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Farmers' willingness to accept compensation to control agricultural nonpoint source pollution in the Limpopo River Basin of South Africa

Alfred Tunyire Apio[1], Djiby Racine Thiam[1], Ariel Dinar[2] and Jürgen Meyerhoff[3]

[1] School of Economics, University of Cape Town, South Africa

[2]School of Public Policy University of California, Riverside

[4]Institute for Landscape Architecture and Environmental Planning, Berlin, Germany

Summary:

The Limpopo River Basin is considered one of the most polluted river systems in South Africa, yet the basin is important for agriculture, mining, and industry which contribute to promoting employment, incomes, and poverty alleviation. Policymakers and agricultural water managers are worried about the dangerous effects of agricultural nonpoint source (agNPS) pollution and how to remedy it. Reducing agNPS pollution is part of major plans for the restoration and protection of the basin. But the levels by which farmers must alter their agricultural practices to meet river health goals are not yet well defined. Thus, we investigated farmers' willingness to accept (WTA) compensation to control agNPS pollution in the LRB using choice experiment (CE) approach. Conditional logit and latent class models are used to analyze our survey data from 552 farmers. We found evidence supporting the hypotheses that compensation payment motivates farmers' willingness to alter their unsustainable farming practices to reduce agNPS pollution. The marginal compensation and welfare estimates demonstrate that farmers have strong preferences for mitigating agNPS pollution. Beyond its academic contribution, this study holds value for farmers and policymakers in South Africa and beyond.

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Alfred Tunyire Apio[1], Djiby Racine Thiam[2], Ariel Dinar[3] and Jürgen Meyerhoff[4]

[1,2]School of Economics, University of Cape Town, Rondebosch, South Africa

[3]School of Public Policy, University of California, Riverside, U.S.A

[4]Institute for Landscape Architecture and Environmental Planning, Berlin, Germany

Abstract

The Limpopo River Basin is considered one of the most polluted river systems in South Africa, yet the basin is important for agriculture, mining, and industry which contribute to promoting employment, incomes, and poverty alleviation. Policymakers and agricultural water managers are worried about the dangerous effects of agricultural nonpoint source (agNPS) pollution and how to remedy it. Reducing agNPS pollution is part of major plans for the restoration and protection of the basin. But the levels by which farmers must alter their agricultural practices to meet river health goals are not yet well defined. Thus, we investigated farmers' willingness to accept (WTA) compensation to control agNPS pollution in the LRB using choice experiment (CE) approach. Conditional logit and latent class models are used to analyze our survey data from 552 farmers. We found evidence supporting the hypotheses that compensation payment motivates farmers' willingness to alter their unsustainable farming practices to reduce agNPS pollution. The marginal compensation and welfare estimates demonstrate that farmers have strong preferences for mitigating agNPS pollution. Beyond its academic contribution, this study holds value for farmers and policymakers in South Africa and beyond.

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Keywords: agricultural nonpoint source pollution control, choice experiment, latent class model, willingness to accept, preference heterogeneity, South Africa

[1] Alfred is a PhD-student at the University of Cape Town, South Africa, Email: Alfred Apio APXALF001@myuct.ac.za

[2] Djiby Racine Thiam is Associate Professor in Economics, University of Cape Town, South Africa, Email: djiby.thiam@uct.ac.za

[3] Ariel Dinar is Distinguished Professor of Environmental Economics and Policy, School of Public Policy, University of California, Riverside, USA, Email: adinar@ucr.edu

[4] Jürgen Meyerhoff is Senior Research Fellow in Environmental and resources economics at the Technical University of Berlin, Germany, Email: juergen.meyerhoff@tu-berlin.de

1. Introduction

Agricultural nonpoint source (agNPS) pollution[5] in South Africa and how best to control it, especially in the Limpopo River Basin (LRB) is of concern to policymakers and water resource managers. The LRB is noted as one of the most polluted river systems in South Africa (Lebepe et al., 2016; Marr et al., 2017; Nel & Driver, 2015). Yet, the basin is important for agriculture, eco-tourism, mining, and industry which contribute to promoting employment, incomes, and poverty alleviation. This does not augur well for a water-stressed country like South Africa. agNPS pollution degrades water quality at the farm level and causes serious eutrophication in water bodies, which precludes water use for other key sectors in the economy including industry, fishery, and recreation services (Halliday et al., 2014). The salinity of water caused by this canker decreases agricultural yields, farm profits, and efficiency in irrigation systems. Economic-wide, agNPS pollution is a major factor limiting economic growth, causing worsening health conditions, reducing food production, exacerbating poverty, and threatening the water and food security goals amongst others (World Bank, 2019). Therefore, reduced agNPS pollution is expected to improve water resources management and contribute to mitigating water scarcity in the country for farmers to make meaningful contributions to economic growth.

Given the difficult to control nature of agNPS pollution, various efforts and policies have been applied to control and limit it. These include the use of mandatory or voluntary measures. Mandatory measures include instruments that force and constraint farmers to use pollution control practices—higher taxes on inputs causing pollution (Feather & Cooper, 1995), using tax subsidy schemes (Segerson, 1988; Xepapadeas, 1997,) and direct regulations (Feather & Cooper, 1995). However, given the characteristics[6] of agNPS pollution, these instruments are often perceived as ineffective and administratively costly to apply. Economists alternatively rely on voluntary incentives which provide farmers with the motivation to voluntarily change their inherent behaviours and adopt practices that lead to improved water quality. The voluntary incentives may include, amongst others, cost-sharing, incentive payments, education to raise

5 This is the runoff and leaching into water bodies of fertilizers pesticides, agricultural waste (film and animal) and soil sediments from farms (Ribaudo et al., 1999).

6 Agricultural nonpoint emissions are essentially unobservable (neither the source nor the size of the specific loads can be observed or identified with sufficient accuracy) and highly stochastic due to natural variation in weather and other environmental processes (Horan et al., 1999). Efforts to identify the origin or specific loads could be prohibitively costly and ineffective, hence, they do not easily lend themself to traditional forms of regulation.

awareness, and technical assistance (Feather & Cooper, 1995). Some recent studies that have empirically examined how monetary incentives influence farmers to alter their farming practices to control agNPS pollution include (Beharry-Borg et al., 2013; Li et al., 2019; Lu et al., 2021). However, these kinds of studies are non-existent in South Africa to the best of our knowledge. This lack of empirical studies leads to a gap in our understanding of how best to control this canker. Furthermore, the lack of empirical studies hinders the crafting of cost-effective and proactive water quality improvement policies in the agricultural sector to deal with the issue. From the foregoing, it is absolutely clear that reducing agNPS pollution loads in the LBR is part of major plans for the restoration and protection of the basin. However, the extent to which farmers must alter their agricultural practices to meet river health goals is not yet known. Whatever these goals are, reaching them will require changes in the way farmers produce crops and interact with nature. It is thus, imperative to investigate how monetary incentives can be used to incentivize farmers to reduce or limit agNPS pollution in the basin to advise policy.

Given this, the purpose of this paper is to investigate the extent to which the adoption of more sustainable farming practices could contribute to reducing agNPS pollution in the LRB of South Africa. We rather focus on sustainable practices that emanate from voluntary measures, where farmers choose several water quality mitigation options that are presented to them. We target practices that range from reduced use of fertilizers and pesticides during production, to the construction of ecological ditches and agricultural waste recovery initiatives, all of which contribute to reducing releases of harmful pollutants. We make use of choice modeling to identify the attributes and socio-economic characteristics that influence the adoption of such sustainable farm management practices. The estimates are used to derive the willingness of farmers to accept (WTA[7]) compensation to forgo some farming practices. The underlying assumption is farmers are more willing to take actions that lead to improved water quality if they receive financial compensation. Hinged on this, therefore, is a threefold step. First, we sought to determine the compensation appropriate to encourage farmers' participation in the scheme to control agNPS pollution in the country. Second, we determined the attributes and socio-economic factors that drive farmers' willingness to control agNPS pollution, and finally, we explored the scale heterogeneity of preferences among farmers in our sample. Two

7 This is the minimum monetary amount required for an individual to forgo some good (Martín-Fernández et al., 2010). Thus, WTA is defined here as the minimum payment that a farmer requires to forgo some agricultural practices (i.e., fertilizer and pesticide reduction amongst others to reduce agriculture's impact on water quality).

estimation techniques—a conditional logit model (CLM) and a latent class model (LCM) were used to analyze our survey data of farmers from the basin. Our findings show that four classes of farmers with different preferences (non-resistance, low-resistance, moderate-resistance, and high-resistance farmers) were identified, and that compensation payment motivates farmers to voluntarily control agNPS pollution. Additionally,, younger educated farmers who are members of a cooperative were more willing to participate in the agNPS pollution control programme. Both the marginal WTA and welfare estimates demonstrate that farmers have strong preferences to change from the status quo option to control agNPS pollution. We recommend education and policies that lessen agriculture's negative impact on water quality. That is support for farmers to adopt environmentally friendly farming technologies that use less fertilizers and pesticides. Beyond the academic contributions to the literature, the study holds value for farmers in South Africa and beyond. Its ideas would enlighten farmers on modern agricultural best practices and lead to improvements in water quality. The findings provide a robust basis for the formulation of water quality improvement policies in the agricultural sector.

The rest of the paper is structured as follows. In section 2, we review the related literature. A brief description of the study area is given in section 3. Section 4 comprises the methodology. The results and discussion are in section 5, and section 6 concludes, provides policy implications and direction for future research

2. Related Literature

Growing evidence of surface and groundwater quality deterioration has led to demands for water quality restoration and protection policies around the world. Agriculture as the chief culprit of the water quality problem has been an important target of such policies. Thus, we focused initially on the theoretical literature on the control of nonpoint source (NPS) pollution in general and later the empirics on the control of agNPS pollution and the findings of such studies. The theoretical literature for the control of NPS pollution mostly focused on policies (both voluntary and mandatory) for mitigating the water quality problem. For example, Abler and Shortle (1991) identified four general strategies to protect water quality from agricultural chemicals: moral suasion and education, direct regulation, economic incentives, and research. They were unable to ascertain the superiority of any of the four general strategies. They, however, concluded that a policy is economically and politically questionable if the costs of administration and enforcement are large. The actual performance of any policy option would, therefore, depend on details of its implementation and on the economic and political environment in which it was enacted and administered. Ribaudo et al. (1999) extended the discussions of Abler and Shortle (1991) by systematically and extensively evaluating the economic characteristics of five instruments for the control of agNPS pollution—economic incentives, standards, education, liability, and research. They concluded that these instruments perform best when the incentives provided by the instrument coincide with the goals of the resource management agency. Characteristics of NPS pollution (i.e., heterogeneous nature, variability, etc.) and the attractiveness of second-best policies (due to administrative costs, etc.) rule against a single policy tool. Therefore, the most appropriate tool(s) for a particular problem is an empirical issue based on policy goals, local conditions, and costs of acquiring information and implementation of the policy.

