (\$0.85). The ALS test was used to investigate the significance of the WTP estimates. The null hypothesis says WTP estimates are equal to zero against the alternative that they are greater than zero. The null is rejected indicating all estimates of farmer’s willingness to pay for hand pollination were significant at 1% level.

The double bound WTP estimates with covariates (Table 7) is preferred since the regression results (Table 5) from which these were computed controlled for observed heterogeneity in individual demographic characteristics and facilitated the testing of construct validity which is essential for contingent valuation. This being the case, the computed mean willingness to pay for hand pollination by cocoa farmers in Ghana is Gh¢5.94 (\$1.30) per acre of cocoa land.

Table 6. Mean and median willingness to pay for hand pollination (without covariates)

Measure	WTP	Lower Bound	Upper Bound	ASL	CI/Mean
<i>Single Bound</i>					
Mean	4.86	3.50	8.94	0.000	1.12
Median	2.77	2.34	3.53	0.000	0.43
<i>Double Bound</i>					
Mean	5.12	3.73	9.00	0.000	1.03
Median	2.83	2.41	3.53	0.000	0.39

Note. ASL indicates the significance level of the WTP estimates CI confidence interval.

Table 7. Mean and median willingness to pay for hand pollination (with covariates)

Measure	WTP	Lower Bound	Upper Bound	ASL	CI/Mean
<i>Single Bound</i>					
Mean	5.18	3.48	11.91	0.000	1.63
Median	2.92	2.40	4.03	0.000	0.56
<i>Double Bound</i>					
Mean	5.94	3.93	13.59	0.000	1.63
Median	3.07	2.52	4.14	0.000	0.53

Note. ASL indicates the significance level of the WTP estimates CI confidence interval.

#### 4.4 Valuing Pollinator Services

Valuation of environmental services is pivoted on revealed consumer choices related to a non-market good. Pollinator services are non-market goods and hand pollination as a substitute product is equally non-marketed. The stated consumer value of that product given the hypothetical market for hand pollination reveals the value of the pollinator services to the cocoa industry. In this paper the value of pollinators for an acre of cocoa farmland as revealed in the mean WTP for hand pollination is Gh¢5.94 (\$1.30). The total hectare of cocoa farm land for 2017/18 crop year is 1,896,290 (COCOBOD, 2019), hence the mean WTP (total value of midges' pollinators for Ghana's cocoa industry) is Gh¢27,833,365. In United States dollars terms and using 2018 average exchange rate of Gh¢4.5853/US\$1, the value of pollinators is averagely \$6.07million per annum with a maximum value of \$13.89 million per annum.

The findings of this study are that the cocoa industry risk losing millions of dollars per annum, if great care is not taken to handle pollinator decline through ecological preservation.

Table 8. Extrapolation value of pollinators

(A) WTP (Acres)	(B) WTP (Hectares)	(C) Cultivated land (Hectares)	(D) Value of Pollinators (GH¢)
<i>Mean GH¢</i>			
5.94	14.6778	1,896,290	27,833,365.36
<i>Upper Limit</i>			
13.59	33.5809	1,896,290	63,679,124.86
<i>Lower Limit</i>			
3.93	9.71103	1,896,290	18,414,929.08

Note. B = A\*2.471; D = C\*B.

Source: Author's computation based on regression estimates. Data on cultivated land obtained from COCOBOD (2018).

From the data analysis to the presentation of results, great effort has been taken in this study to satisfy the conditions for achieving reasonable level of validity and reliability in outcomes. The instrument for this paper was built on other studies and refined through pretesting. Also, the object of valuation was described and known by the respondents. The referendum format for elicitation of bids was applied satisfying content validity and

addressing the key concern of hypothetical bias in stated preference studies. The hypothesis of negative price sensitivity and positive income sensitivity has been met with the estimated outcomes satisfying construct validity. The estimation method was appropriate for the elicited data, with value estimates having small standard errors. Also, the variance in the confidence interval for mean WTP was marginal supporting the reliability of the WTP estimates and satisfying internal validity. External validity was achieved, with the use of probability sampling for the sample data and an operating sample of 608 for the valuation survey. This sample size is significant for the population of cocoa farmers at a 95% confidence level and 5% precision level. This being achieved the results for the study are generalizable for the cocoa industry.