The empirical literature that examined the effectiveness of some of the above policy instruments includes Taylor et al. (2004) who used experimental auctions to examine group contracts for voluntary NPS pollution reductions. The authors provided evidence that the contracts proposed could be an effective and efficient mechanism for pollution control as the bidding mechanism efficiently limits the overall costs of pollution abatement. Winsten (2009) specifically investigated how to improve the cost-effectiveness of agNPS pollution control through performance-based incentives. These are designed to reward farmers for achieving specified environmental performance targets. The payments, based on outcomes, are not tied to the use or cost of any specific practice(s). As such, farmers have the flexibility to use the most appropriate and cost-effective way(s) to achieve the specified environmental outcome. This approach has the potential to improve environmental quality, enhance farm income, and provide greater accountability to taxpayers.

Furthermore, Drevno (2016), based on a review of relevant literature as well as case studies from the USA and Europe, identified the regulatory tools and management approaches that specifically target agNPS pollution and the factors that drive or impede their implementation and enforcement for the desired environmental outcomes. The author found that, controlling numerous diffuse sources of agNPS pollution requires an integrated approach. Moreover, the study finds that transitioning from voluntary mechanisms to more constraining instruments based on measurable water quality performance relies predominantly on three factors—more robust quality monitoring data and models, local participation, and strong political will. Malik et al. (1994) highlighted the importance of economic incentives for agricultural NPS pollution control in the US. The study underscored that there is no single and ideal policy instrument for controlling the many types of agricultural NPS water pollution given the characteristics of NPS pollution (uncertainty and asymmetrical information). Market-based instruments may be appropriate in some cases whereas command-and-control may be preferable in other instances. There are even circumstances when the combination of these two types provides a better outcome, since they may complement each other. The choice of instruments should be dictated by the characteristics of the particular pollution problem and the institutional and socio-economic context of the area that is under study. However, the use of financial incentives to encourage desirable farming practices are seen as a good complement to approaches focusing on restrictions on farming practices. Therefore, for the rest of the literature review, we concentrated on studies using financial incentives to encourage desirable farming practices to protect water quality.

This strand of literature mostly comes under the agri-environmental schemes (AESs[8]) and payment for ecosystem services (PESs[9]) programmes. By paying farmers to reduce the damage agricultural activities have on the environment, especially water quality, and to support the positive environmental effects of agriculture, AESs and PESs incentivize farmers to provide environmentally non-market goods in greater quantities than would otherwise be the case. Farmers' participation in these AESs and PESs programmes is highly heterogeneous. Whiles some farmers are willing to accept monetary compensations to participate in these programmes (Beharry-Borg et al., 2013; Li et al, 2019; Lu et al., 2021), others are hesitant, indicating strong preferences for their current situation (Beharry-Borg et al., 2013; Christensen et al., 2011). Others also appear willing to trade-off compensation payments with the restrictions imposed by the various schemes, particularly for flexibility of land management restrictions within schemes, fertilizer and pesticide management restrictions, the option of cancelling contracts, duration, monitoring, and the amount of paperwork involved (Beharry-Borg et al., 2013; Broch & Vedel, 2012 Christensen et al., 2011; Ruto & Garrod, 2009). Recent contributions in the literature also show how differences in age, education, gender, occupation (both farm and/or non-farm), and other socio-economic characteristics, as well as attitudinal characteristics,

[8] AESs are voluntary incentive-based payments to farmers and land managers to operate in environmentally friendly ways that support biodiversity, conserve and enhance landscape (beach, forest, mountains etc.) and improve the quality of water, air and soil.

[9] PESs compensate individuals or communities to undertake actions that increase the provision of ecosystem services including water quality improvement, flood mitigation, and carbon sequestration amongst others.

influence the adoption of various conservation practices typified by Aguilar et al. (2018) and Claassen et al. (2008). Specifically, Lin et al. (2021), used a multinominal logit (MNL) model to analyze the key factors determining farmers' WTA compensation to control agNPS pollution in the Xin'an River Reservoir. The factors included social and economic information of the farmers (i.e., gender, age, family size, etc.), farmland management behaviours (agNPS pollution and environmental protection awareness, pesticide and fertilizer application reduction actions,) and different scheme attributes (fertilizer use management, pesticide use management, technical support, etc.). They confirmed that farmers' participation mainly depended on satisfactory compensation incentives that cover the losses of farmers. Table 1 (in the Appendix) presents an overview of key-related empirical studies from around the world.

Fundamentally, the consensus from the literature shows that remedying agNPS pollution is feasible with monetary incentives. Our study departs from the above studies in many ways. First, we focus attention on South Africa, especially in the LRB where no such study has been conducted before. We present the first study that used CE methodology to gauge farmers' WTA compensation to control agNPS pollution in South Africa. Second, our use of the latent class model to account for class heterogeneity instead of individual heterogeneity, as in the random parameter logit (RPL) which is the model of choice for almost all the agNPS pollution control studies we found (except Beharry-Borg et al., (2013) for the UK), makes our study different. The model allowed us to classify farmers into befitting groups (of non, low, moderate, and high resistance farmers) where tailored policies with preference and equity concerns can be applied. Third, in terms of attributes, this study has explored a lot more attributes (7) than most of the agNPS pollution control studies (usually 5) presented in the literature. This provides a richer and more robust picture of the practices that control agNPS pollution at the farm level. Our use of the construction of ecological ditches (vegetative buffer strips) and monitoring for compliance is especially novel as none of the agNPS pollution control studies have used these. Even though their use in the other AESs and PESs studies (forest, coastal, and mangrove conservation, etc.) and the non-choice experiment literature is popular. For monitoring see (Broch & Vedel 2012; Greiner, 2016) and for ecological ditches see (Blankenberg et al., 2007; Hernandez & Mitsch, 2007). Lastly, our choice of farmers who grow multiple crops including vegetables (tomatoes, green beans, green pepper, chillies, onions, garlic), sweet potato, and maize (corn) amongst others, instead of farmers who grow a single crop like rice, olives or wheat, etc. Our choice of farmers is informed by the fact that the crops they grow are particularly prone to fertilizer and pesticide leaches and runoff due to frequent cultivation, relatively short growing cycles, and low nutrient uptake efficiency (Di & Cameron, 2002). Our study thus, contributes to the agNPS pollution literature and agricultural water management in general, first, by enhancing the understanding of the factors that contribute to reducing agNPS pollution in South Africa and the levels by which agriculture should be altered to deliver the required water quality improvement in the basin. Second, we present a case study of choice modeling supporting the hypothesis that farmers' WTA compensation is possible in a developing countries context. Finally, beyond the academic contributions to the literature and policy, our study holds value for farmers in South Africa and beyond.

3. An Overview of the Study Area

The study was conducted in two farming communities in the Vhembe District of the Limpopo Province of South Africa as shown in Figure 1 in Appendix 2. Folovhodwe is a farming community in the Musina Municipality and Tshiombo is a farming community in the Thulamel Municipality. These two farming communities sit on important tributaries of the Limpopo River. Folovhodwe is located on the Nwanedi River which has a catchment area of about 897 km^2. As per the 2011 census, Folovhodwe had a population of 2806 people and an area of about 3.24 km^2 (Census, 2011). The Tshiombo Irrigation Scheme is among the largest in the Limpopo Province, covering an area of 1,196 hectares. It is in the western end of the Tshiombo valley on the south bank of the Mutale River (Lahiff, 1997). Tshiombo had a population of 1,415 people and an area of about 1.58 km^2 (Census, 2011). Agricultural activities are predominant. Citrus fruits, vegetables, melons, corn (maize), sweet potatoes/potatoes, tobacco, peanuts (groundnuts), and spices are grown in the area.

4. Methodology

4.1 Model Specification

The CE methodology has its theoretical foundation in Lancaster's model of consumer choice (Lancaster, 1966) and its econometric basis in the Random Utility Theory [RUT] (Luce, 1959; McFadden, 1974). Based on the RUT, farmers choose the alternative that provides them with the highest expected utility associated with the choice attributes of agNPS pollution control. Therefore, the ith farmer's utility of the jth alternative associated with choosing an agNPS pollution control intervention is given by Equation (1)

$$U_{ij} = \beta_i x_{ij} + \varepsilon_{ij} = V_{ij} + \varepsilon_{ij} \quad (1)$$

where β_i is a vector of individual-specific coefficients, (x_{ij}) is a vector of observed agNPS pollution control attributes relating to the ith farmer and the jth alternative. The utility (U_{ij}) of a choice set, thus, comprises a deterministic part (V_{ij}) and a random component (ε_{ij}). Assuming the random components are independent and identically distributed (IID), with a Gumbal (0,1) distribution, then the conditional logit model (CLM), where the probability of the ith farmer choosing the jth alternative is given by Equation (2)

$$P_{ij} = \frac{\exp(\lambda V_{ij})}{\sum_{l=1}^{J} \exp(\lambda V_{il})} \quad (2)$$

where J is the set of available agNPS pollution control alternatives and $\lambda = 1$.
Following Hole (2006), the log-likelihood function of the CLM is given as follows

$$log\mathcal{L} = \sum_{i=1}^{N} \sum_{j=1}^{M} y_{ij} ln \left[\frac{\exp(V_{ij})}{\exp(V_{il})}\right] \quad (3)$$

where y_{ij} is an indicator variable that is equal to 1 if the jth alternative is chosen by farmer i and zero otherwise. N is the total number of farmers $(i = 1, 2, \ldots, N)$, M indicates the jth alternative in a choice set of the farmer (with $j = 1, 2, \ldots, M$).

Although the CLM is the first model of choice for CE data because of its simple mathematical structure and ease of estimation, its strict assumption of the independence of irrelevant alternatives (IIA[10]) makes other models like the latent class models (LCMs) that relax this assumption more desirable. We conducted the Hausman and McFadden (1984) test but found no violation of the IIA. Another limitation of the CLM is its assumption that preferences are homogenous across respondents. However, farmers are heterogeneous, so are their preferences too. Thus, we estimated an LCM as our main model to account for class heterogeneity. Accounting for presence heterogeneity enables the estimation of unbiased estimates of

10 The relative probabilities of two options being chosen are unaffected by the introduction or removal of other alternatives (Hausman & McFadden, 1984).

preferences, enhances the accuracy and reliability of estimates. Furthermore, in the context of policy, accounting for presence heterogeneity provides a broader picture of the distributional consequences of the sample and enables the prescription of policies that take preference and equity concerns into account for better policy outcomes (Garrod et al., 2012; Greene, 2011).

Following Swait (1994), the functional form of the utility function for the LCM of the ith farmer's choice among J alternatives, given that the farmer belongs to class $c = 1, \ldots, C$ is expressed as:

$$U_{ij/c} = \beta_c x_{ij} + \varepsilon_{ij/c} \tag{4}$$

where x_{ij} is a vector of attributes associated with alternative j, β_c is a class-specific parameter vector associated with the vector x_{ij} and $\varepsilon_{ij/c}$ represents the random variations for the ith farmer. Assuming that the error terms are IID and follow a Type 1 extreme value distribution across classes and individuals, the probability that the ith farmer belongs to class c and selects alternative j is given by:

$$P_{ij/c} = \frac{\exp(\beta_c x_{ij})}{\sum_J exp\ (\beta_c x_{ij})} \tag{5}$$

The joint probability of farmer i belonging to class c and selecting alternative j is $P_{ijC} = P_{ij/c} * P_{ic}$, where $P_{ic} = \frac{\exp(\delta Z_i)}{\sum_C exp(\delta Z_i)}$ with Z_i being a vector of the class-specific parameters and δ being a scale factor $= 1$. Thus, each respondent has a probability of belonging to a particular class (Boxall & Adamowicz, 2002). Accordingly, the marginal probability of observing the ith farmer in class c choosing alternative j is expressed as:

$$P_{ij} = \sum_{c=1}^{C} \left[\frac{\exp(\beta_c x_{ij})}{\sum_J exp\ (\beta_c x_{ij})}\right] \left[\frac{\exp(\delta Z_i)}{\sum_C exp\ (\delta Z_i)}\right] \tag{6}$$

Equation (6) implies the probability of selecting the jth alternative is equal to the sum over all latent classes c of the class-specific membership model conditional on ($P_{ij/c}$) multiplied by the probability of belonging to that class (P_{ic}).

The log-likelihood function to obtain the parameters δ and β_c is given as:

$$\mathcal{LL} = \sum_{n=1}^{N} \sum_{j=1}^{J} y_{ij} ln \left(\sum_{c=1}^{C} P_{ij/c} * P_{ic} \right) \quad (7)$$

where J is the total number of alternatives, y_{ij} is the observed frequency of choice of alternative j by the ith farmer. All other indicators have their usual meaning.

The marginal willingness to accept (mWTA) measure, which is the maximum amount of compensation a farmer is willing to accept to forgo some farm management practices (change from the status quo behaviour) to reduce agriculture's impact on water quality and deliver some improvements in water quality. The mWTA is derived by taking the ratio of an attribute's parameter coefficients to the marginal utility of the compensation attribute. This represents the marginal rate of substitution (MRS) between the agNPS pollution control attributes and the compensation payment attribute. The mWTA are derived as follows:

$$WTA_{i,k,l} = \sum_{c=1}^{C} P_{ic} \left(\frac{-\beta_{c,attributes}}{\beta_{c,compay}} \right) \quad (8)$$

where P_{ic} is the estimated matrix of individual n-specific probabilities of segment membership, and $\left(\frac{-\beta_{c,attributes}}{\beta_{c,compay}} \right)$ is the ratio of implicit price for the attribute change being valued, relative to the probability of the status quo option.

In addition to the mWTA estimates, we also estimated the compensating surplus (CS) welfare measures. Following Hanemann (1984), the CS is calculated as follows:

$$CS = -\frac{1}{\beta_{cpay}} \left[\ln \left(\sum_{i} \exp(V_i^1) \right) - \ln \left(\sum_{i} \exp(V_i^0) \right) \right] \quad (9)$$

where β_{cpay} is the coefficient of the compensation attribute. It captures the marginal utility of income. V_i^0 and V_i^1 represent the ith farmer's indirect utility functions before and after the change under consideration.

4.2 Design of the Choice Experiment

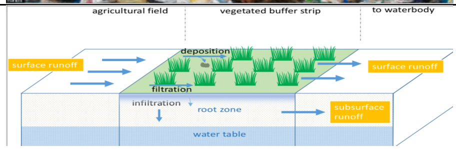
4.2.1 Attributes, Levels and Validation

The authenticity and reliability of a choice scenario in a CE study greatly depend on the attributes and their associated levels. Since agNPS pollution mostly originates from agricultural waste (mainly crop straw, pesticide packaging, plastic film, and so on resulting from arable land utilization, livestock and poultry dung, and urine etc.), excessive use of fertilizers and pesticides amongst others, we identified and employed seven attributes[11] with their respective levels in the study. This was done based on the objectives of the study, coupled with the literature reviewed and focus group discussions (FGDs). Table 2 shows the attributes, a brief description, and their respective levels. In addition to the choice experiment variables, socio-demographic and attitudinal data of representative farmers were also collected.

The criticism of the CE method is primarily on the reliability and validity of the survey results and various biases (Train & Wilson, 2008). To ascertain the accuracy and reliability of our results, we endeavoured to mitigate hypothetical biases. First, before finalizing our questionnaire, we had two focus group discussions (FGDs) in the study area. One with farmers and extension service officers and another with stakeholders and industry experts from the Department of Agriculture, Forestry and Fisheries (DAFF), the DeBeers group, and LIMA Rural Development Foundation. We discussed the purpose of the research, the choice sets and sought opinions on how to improve the questionnaire. The discussions resulted in a revision of the compensation attribute upwards to the current levels for all the levels (R3000.00 to R9000.00, from R9000.00 to R15, 000.00, and from R21000.00 to R29000.00). Overall, the participants validated our attributes and their levels.

11 (1) Fertilizer reduction, (2) pesticide reduction, (3) agricultural waste recovery, (4) construction of an ecological ditch (vegetative strips), (5) duration of the programme (in years), (6) monitoring for compliance and (7) the compensation payment (in Rands per hectare per year).

Table 2: Attributes, Description, and Levels

Attribute	Picturesque	Description	Levels
Fertilizer application		Fertilizer promotes plant growth and crop yield, but its excessive application aggravates the water quality problem (Ribaudo et al., 1999). Fertilizer reduction is highlighted as an important factor in reducing agNPS pollution (Beharry-Borg et al., 2013; Li et al., 2019).	Use current levels* Reduce by 25% Reduce by 50%
Pesticide application		Pesticides are applied to crops to control pests, fungus and disease. But their excessive application worsens water quality (Li et al., 2019; Ribaudo et al., 1999). Therefore, to control the water quality problem, pesticides usage must be reduced. Christensen et al. (2011) and Li et al. (2019) used this attribute.	Use current levels* Reduce by 25% Reduce by 50%
Agricultural waste recovery		These enter the soil and watercourses and aggravate agNPS pollution. They are strictly undesirable in water sources. Agricultural waste includes film and crop straw, livestock and poultry dung and urine, etc. (Briassoulis et al., 2012) Li et al. (2019) and Lu et al. (2021) utilized this attribute.	No recovery* 50% recovery 100% recovery
Construct ecological ditch		Constructed wetlands and vegetative buffer strips are used to control agNPS pollution and runoff by stabilizing banks, trapping sediments, and filtering out pollutants, thereby sustaining water quality and protecting aquatic habitats and associated biota. They are increasingly being incorporated into farming systems to improve downstream water quality (Brodie et al. 2011).	Not required* 25 metres 50 metres
Duration of programme		This is the number of years the agNPS pollution control programme will remain active. Remedying agNPS pollution through altering farming practices takes a long time for the needed results to be had. We chose 2 years as the minimum for such results to be had. Beharry-Borg et al. (2013) used this attribute	2 years* 5 years 10 years
Monitoring		Monitoring the programme for compliance is key to preventing the problem of moral hazards (Broch & Vedel, 2012). *Partial monitoring* (intra—farmers monitoring each other) and *external* (farmers receive visits from local authorities). Broch and Vedel (2012) employed this attribute.	No monitoring* Partial monitoring External monitoring
Compensation payment		This is payment to compensate farmers' loss and subsequent uncertainty associated with joining the scheme. Wilson (1997) asserts that low payments are the reason for non-participation, whilst finance is the main reason for participation. Most AES and PES studies utilize this attribute.	0.00 ZAR* 9,000.00 ZAR R15,000.00 ZAR R29,000.00 ZAR

4.3 Experiment and Survey Design

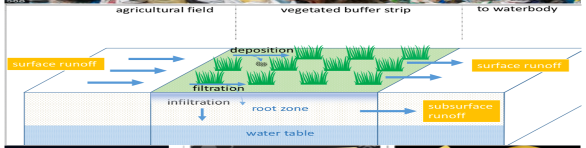
Having determined the relevant attributes and levels, an experimental design was produced from which the choice sets were generated. The experimental design gave $3^6 \times 4^1$ possible combinations (2,916) for a full factorial design. However, a fractional factorial design[12] that was both orthogonal and balanced was used. It produced 72 choice sets in total, which were 'blocked' orthogonally into eight blocks of 9 choice sets. Meaning there were eight versions of the questionnaire and each version included nine choice sets with no dominant or redundant alternatives in the choice task. Each questionnaire was randomly given to a farmer and the farmer voted nine times to complete the questionnaire.

All choice sets were generated with Ngene 1.2.1 software. Each choice set consisted of two alternatives (the agNPS pollution control alternatives) and one opt-out alternative (the status quo alternative). Farmers choose their most preferred alternatives (*Option 1* or *Option 2*) or neither alternative (*Status quo*). Those who chose *Option 1* or *Option 2* desired improvements in water quality, whilst those who chose the '*status quo'* were unwilling to undertake actions to improve water quality. These choices allowed us to explore farmers' preferences on different aspects of agNPS pollution control. An example of one of the choice sets used in the choice experiment survey is shown in Table 3. All attributes were dummy coded, except the compensation payment.

The study used a survey-based CE, where enumerators were able to explain the purpose of the study, difficult concepts, the background, and choice task objectively to farmers without ambiguity. 11 enumerators were recruited. In preparations for the face-to-face interviews with farmers, enumerators were taken through a rigorous two-day training. A detailed album with coloured pictures of all the attributes and their respective levels was given to enumerators to help explain the attributes in both words and pictures. This facilitated understanding (Brown et al., 2003). The pictures of the album are the ones shown on the card in Table 3. In addition, enumerators communicated in farmers' own language.