## 5. Conclusion and Recommendations

This paper sought to estimate the value of pollinator services to the cocoa industry of Ghana. Using contingent valuation, we estimate that cocoa farmers in Ghana averagely value pollinator services at \$1.3 per acre of land. Extrapolated to cover all cultivated cocoa lands for the 2017/18 crop year, the average value of pollinator services to Ghana's cocoa industry is \$6.1 million per annum. In terms of the effect of hand pollination on farm plots, a test of means reveals farm plots that were hand pollinated posted higher yields as compared to plots that were not. This is an indication that hand pollination holds the potential for improving cocoa productivity into the future. This fact is known to scientists using demonstration farms to clone hybrid cocoa for seedling (Baah et al., 2011). However, the evaluation of hand pollination as a national programme for farm plots with varied farm conditions different from the ideal farm environment on experimental farms had not been undertaken. The paper also finds that farmers are willing to pay for hand pollination, which is a critical information given that the initial roll out of the programme was at no cost to the farmer and may not be sustainable going in to future.

Sustainability of the cocoa industry is of utmost concern given its contribution to the economy of Ghana. Aside from dealing with fluctuations in the world price of the crop, productivity on farms is being challenged by pollinator loss, reflecting the intensification of input applications; such as chemical fertilizers, fungicides and pesticides. Ghana stands to lose millions of dollars from pollinator loss as revealed by this study. In view of the above, there is a critical need for policy makers to bridge the gap between increasing input applications and conserving farm ecology. Priorities must shift from deploying more resources to agrochemicals to support farm yields, to the release of greater resources for the conservation of cocoa farm ecology.

## Acknowledgements

Appreciations goes to the staff of Social Studies and Statistic Unit (SSSU) of Cocoa Research Institute Ghana (CRIG) for the technical support in gathering data for this study and to CRIG for the financial support.

## References

- Ahiale, E. D., Balcombe, K., & Srinivasan, C. (2019). Determinants of Farm Households' Willingness to Accept (WTA) Compensation for Conservation Technologies in Northern Ghana. *Bio-based and Applied Economics*, 8(2), 211-234.
- Aizen, M. A., Garibaldi, L. A., Cunningham, S. A., & Klein, A. M. (2008). Long-term global trends in crop yield and production reveal no current pollination shortage but increasing pollinator dependency. *Current Biology*, 18(20), 1572-1575. <https://doi.org/10.1016/j.cub.2008.08.066>
- Ali, M., Sajjad, A., Farooqi, M. A., Bashir, M. A., Aslam, M. N., Nafees, M., & Khan, K. A. (2020). Assessing indigenous and local knowledge of farmers about pollination services in cucurbit agro-ecosystem of Punjab, Pakistan. *Saudi Journal of Biological Sciences*, 27(1), 189-194. <https://doi.org/10.1016/j.sjbs.2019.07.001>
- Arshad, M., Amjath-Babu, T. S., Kächele, H., & Müller, K. (2016). What drives the willingness to pay for crop insurance against extreme weather events (flood and drought) in Pakistan? A hypothetical market approach. *Climate and Development*, 8(3), 234-244. <https://doi.org/10.1080/17565529.2015.1034232>
- Assessment, M. E. (2005). *Ecosystems and human well-being* (Vol. 5, p. 563). Washington, DC: Island Press.
- Baah, F., Anchirinah, V., & Amon-Armah, F. (2011). Soil fertility management practices of cocoa farmers in the eastern region of Ghana. *Agriculture and Biology Journal of North America*, 2(1), 173-181. <https://doi.org/10.5251/abjna.2011.2.1.173.181>
- Badu-Nyarko, S. K. (2013). *Basic research methods in social science* (Revised ed.). Accra: Woeli Publications.
- Barfield, A., Bergstrom, J. C., & Ferreira, S. (2012). *An economic valuation of pollination services in Georgia* (No. 1372-2016-109075).

- Boyle, K. J. (2017). Contingent valuation in practice. *A primer on nonmarket valuation* (pp. 83-131). Springer, Dordrecht. [https://doi.org/10.1007/978-94-007-7104-8\\_4](https://doi.org/10.1007/978-94-007-7104-8_4)
- Breeze, T. D., Bailey, A. P., Potts, S. G., & Balcombe, K. G. (2015). A stated preference valuation of the non-market benefits of pollination services in the UK. *Ecological Economics*, 111, 76-85. <https://doi.org/10.1016/j.ecolecon.2014.12.022>
- Buckell, J., & Hess, S. (2019). Stubbing out hypothetical bias: Improving tobacco market predictions by combining stated and revealed preference data. *Journal of Health Economics*, 65, 93-102. <https://doi.org/10.1016/j.jhealeco.2019.03.011>
- Carson, R. T., & Hanemann, W. M. (2005). Contingent valuation. In K. G. Mäler & J. R. Vincent (Eds.), *Handbook of Environmental Economics: Valuing Environmental Changes* (Vol. 2). North-Holland/Elsevier. [https://doi.org/10.1016/S1574-0099\(05\)02017-6](https://doi.org/10.1016/S1574-0099(05)02017-6)
- Chatterjee, N. (2019). Valuation of Forestry in Selected Dryland Areas of West Bengal: A Contingent Valuation Approach. *Economic Affairs*, 64(1), 173-183. <https://doi.org/10.30954/0424-2513.1.2019.21>
- Chaudhary, O. P., & Chand, R. (2017). Economic benefits of animal pollination to Indian agriculture. *Indian Journal of Agricultural Sciences*, 87(9), 1117-1138. <https://doi.org/10.56093/ijas.v87i9.73903>
- Claus, G., Vanhove, W., Van Damme, P., & Smagghe, G. (2018). Challenges in cocoa pollination: the case of Côte d'Ivoire. *Pollination in plants* (pp. 39-58). IntechOpen. <https://doi.org/10.5772/intechopen.75361>
- Danso-Abbeam, G., Addai, K. N., & Ehiakpor, D. (2014). Willingness to pay for farm insurance by smallholder cocoa farmers in Ghana. *Journal of Social Science for Policy Implications*, 2(1), 163-183.
- Fahad, S., & Jing, W. (2018). Evaluation of Pakistani farmers' willingness to pay for crop insurance using contingent valuation method: The case of Khyber Pakhtunkhwa province. *Land Use Policy*, 72, 570-577. <https://doi.org/10.1016/j.landusepol.2017.12.024>
- Fisher, B., Bateman, I., & Turner, R. K. (2013). *Valuing ecosystem services: benefits, values, space and time. In Values, Payments and Institutions for Ecosystem Management*. Edward Elgar Publishing. <https://doi.org/10.4337/9781781953693.00009>
- Forbes, S. J., Mustiga, G., Romero, A., Northfield, T. D., Lambert, S., & Motamayor, J. C. (2019). Supplemental and Synchronized Pollination May Increase Yield in Cacao. *HortScience*, 54(10), 1718-1727. <https://doi.org/10.21273/HORTSCI12852-18>
- Frimpong, E. A., Gordon, I., Kwapong, P. K., & Gemmill-Herren, B. (2009). Dynamics of cocoa pollination: tools and applications for surveying and monitoring cocoa pollinators. *International Journal of Tropical Insect Science*, 29(2), 62-69. <https://doi.org/10.1017/S1742758409990117>
- Garratt, M. P., Breeze, T. D., Jenner, N., Polce, C., Biesmeijer, J. C., & Potts, S. G. (2014). Avoiding a bad apple: Insect pollination enhances fruit quality and economic value. *Agriculture, Ecosystems & Environment*, 184, 34-40. <https://doi.org/10.1016/j.agee.2013.10.032>
- Gowdy, J., Krall, L., & Chen, Y. (2013). The parable of the bees: beyond proximate causes in ecosystem service valuation. *Environmental Ethics*, 35(1), 41-55. <https://doi.org/10.5840/enviroethics20133515>
- Hall, D. M., & Martins, D. J. (2020). Human dimensions of insect pollinator conservation. *Current Opinion in Insect Science*, 38, 107-114. <https://doi.org/10.1016/j.cois.2020.04.001>
- Hanley, M. E., Awbi, A. J., & Franco, M. (2014). Going native? Flower use by bumblebees in English urban gardens. *Annals of Botany*, 113(5), 799-806. <https://doi.org/10.1093/aob/mcu006>
- Himes-Cornell, A., Pendleton, L., & Atiyah, P. (2018). Valuing ecosystem services from blue forests: A systematic review of the valuation of salt marshes, sea grass beds and mangrove forests. *Ecosystem Services*, 30, 36-48. <https://doi.org/10.1016/j.ecoser.2018.01.006>
- Hoyos, D., & Mariel, P. (2010). Contingent valuation: Past, present and future. *Prague Economic Papers*, 4, 329-343. <https://doi.org/10.18267/j.pep.380>
- Hynes, S., Ravagnan, E., & Gjerstad, B. (2019). Do concerns for the environmental credentials of salmon aquaculture translate into WTP a price premium for sustainably farmed fish? A contingent valuation study in Ireland and Norway. *Aquaculture International*, 27(6), 1709-1723. <https://doi.org/10.1007/s10499-019-00425-y>