12 A fractional factorial design is a sample of the full design.

Table 3: An example of one the choice set used in the choice experiment

Attribute	**Picturesque**	**Option 1**	**Option 2**	**Neither**
Fertilizer application		Reduce by 50%	Reduce by 25%	
Pesticide application		Reduce by 25%	Reduce by 50%	
Agricultural waste recovery		100% recovery	50% recovery	
Construct ecological ditch		Not required	25 metres	
Duration of programme		2 years	5 years	
Monitoring		Partial monitoring	No monitoring	
Compensation payment		R29,000	R15,000	
Which OPTION do you prefer?		○	○	○

4.4 Data

Our data was obtained from administering the survey in the study area. The data collection exercise spanned one month between March and April 2021. A total of 555 questionnaires were sent out, and 552 valid questionnaires were returned. The questionnaire had four sections. Section A sought information on the farmers' socio-economic and demographic characteristics including *gender*, *age, educational level, farming type* (specialized*,* mixed, or diversified farming)*, farm income and off-farm income, social capital* (membership of a cooperative, water user association, or a farmer association) amongst others. Section B contained the choice experiment survey of 9 choice tasks, attitudinal characteristics on *agNPS pollution* like *perceived ecological benefits from improved water quality, agNPS pollution awareness action taken against agNPS pollution* in the study area, and *successor factors*. The section also contained the debrief questions. Sections C and D sought information on the farmers' water conservation behaviour. The data for the socio-demographic and attitudinal characteristics entered for the CE were captured such that for each farmer, they were entered 9 times to correspond with the 9 choice tasks. In Table 4, we present the descriptive statistics of our socio-demographic and attitudinal characteristics

4.8 Descriptive Statistics

Table 4: Summary statistics of the demographic and attitudinal characteristics

Variables	**% Sample (N = 14,904)**	**Mean**	**Std. Dev.**	**Min**	**Max**
Gender		1.55	0.49	1	2
Male	44.75				
Female	55.25				
Age		50.95	15.11	20	95
Education		3.15	1.06	1	5
No school	5.98				
Primary	19.02				
Secondary	41.67				
College	20.47				
University	12.86				
Farm ownership		0.93	0.26	0	1
Leased, rented, or government	7.07				
Owned by the farm or family	92.93				
Farm size		3.27	3.93	0.15	27
Location of farm		1.38	0.48	1	2
Upstream	62.50				
Downstream	37.50				
Source of water for farming		0.11	0.31	1	2

Surface	89.49				
Underground	10.51				
Farm income		0.79	0.40	0	1
Annual farm income less than 11000 ZAR	20.11				
Annual farm income greater than 11000 ZAR	79.89				
Off-farm income		0.31	0.46	0	1
No off-farm income	69.02				
Has off-farm income	30.98				
Member of a cooperative		0.62	0.49	0	1
No	38.04				
Yes	61.96				
Community of farmer		1.46	0.49	1	2
Folovhodwe	54.17				
Tshiombo	45.83				
agNPS Awareness		0.44	0.49	0	1
No	55.43				
Yes	44.57				
Action Taken		0.08	0.27	0	1
No actions taken against agNPS	91.67				
Actions taken against agNPS	8.33				
Perceived benefits of agNPS control		0.98	0.13	0	1
No	1.81				
Yes	98.19				

The descriptive statistics show that *females* constituted 55.25 percent of our sample. This was not surprising as the 2011 Census showed that women constituted 54.35 percent of the population of Folovhodwe and 53.71 percent in Tshiombo (Census, 2011). The average *age* was 51 years. With regards to *education*, the highest group was those who had completed Matric (senior high or secondary). The group constituted 41.67 percent of the sample and those without education were 5.98 percent. 92.93 percent of farmers owned the farms or farmed on family lands, whilst the rest *rented*. The average *farm size* is 3.27 hectares. For *location*, 62.50 percent of the sample were upstream farmers whilst 89.49 percent used surface water sources for farming. Farmers with annual *farm income* greater than 11000 ZAR (US$ 733.91 in April 2021) constituted 80 percent of the sample, whilst 69 percent of the sample did not have off-farm income. 54 percent of our sample is from Folovhodwe whereas 62 percent had membership in a *cooperative association* and 98.2 percent believed that they *stand to benefit* if water quality is improved. 55.43 percent had no *awareness of agNPS pollution* and its associated dangers. So, it is not surprising that only 8.3 percent of the sample had *taken or are taking action against agNPS pollution*. The actions included, not farming close to riverbanks, using more compost instead of fertilizers, gathering agricultural waste to be collected, preventing erosion on farms, cleaning riverbanks and furrow ridges, and education on the appropriate use of fertilizers and pesticides and the time to apply these.

5. Results and Discussions

5. 1 CLM 1 and CLM 2 (interactions)

In Table 5 are the results of the basic conditional logit model (CLM 1) and the extended conditional logit model with interaction terms (CLM 2). CLM 1 is estimated such that the probability of selecting any alternative is a function of the choice attributes and the *ASC*. The *ASC* is a dummy variable with the value of 1 if farmers choose the DO NOT want to participate option and 0 if none of the agNPS pollution control alternatives was chosen. The model showed a modest fit to the data (Pseudo $R^2 = 0.2645$). CLM 2 is used to investigate whether preference heterogeneity might be related to farmers' socio-demographic and attitudinal characteristics. Two levels each of both *fertilizer* and *pesticide* reduction are interacted with the socio-demographic and attitudinal variables. "Gender × Frb_25", is *gender* and *fertilizer reduction* (by 25%). "Gender × Frb_50", is *gender* and *fertilizer reduction* (by 50%), "Gender × Prb_25", is *gender* and *pesticide reduction* (by 25%) and "Gender × Prb_50", is *gender* and *pesticide reduction* (by 50%). The rest of the interactions were obtained in this manner. Significant estimates of the interactions indicate that farmers' socio-demographic and attitudinal characteristics impact preferences for reducing *fertilizer* and *pesticide* application differently, holding all else constant. The results show that the introduction of the interaction terms improved the explanatory power of the basic CLM. This is indicated by the Akaike Information Criterion (AIC), the Bayes Information Criterion (BIC) and Pseudo R^2 statistics. The chi-square statistics of these models show that, overall, the models are significant at 1 percent levels.

In both models, the negative and significant coefficients of *ASCsq* indicate a positive utility in a shift from the business-as-usual alternative. This implies, farmers are more likely to opt for the agNPS pollution control alternatives relative to the status quo option, holding all else constant. Furthermore, the coefficients of *compensation payment* (*CP*) are positive and significant at 1 percent. This suggests that relative to the status quo alternative, farmers are more likely to choose the agNPS pollution control alternatives when compensation offers are sufficiently high, holding all else constant. This is because of the perceived increase in utility associated with increased compensation. At present, farmers don't have this opportunity of receiving compensation to reduce agNPS pollution. Thus, introducing this novelty may lead to greater interest and adoption of the agNPS pollution control intervention and lead to greater improvements in water quality in the LRB.

Table 5: Results of the conditional logit models

Model	Conditional Logit Model (CLM)			
Log likelihood	–4014.04		–3832.51	
Prob > chi^2	0.0000		0.0000	
Pseudo-R^2	0.2645		0.2978	
AIC	8056.09		7805.01	
BIC	8162.62		8337.67	
N	14,904		14,904	
Indicators	CLM 1 (Basic CLM)		CLM 2 (CLM with Interactions)	
	coefficients	|z-values|	coefficients	|z-values|
Reduce fertilizer use by 25%	–0.3298***	6.11	0.8095	1.34
Reduce fertilizer use by 50%	–0.4326***	8.01	0.9755	0.11
Reduce pesticide use by 25%	–0.2231***	4.29	0.1699	0.77
Reduce pesticide use by 50%	–0.3932***	7.56	0.8616	0.15
50% waste recovery	–0.0719	1.33	–0.0567	1.02
100% waste recovery	–0.0282	0.53	–0.0275	0.51
Construct 25m ecological ditch	–0.2610***	4.71	–0.2816***	4.90
Construct 50m ecological ditch	–0.3974***	7.15	–0.4153***	7.28
5-year duration programme	–0.3788***	6.84	–0.3914***	6.83
10-year duration programme	–0.8773***	16.02	–0.9097***	16.07
Partial monitoring	–0.3281***	6.31	–0.3508***	6.56
External monitoring	–0.4279***	7.83	–0.4610***	8.22
Compensation payment	0.00006***	20.35	0.00006***	20.29
ASCsq	–2.2249***	21.26	–2.4075***	22.04
Gender × Frb_25			0.1186	1.13
Gender × Frb_50			–0.1720	1.63
Gender × Prb_25			0.0429	0.41
Gender × Prb_50			–0.0873	0.84
Age × Frb_25			–0.0142***	3.36
Age × Frb_50			–0.0113***	2.68
Age × Prb_25			–0.0041	1.01
Age × Prb_50			–0.0020	0.49
Education × Frb_25			–0.0731	1.20
Education × Frb_50			0.1566***	2.56
Education × Prb_25			0.0025	0.04
Education × Prb_50			0.1047*	1.76
Farm ownership × Frb_25			–0.1133	0.55
Farm ownership × Frb_50			0.1098	0.53
Farm ownership × Prb_25			0.0157	0.08
Farm ownership × Prb_50			0.0115	0.06
Farm size × Frb_25			–0.0312**	2.31
Farm size × Frb_50			–0.0409***	3.01
Farm size × Prb_25			–0.0201	1.46
Farm size × Prb_50			–0.0253*	1.87
Location of farm × Frb_25			–0.1680	1.52
Location of farm × Frb_50			–0.3696***	3.34

Location of farm × Prb_25	–0.2119**	1.97
Location of farm × Prb_50	–0.4314***	3.98
Source of water × Frb_25	–0.1055	0.61
Source of water × Frb_50	–0.5556***	3.12
Source of water × Prb_25	–0.1700	0.99
Source of water × Prb_50	–0.6569***	3.82
Farm income × Frb_25	0.9022***	6.67
Farm income × Frb_50	0.8624***	6.35
Farm income × Prb_25	0.3182**	2.41
Farm income × Prb_50	0.1974	1.50
Off-farm income × Frb_25	–0.0733	0.62
Off-farm income × Frb_50	–0.2149*	1.83
Off-farm income × Prb_25	–0.1269	1.09
Off-farm income × Prb_50	–0.3564***	3.04
Member of cooperative × Frb_25	0.3724***	3.13
Member of cooperative × Frb_50	0.5106***	4.25
Member of cooperative × Prb_25	0.3189***	2.71
Member of cooperative × Prb_50	0.3344***	2.84
Community × Frb_25	–0.3724***	3.01
Community × Frb_50	–0.5428***	4.35
Community × Prb_25	–0.0471	0.39
Community × Prb_50	–0.4617***	3.76
agNPS awareness × Frb_25	0.0074	0.06
agNPS awareness × Frb_50	0.0519	0.42
agNPS awareness × Prb_25	0.0219	0.18
agNPS awareness × Prb_50	0.3214***	2.63
Action taken × Frb_25	–0.2246	1.14
Action taken × Frb_50	–0.2881	1.46
Action taken × Prb_25	–0.1447	0.73
Action taken × Prb_50	–0.6672***	3.41
Perceived benefits × Frb_25	–0.1957	0.52
Perceived benefits × Frb_50	–0.0767	0.20
Perceived benefits × Prb_25	–0.0888	0.24
Perceived benefits × Prb_50	0.3491	0.89

NOTE: ***, ** and * represents the levels of significance at 1 percent, 5 percent and 10 percent respectively. The base categories are the reference point for all the indicators.