- Jeanty, P. W. (2007). *Constructing krinsky and robb confidence intervals for mean and median willingness to pay (wtp) using stata* (pp. 13-14). 6th North American Stata Users' Group Meeting, Boston, August 2007, USA.
- Johnston, R. J., Boyle, K. J., Adamowicz, W., Bennett, J., Brouwer, R., Cameron, T. A., & Tourangeau, R. (2017). Contemporary guidance for stated preference studies. *Journal of the Association of Environmental and Resource Economists*, 4(2), 319-405. <https://doi.org/10.1086/691697>
- Kim, G., Petrolia, D. R., & Interis, M. G. (2011). *Using Multiple-Scenario Contingent Valuation Data to Estimate Willingness to Pay for Restoration of Mississippi's Barrier Islands* (No. 1371-2016-108953).
- Knapp, J. L., & Osborne, J. L. (2017). Courgette production: pollination demand, supply, and value. *Journal of Economic Entomology*, 110(5), 1973-1979. <https://doi.org/10.1093/jee/tox184>
- Loomis, J. B., Huber, C. C., & Richardson, L. (2019). *Methods of environmental valuation*. USGS Publications Warehouse. [https://doi.org/10.1007/978-3-642-36203-3\\_54-1](https://doi.org/10.1007/978-3-642-36203-3_54-1)
- Magrach, A., Champetier, A., Krishnan, S., Boreux, V., & Ghazoul, J. (2019). Uncertainties in the value and opportunity costs of pollination services. *Journal of Applied Ecology*, 56(7), 1549-1559. <https://doi.org/10.1111/1365-2664.13399>
- Marczyk, G., DeMatteo, D., & Festinger, D. (2005). *Essentials of research design and methodology*. John Wiley & Sons Inc.
- Mburu, J., Hein, L. G., Gemmill-Herren, B., & Collette, L. (2006). *Economic valuation of pollination services: Review of methods*. FAO.
- Molina, R., Letson, D., McNoldy, B., Mozumder, P., & Varkony, M. (2020). *A Contingent Valuation of Hurricane Forecast Improvement*.
- Mueller, J. M., Soder, A. B., & Springer, A. E. (2019). Valuing attributes of forest restoration in a semi-arid watershed. *Landscape and Urban Planning*, 184, 78-87. <https://doi.org/10.1016/j.landurbplan.2018.12.012>
- Mwebaze, P., Marris, G. C., Brown, M., MacLeod, A., Jones, G., & Budge, G. E. (2018). Measuring public perception and preferences for ecosystem services: A case study of bee pollination in the UK. *Land Use Policy*, 71, 355-362. <https://doi.org/10.1016/j.landusepol.2017.11.045>
- Oerlemans, L. A., Chan, K. Y., & Volschenk, J. (2016). Willingness to pay for green electricity: A review of the contingent valuation literature and its sources of error. *Renewable and Sustainable Energy Reviews*, 66, 875-885. <https://doi.org/10.1016/j.rser.2016.08.054>
- Popak, A. E., & Markwith, S. H. (2019). Economic Valuation of Bee Pollination Services for Passion Fruit (Malpighiales: Passifloraceae) Cultivation on Smallholding Farms in São Paulo, Brazil, Using the Avoided Cost Method. *Journal of Economic Entomology*, 112(5), 2049-2054. <https://doi.org/10.1093/jee/toz169>
- Poudel, D., & Johnsen, F. H. (2009). Valuation of crop genetic resources in Kaski, Nepal: Farmers' willingness to pay for rice landraces conservation. *Journal of Environmental Management*, 90(1), 483-491. <https://doi.org/10.1016/j.jenvman.2007.12.020>
- Ramli, F. A. T. I. N., Samdin, Z. A. I. T. O. N., & Ghani, A. N. A. (2017). Willingness to pay for conservation fee using contingent valuation method: The case of Matang Mangrove Forest Reserve, Perak, Malaysia. *Malaysian Forester*, 80(1), 99-110.
- Rhodes, C. J. (2018). Pollinator decline—an ecological calamity in the making? *Science Progress*, 101(2), 121-160. <https://doi.org/10.3184/003685018X15202512854527>
- Sawe, T., Nielsen, A., & Eldegard, K. (2020). Crop Pollination in Small-Scale Agriculture in Tanzania: Household Dependence, Awareness and Conservation. *Sustainability*, 12(6), 2228. <https://doi.org/10.3390/su12062228>
- Syuhada, C. N., Mahirah, K., & Roseliza, M. A. (2020). Dealing with attributes in a discrete choice experiment on valuation of water services in East Peninsular Malaysia. *Utilities Policy*, 64, 101037. <https://doi.org/10.1016/j.jup.2020.101037>
- Toledo-Hernández, M., Wanger, T. C., & Tschardtke, T. (2017). Neglected pollinators: Can enhanced pollination services improve cocoa yields? A review. *Agriculture, Ecosystems & Environment*, 247, 137-148. <https://doi.org/10.1016/j.agee.2017.05.021>