The results for CLM 1 show that all the choice attributes have the expected signs (negative) and are highly significant except the different levels of agricultural waste recovery. This implies in comparison with the status quo alternative farmers are less likely to reduce their fertilizer and pesticide usage, construct ecological ditches and be monitored for a period of five or ten years to control agNPS pollution, other things being equal. This strong aversion stems from the fact that the status quo option offers farmers the highest level of utility. Thus, decreasing this utility through a reduction of fertilizers and pesticide usage brings farmers less utility. The findings of Beharry-Borg et al. (2013) and Li et al. (2019) substantiate these results.

In CLM 2, the introduction of the interactions neutralized the statistical significance of the different levels of *fertilizer and pesticide* usage. Again, the different levels of agricultural waste recovery are insignificant but had the expected signs. All the other choice attributes, however, had the expected signs and are highly significant. This indicates that farmers are less likely to construct ecological ditches and be monitored for a period of five or ten years to control agNPS pollution, other things being equal. The interactions of *age* and (*fertilizer reduction* by 25% and 50%), *farm size* and (*fertilizer reduction* by 25% and 50% and *pesticide reduction* by 50%), *location of the farm* and (*fertilizer reduction* by 50% and *pesticide reduction* by 25% and 50%), *source of water* and (*fertilizer reduction* by 50% and *pesticide reduction* by 50%), *off-farm income* and (*fertilizer reduction* by 50% and *pesticide reduction* by 50%), the *community of farmer* and (*fertilizer reduction* by 25% and 50% and *pesticide reduction* by 50%) and *action taken against agNPS pollution* and (*pesticide reduction* by 50%) are negative and significant at various levels. This implies older farmers relative to their younger counters are less likely to reduce their fertilizer and pesticide usage, relative to the status quo, holding all else constant. According to Li et al. (2019), the rationale for such an outcome is that the current rural old-age security is not perfect. Agricultural output is the main source of income for older rural farmers. They are afraid of the decline of agricultural output and are unwilling to participate in the scheme to control agNPS pollution. The interactions further show that downstream farmers with off-farm activities who have farm sizes greater than 3.27 hectares and use underground water sources from Tshiombo and are taking measures against agNPS pollution are less likely to reduce their fertilizer and pesticide usage, relative to the status quo.

Furthermore, the interactions of *education* and (*fertilizer reduction* by 50% and *pesticide reduction* by 50%), *farm income* and (*fertilizer reduction* by 25% and 50% and *pesticide reduction* by 25%), *membership of a cooperative* and (*fertilizer reduction* by 25% and 50% and *pesticide reduction* by 25% and 50%) and *awareness of agNPS pollution* and (*pesticide reduction by 50%*) are positive and significant at various levels. This means educated farmers with farm income greater than 11000 ZAR (US$ 733.91 in April 2021), who are members of a cooperative association and are aware of agNPS pollution and its dangers are more likely to make *25 and 50 percent* reductions in their *fertilizer* and *pesticide usage* to *control agNPS pollution*, relative to the probability of the status quo, other things being constant. The rationale for this outcome comes from the fact that the level of education affects the farmer's level of understanding, learning abilities (Li et al., 2019), and appreciation of modern challenges of farming. Also, regarding income, Li et al. (2019) provided two possible reasons that may account for this income effect on participation in the agNPS pollution control schemes with high incomes. First, the economic loss of reducing fertilizer and pesticide application has a little negative impact on high-income farmers. Secondly, the demand of high-income farmers is different from those of low-income farmers. High-income farmers often pay more attention to the quality of life and environmental safety, so they are more willing to participate in agNPS pollution control programmes. Additionally, Cooperatives are an important avenue for information sharing, trust and social networking development for farmers. Most farmer cooperatives operate like activists and promote better farming practices and environmental protection policies. The cooperatives then inculcate higher enthusiasm for environmental protection policies including agNPS pollution control. Accordingly, these reasons may have accounted for the more likelihood of farmers' WTA compensation to control agNPS pollution for these interactions.

5. 2 The LCM

Even though heterogeneity could have been introduced in the CLM by interacting the socio-economic and attitudinal characteristics of farmers with the alternative specific constant (ASCsq) or the choice attributes, it could not have accounted for class heterogeneity, which is one of the objectives of this study. The LCM is thus used to overcome this flaw of the CLM. To find a more flexible and preferred LCM with the required optimal number of classes that provide an interpretable depiction of heterogeneity, statistical measures of fit, interpretive simplicity, and relevance of the classes (Boxall & Adamowicz, 2002; Swait, 1994), different classes were examined and based on the log-likelihood, AIC, AIC3 and BIC criteria, we opted for the four-class latent model (FCLM). As seen in Table 6, our model statistics and the preference parameter estimates are in the upper part, while the lower part reflects the effects of the socio-demographic and attitudinal characteristics on class membership probability. The FCLM showed an uneven distribution of farmers' preferences across the four classes. The percentage of farmers strongly associated with class 1 (C1) is 38 percent. Class 2 (C2) is 32 percent, whilst classes 3 and 4 (C3 and C4) represent 20 and 10 percent of farmers in our sample, respectively. Additionally, we found that preference patterns were different in these classes. Parameter estimates did not only differ in terms of magnitudes, but also signs. Not all the parameter estimates were statistically significant in all the classes. This shows that there were clear differences in the preferences of the choice attributes amongst these classes.

Table 6: Results of the Four Latent Class Logit Model

Model	Latent Class Logit Model							
Log-likelihood								–3348.69
R^2								0.3174
$R^2(0)$								0.4216
AIC								6917.39
BIC								7391.88

	Class 1		**Class 2**		**Class 3**		**Class 4**	
Label	**Low Resistance**		**Moderate Resistance**		**High Resistance**		**Non–Resistance**	
Class Share (in %)	**38**		**32**		**20**		**10**	
	coefficient	|*z*-value|	coefficient	|*z*-value|	coefficient	|*z*-value|	coefficient	|*z*-value|
Reduce fertilizer use by 25%	–0.4234***	3.73	–0.0802	0.77	–1.5062***	9.84	1.4485***	5.56
Reduce fertilizer use by 50%	–0.5703***	4.93	–0.1204	1.17	–2.2821***	13.05	2.9439***	9.56
Reduce pesticide use by 25%	–0.3265***	2.97	–0.2453***	2.50	–1.0030***	7.18	1.3624***	5.59
Reduce pesticide use by 50%	–0.6686***	5.86	–0.2364***	2.47	–1.6778***	11.03	1.8075***	6.55
50% waste recovery	–0.3084***	2.62	0.0010	0.01	–0.2949*	1.92	0.9883***	3.71
100% waste recovery	–0.00653	0.06	–0.0674	0.65	–0.2734*	1.97	–0.0139	0.06
Construct 25m ecological ditch	–0.3130***	2.56	–0.1051	0.99	–0.7189***	4.99	0.1098	0.45
Construct 50m ecological ditch	–0.6510***	5.16	–0.0989	0.93	–1.0786***	7.34	0.1124	0.50
5-year duration programme	–1.3596***	10.72	–0.0127	0.12	0.0308	0.20	–0.5789**	2.04
10-year duration programme	–3.0943***	19.28	–0.0051	0.05	–0.2531*	1.75	0.3559	1.40
Partial monitoring	–0.4509***	4.24	–0.5002***	4.97	–0.3737**	2.61	0.6199**	2.38
External monitoring	–0.3284***	2.92	–0.9938***	8.73	–0.5689***	3.84	0.9188***	3.51
Compensation payment	0.00012***	16.91	0.00005***	9.55	0.00002***	2.73	0.00009***	7.02
ASCsq	–1.9799***	9.72	–6.1846***	5.04	–4.3222***	14.92	0.8659	1.19
			Class Membership Function					
ASC (Class)			3.5544	1.57	–14.346***	2.65	5.4767	0.32
Gender			0.2283	0.64	–0.5366	0.80	–2.5114***	2.71
Age			–0.0198	1.42	0.0375	1.56	–0.0682*	1.85
Education								
Primary			2.2048**	2.53	1.3807	1.02	–8.5081*	1.71

Secondary	2.4842***	2.81	2.5707**	2.23	–0.4956	0.39
College	2.2843**	2.33	–0.1543	0.11	–2.6374	1.63
University	2.1608*	1.95	0.5227	0.37	–3.5372*	1.87
Farm ownership	–0.4572***	2.65	–0.3152	1.08	–2.3725**	2.42
Farm size	–0.3215***	4.60	–1.1438***	4.14	–2.9393***	4.84
Location of farm	–1.0393***	2.59	–3.0905***	3.64	–3.7918***	2.92
Source of water	–0.1611	0.21	0.2229	0.22	–5.9932	0.94
Farm income	0.0266	0.24	0.6069**	2.08	1.6172***	4.00
Off-farm income	0.0888	1.10	0.2193*	1.80	–0.0374	0.23
Membership of a cooperative	0.6439	1.52	–3.1396***	3.27	3.8279***	2.71
Community of farmer	–3.3223***	3.18	9.5353***	4.71	6.0646***	3.21
Awareness of agNPS pollution	–0.2201	0.49	1.1803*	1.70	3.4564***	3.22
Action against agNPS pollution	–0.5568**	2.16	0.3723	1.06	–0.6014	1.17
Perceived benefits	1.6397	1.22	0.3579	0.10	–1.0625	0.07

Note: ***, ** and * represents the levels of significance at 1 percent, 5 percent and 10 percent respectively

The FCLM showed a remarkable improvement in the predictiveness of our sample over our conditional logit models (decreased log-likelihood, AIC and BIC statistics while Pseudo-R^2 increases). The general aversion of farmers to reduce fertilizer and pesticide usage, construct ecological ditches and be monitored for a period of five or ten years to control agNPS pollution in the conditional logit models are also evident in the FCLM, especially for C1 and C3. First, the ASC is negative and highly significant for classes 1, 2 and 3. This indicates that on average farmers in these classes are more likely to prefer the agNPS pollution control alternatives of water quality improvement instead of the business-as-usual alternative. That is, these groups of farmers are motivated to alter their current unsustainable farm management practices (status quo) to new sustainable farm management practices that contribute to reducing agNPS pollution and hence, water quality improvement. However, the *ASCsq* for C4 is positive and statistically insignificant. This indicates that, all else being constant, these groups of farmers are indifferent between the status quo option and the agNPS pollution control alternatives given the current choice attributes of the study. Second, the coefficients of *CP* for all classes of the LCM have the expected positive signs and are highly significant at 1 percent. This suggests that on average, farmers in these classes want to move away from the business-as-usual alternative given that compensation payments are high enough to persuade even the most resistant farmers.

With regards to the classes, all the choice attributes for C1 are negative and highly significant except 100 percent agricultural waste recovery is insignificant. The results imply that, farmers of C1 are less likely to reduce their fertilizer and pesticide usage, recover 50 percent of agricultural waste, construct ecological ditches, and be monitored to control agNPS pollution, holding all else constant. The 50 percent waste recovery that was previously insignificant in the conditional logit models is now statistically significant. This is an indication that the FCLM provided additional information on preferences than the conditional logit models. Comparing the magnitude of the utility coefficients (absolute size) shows that, relative to the other classes, there is a strong aversion for the duration of the programme, whether it be for 5 or 10 years in this class. The aversion, however, is strongest with the 10 years duration. This is not surprising because previous evidence showed that, overall, farmers prefer shorter rather than longer AES contracts (Ruto and Garrod, 2009),. Our descriptive statistics across the classes in Table 7 shows that the average age of the class is 50 years. Females constitute 51 percent. Farms sizes are relatively larger, averaging 6 hectares (greater than the sample mean of 3.27 hectares).

Table 7: Descriptive Statistics across Classes

Label	**Class 1 Low Resistance**	**Class 2 Moderate Resistance**	**Class 3 High Resistance**	**Class 4 Non–Resistance**		
Class Share (in %)	**38**	**32**	**20**	**10**	**Test of significant differences**	
Farm/Farmer characteristics					χ^2	P-value
Gender[b]	50.92	62.94	58.56	41.51	10.26	0.016
Age[a]	50	51	51	46	9.11	0.0279
Education[b]					45.34	0.000
No school	8.26	1.76	5.41	11.32		
Primary	17.89	27.06	18.02	0.00		
Secondary	33.49	46.47	46.85	49.06		
College	24.77	18.82	14.41	20.75		
University	15.60	5.88	15.32	18.87		
Farm ownership[b]	88.53	96.47	92.79	100.00	13.71	0.003
Farm size[a]	5.70	2.10	1.40	1.122	140.88	0.0001
Location of farm[b]	52.29	34.71	28.83	3.77	50.21	0.000
Source of water[b]	14.22	4.12	18.02	0.00	23.46	0.000
Farm income[b]	78.90	85.29	66.67	94.34	22.19	0.000
Off-farm income[b]	29.36	22.94	51.35	20.75	29.54	0.000
Membership of a cooperative[b]	68.81	53.53	47.75	90.57	37.38	0.000
Community of farmer[b]	44.95	1.76	97.30	83.02	280.99	0.000
Awareness of agNPS pollution[b]	44.04	20.00	62.16	88.68	97.21	0.000
Action against agNPS pollution[b]	10.55	2.35	15.32	3.77	17.89	0.000
Perceived benefits[b]	96.79	99.41	98.20	100.00	4.81	0.186

Note: [a]Kruskal-Wallis test
[b]Chi-square test

The class has 52.3 percent downstream farmers, whilst 86 percent use surface water. 45 percent of farmers in this class are from Tshiombo. 44 percent are aware of agNPS pollution but 11 percent have acted against it whilst 97 percent perceive to benefit if the quality of water is improved through the agNPS pollution control programme. Based on the marginal WTA (mWTA) estimate for the *ASC*sq, this class of farmers requires a compensation of 16824.2 ZAR (US$ 1122.5 in April 2021) to be persuaded to move from the business-as-usual alternative to the agNPS pollution control alternatives, all else constant. This is the smallest mWTA required by a class to move away from the status quo option. Therefore, C1 is characterized as “low resistance farmers”.

C2 farmers are mostly indifferent towards fertilizer reduction, agricultural waste recovery, construction of ecological ditches, and duration of the programme. These do not impact the preferences of this class. They are, however, highly influenced by the different levels of *pesticide reduction and monitoring.* The utility coefficients for these parameters are negative and statistically significant at 1 percent. This suggests that on average, C2 farmers are less likely to reduce their pesticide usage and be monitored for a period to control agNPS pollution. Farmers of the class have an average of 51 years and are composed of a larger number of females (63%). The class is highly more educated with 98.23 percent of farmers educated at various levels relative to the other classes. 96 percent of farmers in the class own their farms or cultivate family farms, which are relatively small in size (2 hectares). The class is made up of 35 percent downstream farmers, who mostly use surface water sources (96%) relative to the other classes. 98 percent of farmers in this class are from Folovhodwe. Furthermore, relative to the other classes, 20 percent are aware of agNPS pollution, yet only 2 percent have acted against it whilst 99 percent perceive to benefit if the quality of water is improved through the agNPS pollution control programme. The mWTA estimate for the *ASCsq* for C2 shows that farmers require compensation of 116317.6 ZAR (US$ 7760.61 in April 2021) to be persuaded to move from the business-as-usual alternative to the agNPS pollution control alternatives, all else constant. Therefore, C2 is characterized as “moderate resistance farmers”.

The 5-year duration programme (insignificant) does not impact the preferences of farmers in C3. All the other choice attributes are, however, negative and statistically significant at different levels. This implies, on average, farmers of this class, just like their counterparts in C1 are less likely to reduce their fertilizer and pesticide usage, recover agricultural waste, construct ecological ditches, and be monitored for a period of time to control agNPS pollution, holding all else constant. The average age of the class is 51 years and females constituted 59 percent. The class is slightly more educated with 94.6 percent of farmers educated at various levels relative to the other classes. The average farm size of the class is relatively small (1.4 hectares compared to the sample mean of 3.27 hectares). Compared to the other classes, this class has 29 percent downstream farmers, who are also mostly surface water users (82%). Many farmers in this class are from Tshiombo (97%). 62 percent are aware of agNPS pollution but only 15.3 percent have acted against it whilst 98.2 percent perceive to benefit if the quality of water is improved through the agNPS pollution control programme. This class is termed "high resistance farmers" given that farmers in this class require a very high compensation amount (221211.3 ZAR (US$ 14759.03)) to be persuaded to move from the status quo option, holding all else constant.

The coefficients of the different levels of *fertilizer* and *pesticide reduction,* the different levels of *monitoring,* 50 percent of *agricultural waste recovery* are positive and statistically significant at various levels for C4. But the coefficient for the 5-year *duration programme* is negative and highly significant. This indicates that farmers in C4 are more likely to reduce their fertilizer and pesticide usage, recover 50 percent of agricultural waste, and be monitored for ten years, but are less likely to do all the above within the 5-year *duration* of the programme*,* all else constant. This outcome is in contrast with the preferences of farmers in all the other classes, where we saw a strong aversion for the choice attributes of the scheme. This class has the youngest average age (46 years) relative to the other classes. Females constituted 42 percent of the class. In terms of education, the class has the highest number of the non-educated (11.3%), the highest number of both university (18.9) and secondary (49.1) graduates compared to the other classes. Farmers of C4 are mostly upstream farmers (96%) relative to the other classes. None of the farmers here use underground water sources. The class is largely made up of farmers from Tshiombo (83%). 89 percent of the class are aware of agNPS pollution, but only 4 percent have acted against it whilst 100 percent of the class perceives to benefit if the quality of water is improved through the agNPS pollution control programme. Given that farmers in C4 are indifferent between the status quo option and the agNPS pollution control alternatives, C4 is characterized as "non-resistance farmers".

For purposes of interpretation, the coefficients of our covariates are based on dummy coding. The membership coefficients for the first class are normalized to zero. This allowed the remaining coefficients of the model to be identified and interpreted relative to the normalized class (Boxall & Adamowicz, 2002). Thus, the direction of significant coefficients (+ / −) of the covariates are interpreted as a farmer is more (or less) likely to belong to the respective class than belonging to C1. Educated farmers (primary, secondary, college and university) are more likely to have preferences aligned with C2, whilst downstream farmers from Tshiombo with self-owned small farms (or family farms), who are acting against agNPS pollution are less likely to be associated with this class. Farmers with secondary education with off-farm activities from Tshiombo who have farm income greater than 11000 ZAR (US$ 733.91) are more likely to belong to C3, whilst downstream farmers with small farms with membership in a cooperative are less likely to belong to C3. Farmers from Tshiombo with membership in a cooperative, who earn about 11000 ZAR (US$ 733.91) from farming and are aware of agNPS pollution are more likely to belong to C4, whilst younger educated (at both primary and university levels) downstream farmers with self-owned small farms (or family farms) are less likely to be associated with this class. Overall, our FCLM provided a good fit to our choice data and the classes appeared to be an interpretable depiction of farmers' preferences for the agNPS pollution schemes proposed.

5. 3 Marginal Willingness to Accept (mWTA) Compensation

We applied the Delta method[13] to calculate the mWTA estimates by class and as a weighted average across classes to gain further insight into farmers' preference patterns. The results are reported in Table 8. The weighted average across classes is based the statistically significant marginal WTA estimates. Overall, the mWTA estimates for C3 are the highest of the FCLM, whilst C4 had the least mWTA for the attributes. Specifically, the mWTA for the different levels of the duration of the progrmme and pesticide reduction (by 50%) is higher for C1, relative to C2, C3, and C4. This suggests that farmers in this class are more averse to the duration of the progrmme and pesticide reduction (by 50%) when opting for the agNPS pollution control programme.

For C2, the mWTA for the different levels of monitoring and pesticide reduction (by 25%) is higher, relative to the other classes. This suggests that farmers in this class are more averse to monitoring and pesticide reduction (by 25%) when opting for the agNPS pollution control programme. Monitoring is generally believed to have a negative impact on farmers' utility.

13 The method allows us to analytically determine the variance, the standard error and 95% confidence intervals of the WTA estimate and subsequently its significance.