- Toni, H., & Djossa, B. A. (2015). Economic value of pollination services on crops in Benin, West Africa. *International Journal of Biological and Chemical Sciences*, 9(1), 225-233. <https://doi.org/10.4314/ijbcs.v9i1.20>
- Vaissière, B., Freitas, B. M., & Gemmill-Herren, B. (2011). *Protocol to detect and assess pollination deficits in crops: a handbook for its use* (pp. 81-p). FAO.
- Vanhove, W., Yao, R. K., N'Zi, J. C., Toussaint, L. A. N. G., Kaminski, A., Smagghe, G., & Van Damme, P. (2020). Impact of insecticide and pollinator-enhancing substrate applications on cocoa (*Theobroma cacao*) cherelle and pod production in Côte d'Ivoire. *Agriculture, Ecosystems & Environment*, 293, 106855. <https://doi.org/10.1016/j.agee.2020.106855>
- Vossler, C. A., & Zawojska, E. (2020). Behavioral drivers or economic incentives? Toward a better understanding of elicitation effects in stated preference studies. *Journal of the Association of Environmental and Resource Economists*, 7(2), 279-303. <https://doi.org/10.1086/706645>
- Winfree, R., Gross, B. J., & Kremen, C. (2011). Valuing pollination services to agriculture. *Ecological Economics*, 71, 80-88. <https://doi.org/10.1016/j.ecolecon.2011.08.001>

## Notes

Note 1. COCOBOD is the state agency established to encourage and facilitate the production, processing and marketing of good quality cocoa.

## Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/4.0/>).