This disutility of monitoring may be due to risk aversion and personal disutility of being monitored (Frey, 1993). To be compensated appropriately, farmers require 9407.4 ZAR (US$ 627.7) and 18590.6 ZAR (US$ 1247.1) hectare^{-1} year^{-1} for the different levels of monitoring and 4613.9 ZAR (US$ 307.8) hectare^{-1} year^{-1} for *pesticide reduction* (by 25%)**.**

In C3, the mWTA for the different levels of *fertilizer* and *pesticide reduction* (by 25% and 50%) and *construction of ecological ditches* (by 25 and 50 metres) are higher relative to the other classes. This implies farmers in this class have a strong aversion to *fertilizer* and *pesticide reduction* and *construction of ecological ditches* than in the other classes. Therefore, to compensate this class of farmers appropriately, higher compensations are required for the different levels of *fertilizer reduction* (77087.4 ZAR (US$ 5143.2) and 116795.3 ZAR (US$ 7792.5) hectare^{-1} year^{-1}), *pesticide reduction* (51335.7 ZAR (US$ 3425.1) and 85870.4 ZAR (US$ 5720.2) hectare^{-1} year^{-1}) and *construction of ecological ditches* (36790.9 ZAR (US$ 2451) and 55201.4 ZAR (US$ 3682.9) hectare^{-1} year^{-1}).

Lastly, C4 farmers have the least mWTA for most of the choice attributes except for the 5-year duration of the progrmme and agricultural waste recovery by 100. This is because C4 farmers have significant preferences for most of the choice attributes relative to the other classes where farmers have mostly exhibited an aversion for the choice attributes. The farmers in this class are willing to accept approximately 11300 ZAR (US$ 754) less in compensation if the purpose is to recover agriculture waste by 50 percent. If the purpose is fertilizer reduction, they are willing to accept approximately 16560 ZAR (US$ 1105) and 33650 ZAR (US$ 2245) less in compensation for fertilizer reduction (by 25 and 50%), respectively. Further, they are willing to accept approximately 15580 ZAR (US$ 1040) and 20660 ZAR (US$ 1379) less in compensation if the purpose is pesticide reduction (by 25 and 50%), respectively. However, the class has a positive willingness for agriculture waste recovery by 100 percent 160 ZAR (US$ 11) and the 5-year duration programme 6620 ZAR (US$ 442).

Table 8: Marginal WTA compensation estimates (in South African Rands (ZAR) hectare^{-1} year^{-1}) by class and weighted average.

Label	**Class 1** Low Resistance	**Class 2** Moderate Resistance	**Class 3** High Resistance	**Class 4** Non–Resistance	
Class Share (in %)	**38**	**32**	**20**	**10**	**Weighted Average**
Reduce fertilizer use by 25%	3597.70***	1508.51	77087.42***	–16554.67***	15809***
	(1697.91/5497.49)	(–2353.75/5370.78)	(22054.4/132120.4)	(–22451.12/–10658.22)	(4642.55/26975.46)
Reduce fertilizer use by 50%	4846.09***	2265.19	116795.28***	–33647.91***	22885.33***
	(2889.59/6802.59)	(–1568.67/6099.05)	(33748.45/199842.1)	(–42908.33/–24387.48)	(6098.85/39671.8)
Reduce pesticide use by 25%	2774.27***	4613.89**	51335.65***	–15572.29***	11350.88***
	(942.71/4605.84)	(891.94/8335.83)	(13032.56/89638.73)	(–21442.55/–9702.03)	(3543.49/19158.28)
Reduce pesticide use by 50%	5681.29***	4446.45**	85870.42***	–20659.29***	18909.69***
	(3786.23/7576.34)	(804.71/8088.19)	(23976.65/147764.2)	(–27811.3/–13507.29)	(6382.25/31437.13)
50% waste recovery	2621.16***	–18.81	15091.14	–11296.09***	2983.93
	(670.97/4571.35)	(–3677.83/3640.22)	(–3464.06/33646.33)	(–17723.49/–4868.70)	(–999.84/6967.70)
100% waste recovery	55.51	1267.78	13992.89	159.85	3242.37*
	(–1788.46/1899.47)	(–2559.89/5095.45)	(–3296.51/31282.29)	(–5294.33/5614.02)	(–456.11/6940.84)
Construct 25m ecological ditch	2659.40**	1975.86	36790.86**	–1255.13	8941.12***
	(598.57/4720.23)	(–1942.32/5894.03)	(6621.50/66960.22)	(–6671.31/4161.05)	(2702.70/15179.35)
Construct 50m ecological ditch	5531.47***	1861.52	55201.35**	–1284.39	13743.26***
	(3360.55/7702.39)	(-2058.65/5781.68)	(12556.84/97845.85)	(–6295.92/3727.14)	(5064.59/22421.94)
5-year duration programme	11552.73***	239.86	–1576.43	6617.78*	4960.30***
	(9454.49/13650.96)	(-3717.92/4197.64)	(–17136.7/13983.85)	(0.9842/13234.57)	(1499.02/8421.58)
10-year duration programme	26292.48***	95.91	12954.06	–4067.93	12644.4***
	(23394.5/29190.46)	(–3994.78/4186.61)	(–4551.68/30459.8)	(-9679.74/1543.87)	(8754.65/16534.15)
Partial monitoring	3831.76***	9407.39***	19125.59*	–7086.42**	7575.77***
	(2019.26/5644.26)	(5295.25/13519.53)	(–308.06/38559.24)	(–12716.26/–1456.58)	(3410.07/11741.47)
External monitoring	2790.35***	18690.64***	29114.09**	–10501.90***	11699.71***
	(910.43/4670.26)	(13355.98/24025.29)	(3282.91/54945.26)	(–16365.21/–4638.59)	(6199.37/17200.04)
ASCsq (Standard error)	16824.2 (2232.9)***	116317.6 (27037.5)***	221211.3 (87031.7)***	–9896.89 (7645.24)	—

Note: ***, ** and * represents the levels of significance at 1 percent, 5 percent and 10 percent respectively and 95% confidence intervals in brackets. The exchange rate during the period of our survey was 1 US Dollar = 14.9882 (in April 2021)

5. 4 Welfare and Alternative Policy Scenarios

The non-marginal welfare or compensating surplus (CS) measures the change in required compensation between the initial situation of agNPS pollution (lower water quality) and subsequent situations (improved water quality) needed to render the farmer indifferent to a change. CS allows policymakers to choose not only the alternatives providing farmers with the highest utility but also those alternatives that provide the needed high water quality improvement. We omitted the ASC in calculating the welfare measures. The literature is not clear on whether the ASC reflects an inherent part of welfare or whether including it would increase welfare measures substantially (Meyerhoff et al., 2021). Four water quality improvement policy scenarios are simulated and described in Table 8.

Table 9: Welfare measure for different water quality improvement strategies (in South African Rands (ZAR) hectare^{-1} year^{-1})

Indicators	**Scenario I**	**Scenario II**	**Scenario III**	**Scenario IV**
	High impact water quality improvement	Medium impact water quality improvement 1	Medium impact water quality improvement 2	Low impact water quality improvement
Fertilizer reduction	Reduce by 50%	Reduce by 25%	Reduce by 50%	Reduce by 25%
Pesticide reduction	Reduce by 50%	Reduce by 50%	Reduce by 25%	Reduce by 25%
Agricultural waste recovery	100% recovery	50% recovery	100% recovery	50% recovery
Construction of ecological ditch	25 metres	25 metres	50 metres	50 metres
Duration of programme	10 years	5 years	10 years	5 years
Monitoring for compliance	External	Partial	Partial	Partial
Compensating surplus	78322.62*** (35185.8/121459.4)	59179.82*** (25759.3/92600.4)	71442.02*** (32066.6/110817.5)	56423.16*** (25154.9/87691.4)

Note: 95% confidence intervals in brackets
The exchange rate during the period of our survey was 1 US Dollar = 14.9882 (in April 2021)

The results show that scenario I is the highest (78322.6 ZAR (US$ 5225.6) ha^{-1} year^{-1} followed by scenario III (71442.02 ZAR (US$ 4766.6) ha^{-1} year^{-1}. This indicates that farmers in our sample are willing to accept 78322.6 ZAR (US$ 5225.6) ha^{-1} year^{-1} and 71442.02 ZAR (US$ 4766.6) ha^{-1} year^{-1} to implement the high and medium impact water quality improvement alternatives of scenarios I and III rather than accept the status quo alternative. Similarly, they are willing to accept 59179.8 ZAR (US$ 3948.4) ha^{-1} $year^{-1}$ and 56423.2 ZAR (US$ 3764.5) ha^{-1} $year^{-1}$ for the implementation of the medium and low impact water quality improvement alternatives of scenarios II and IV rather than accept the status quo option.

6. Conclusion and policy implications

The study reported the results of a CE study in which we investigated farmers' WTA compensation to control agNPS pollution in the LRB. We used CLM and LCM to analyze our data. We found first that, compared to the status quo alternative, farmers generally preferred the agNPS pollution control alternatives of improved water quality. Second, compensation payment has a positive incentive effect on farmers and increases their willingness to alter their farming practices to control agNPS pollution. We identified *gender, age, farm income, agNPS pollution awareness, perceived benefits of agNPS pollution control, and membership of cooperative,* as the main drivers underlying preference heterogeneity in our study. The mWTA and the CS estimates demonstrated that farmers have strong preferences for mitigating agNPS pollution. Our results suggest that the cost of using monetary incentive mechanisms to persuade farmers to reduce agNPS pollution may not be prohibitive. High compensation payments may be required to incentivize farmers to overcome their distaste. If the desired futures of the Limpopo River could be realized through a possible future water quality improvement policy, a combination of all or some of the attributes in this study may be employed. This may, however, be dependent on the budget of agricultural water managers.

Furthermore, we advocate for policies that lessen agriculture's impact on water quality. That is a massive shift to environmentally friendly farming technologies (green agrochemicals and fertilizers etc.). We propose making the construction of ecological ditches compulsory in severely water-impaired areas. Lastly, this study calls for training and education to increase farmers' awareness and stimulate participation in agNPS pollution control programmes. This study could be further advanced with similar research in the other parts of the Limpopo Water Management Area or other parts of South Africa. Furthermore, understanding how the cost of the mitigation actions will change if the monetary values of the agNPS pollution control attributes (mWTA) and CS of the future alternative policy scenarios are taken into consideration in decision-making is necessary. Such cost-benefit analysis would provide policymakers with more information to design effective agNPS pollution control programmes.

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Appendix

Table 1: An overview of key related studies for agNPS pollution control around the world.

Authors	Study area/Sample size (N)	Attributes	Empirical models	Findings
Lu et al. (2021)	China N = 238	Chemical fertilizer application reduction, pesticide application reduction, agricultural waste recovery rate, compensation	Multinomial logit	1. The results showed that financial compensation can effectively stimulate farmers' willingness to control agNPS pollution. 2. The willingness of farmers to participate in the ecological compensation is greater when there prevails a higher level of risk preferences and higher understanding of farmland nonpoint source pollution control policy. 3. Additionally, willingness is higher in younger, highly educated, and highly involved in a part-time family business with higher recognition degree in the ecological function of farmland nonpoint source pollution control.
McGurk et al. (2020)	Ireland N = 800	Not applicable	Bivariate probit model	1. Results showed that increased compensation levels may increase participation rates among some farmers who hitherto are unlikely to participate. 2. 30 percent of farmers are unlikely to ever participate in the AES, with the remaining open to participation depending on the compensation offered.
Chêze et al. (2020)	France N = 90	Profit, production risk, administrative commitment, health and environmental impacts	Random parameter logit	1. Results indicated that the risk of large production losses due to pests strongly limits farmers' willingness to change their practices, regardless of the consequences on average profit. 2. Reducing the negative health and environmental impacts of pesticides is a significant motivator only when respondents believe that pesticides affect the environment. 3. Farmers who earn revenue from outside their farms and/or believe that yields can be maintained while reducing the use of pesticides are significantly more willing to adopt low-pesticide practices.
Li et al. (2019)	Qinba Water Source Area in Northwest China	Fertilizer reduction, pesticide reduction, agricultural waste recovery rate and compensation standards	Random parameter logit (RPL) model	1. The results revealed that compensation was important for rural households' willingness to control agNPS pollution. 2. The marginal compensation for reducing fertilizer and pesticide use was \$3.40 ha^{-1} and \$2.00 ha^{-1} respectively.

	N = 632			3. Households with younger residents, higher family income, higher perception of the ecological benefits, and higher perception of government policy were more willing to participate in the compensation policy.
Wu and Ge (2019)	Heyang County, Shaanxi Province in China N = 516	Organic fertilizer subsidy, agricultural tailwater discharge standards, planting technology guidance, fertilizer application changes.	Multinomial logit model (MNL)	1. Households had different preferences for the three policy settings. Fertilizer application was reduced by 6.98 percent for full technological guidance for farmers and by 5.18 percent under the background of providing appropriate organic fertilizer subsidies. 2. Agricultural tailwater discharge standards had the least impact on reducing the level of chemical fertilizer application. 3. The decreased amounts were 1.85 percent and 0.77 percent for the second and first levels agricultural tailwater discharge standards respectively.
Villamayor-Tomas et al. (2019).	Germany, Switzerland, and Spain N = 224	Location of trees, share of farm, recommendation and payment for action	Conditional logit model	1. Findings revealed that the resistance of farmers to participate in coordinated programmes was not insurmountable but had to do with transaction costs as well as beliefs about other farmers' behaviour 2. Having conservation programmes recommended by farmers can encourage other farmers to participate. 3. Different conservation framings could affect the resistance of farmers to participate depending on the emphasis put on the environmental benefits that farmers obtain from the programmes.
Zhang et al. (2019)	Three Gorges Reservoir Area of China N = 685	Not Applicable	Multinomial probit and structural equation models	1. Farmers' characteristics impact positively on the adoption of agricultural cleaner production techniques (CPTs). 2. The Farmers' perceived usefulness and their satisfaction with their technical adoption positively impacts on whether farmers would intend to adopt the CPTs over the long-term. 3. Although most farmers had some awareness of the environmental pollution caused by the traditional agriculture, their adoption behaviours of the CPTs remain insufficient.
Lee et al. (2018)	The Soyang Watershed in South Korea	Agricultural profits, water quality, and biodiversity level	Conditional logit model	1. Results showed that water quality is the most important attribute that is preferred by both downstream water users and upstream farmers. 2. Both water users put substantial values on the protection of water bodies in the Soyang watershed and are concerned about the consequences of water usage on the environment and human health.

	N = 240			3. Income groups in different local communities seemed to have different implicit costs for water quality improvement in the Soyang watershed.
Aguilar et al. (2018),	U.S.A N = 1200	Water quality, flood control, landscape beauty, habitat for plant and animal species and PES management fees	Mixed logit model	1. Results showed limited knowledge of payment for ecosystem service (PES) programmes and antagonistic opinions regarding initial WTP for watershed conservation and corresponding PES financial charges. 2. Findings support the establishment of PES initiatives that enhance forested watersheds conditions across the U.S. primarily driven by improvements in water quality. Water quality (30.4%) dominated importance among selected PES attributes used in the study followed by provisioning of habitat for threatened plant and animal species (23.4%), flood control (21.4%), and landscape aesthetics (14.0%). 3. Environmental attitudes significantly influenced WTP results even more than annual household income. Results show WTP levels for improvements in water quality were homogeneous across the nation but heterogeneous for the enhancement of habitat, landscape and flood control.
Aslam et al. (2017)	UK (Yorkshire, Midlands, Norwich, and Scotland) N = 115	Enrolment for permanent grassland, enrolment for afforestation, grazing intensity, ploughing methods, length of agreement and compensation.	Conditional logit and latent class models	1. The findings revealed in general that farmers showed an aversion to drastic changes in land management activities, but they could be encouraged to adopt relatively less restrictive activities through appropriate compensations.
Pan et al. (2016)	China N = 754	Technical support, pollution fees, technical standards, biogas subsidies, and the manure market	Random parameter logit	1. The biogas subsidy, technical support, pollution fees and manure market are significant factors of preference over alternative policy designs in terms of incremental changes in environmentally friendly manure handling. 2. Farmers' choices of improved pollution policy options were significantly influenced by their education, the size of their farms and their willingness to treat pollution. 3. Farmers showed the highest preferences for a biogas subsidy policy, followed by a high technical support policy, a pollution fee policy, a medium technical support policy, a manure market policy and finally a technical standard policy.

Greiner (2015)	Northern Australian N = 104	Conservation requirement, annual conservation payment, contract duration and flexibility in contract conditions and monitoring	Random parameter logit and latent class models	1. Findings revealed that of contract attributes, conservation requirement, stewardship payment, contract duration and flexibility in contract conditions significantly influenced choices. Land productivity was a significant factor as were attitudes. 2. Conservation investment strategies, which offered farmers contract options that met biodiversity requirements while accommodating heterogeneous attribute preferences, were likely to lead to increased participation rates. 3. Complementary suasion efforts are also required which espouse the benefits that pastoralists derive from biodiversity and participation in voluntary conservation contracts.
Villanueva et al. (2015)	Southern Spain N = 295	Cover crop area, cover crop management ecological focus area, collective participation, monitoring and payment.	Latent class model	1. High heterogeneity among farmers, with different classes was identified, including potential participants and non-participants. 2. With ecological focus area (EFA), almost half of the farmers were willing to accept it up 2 percent for low monetary incentives (€8–9/ha per additional 1 percent of the farmland devoted to EFA) while the rest did it for moderate-to-high monetary incentives (€41–151/ha per additional 1 percent of EFA). 3. However, for a high share of EFA (e.g., 5–7 percent) higher incentives were presumably required due to the intrinsic spatial restrictions of farmers. 4. For collective participation, they found that it is unlikely that farmers would participate collectively with the incentive of up to 30 percent EU-wide bonus.
Mulatu et al. (2014)	Kenya N = 205	Restoration of riparian land and floodplain areas, environment-friendly agricultural farming practices, reforestation and compensation	Random parameter logit	1. Sub-basins where payment for water related ecosystem services (PWES) are existent, environment-friendly agricultural practices to farmers' choice to improve water-related ecosystem services (WES). 2. Reforestation and environment friendly agricultural practices are significant attributes for sub-basins where PWES are nonexistent. 3. In general, farm households are willing to accept compensation to improve WES but there appears to be heterogeneity in preferences.
Beharry-Borg et al. (2013)	Nidderdale and the Washburn valley in Yorkshire, UK	Inorganic fertilizer application, farmyard manure application, blocking of drainage	Conditional logit and latent class models	1. Farmers were willing to modify their land management practices to protect water quality if compensation payments were sufficient. 2. Farmers were generally averse to reducing nitrogen applications, though the aversion to manure reductions was stronger than the aversion to fertilizer

	N = 97	'grips' duration of compensation agreement and compensation payment		reductions. Farmers who operate cattle-orientated mixed farming businesses were, understandably, more averse to these changes. 3. A smaller proportion of farmers appeared very reluctant to change their management practices, and that many farmers regarded the transaction cost of changing from status quo as substantial
Broch and Vedel (2012)	Denmark N = 853	Purpose of afforestation, option of cancelling the contract, monitoring, and compensation level	Random parameter logit and latent class models	1. Their results showed that having the option to cancel the contract decreased farmers' required compensation level and monitoring increased it. 2. Furthermore, farmers were willing to accept a lower compensation when the aim was to protect biodiversity and ground water relative to recreation. 3. Their latent class model reveals discrete heterogeneity—a group of farmers who already had forest areas did not find the option of cancelling the contract important, whereas another group relying on the farm for income required higher compensation.
Christensen et. al. (2011)	Denmark N = 444	Contract length, release option, buffer zone width, changed agricultural practice, application method, and size of subsidy	Random parameter logit model	1. Payments above and beyond direct costs are a necessary condition for showing interest in a subsidy scheme. 2. Majority of farmers are willing to trade off the size of the subsidy for less restrictive scheme requirements. 3. The amount of the subsidy they were willing to trade-off varies with specific scheme requirements. Additionally, farmers value flexible contract terms higher than reduced administrative burdens.
Espinosa-Goded et al. (2010)	Aragón and Andalusia in Spain N = 300	Surface, grazing in the enrolled surface, technical advisory service compulsory and free of charge, fixed premium and premium level	Error component and Random Parameter Logit	1. Results showed significant heterogeneity in preferences for AES design attributes across the regions and farmers. However, there was a significant reluctance of farmers to participate in certain schemes. 2. In general, Spanish farmers were more willing to participate in AES that only required low levels of involvements (small restrictions on farm management and small payments).
Ruto and Garrod (2009)	10 case study areas (cities) across the European Union	Minimum length of agreement (years), flexibility over what areas of the farm are entered into the scheme, flexibility over	Mixed logit and latent class models	1. Farmers were found to require greater financial incentives to join schemes with longer contracts or that offered less flexibility or higher levels of paperwork. 2. Additionally, they observed a large segment of farmers 'low resistance adopters' were willing to accept relatively small incentive payments for their participation in schemes offering relatively little flexibility and high levels

	N = 2262	undertaking some of the measures required under the scheme, average time spent on paperwork/administration and additional payment per hectare made under the scheme		of additional paperwork, when compared to a contrasting segment of ‘high resistance adopters’
Vanslembrouck et al. (2002)	Wallonia and Flanders in Belgium N = 347	Not applicable	Conceptual micro-economic model and probit model.	1. Consistency is found between the theoretical framework and the empirical results. Both indicate that the expected effect on farm production and the farmers’ environmental attitude is more positive among younger and better educated farmers and are significant determinants of the acceptance rate of agri-environmental policies. 2. Farm size and previous experience of farmers or of neighbouring farmers with agri-environmental measures influences participation decisions

Appendix 2: Research area

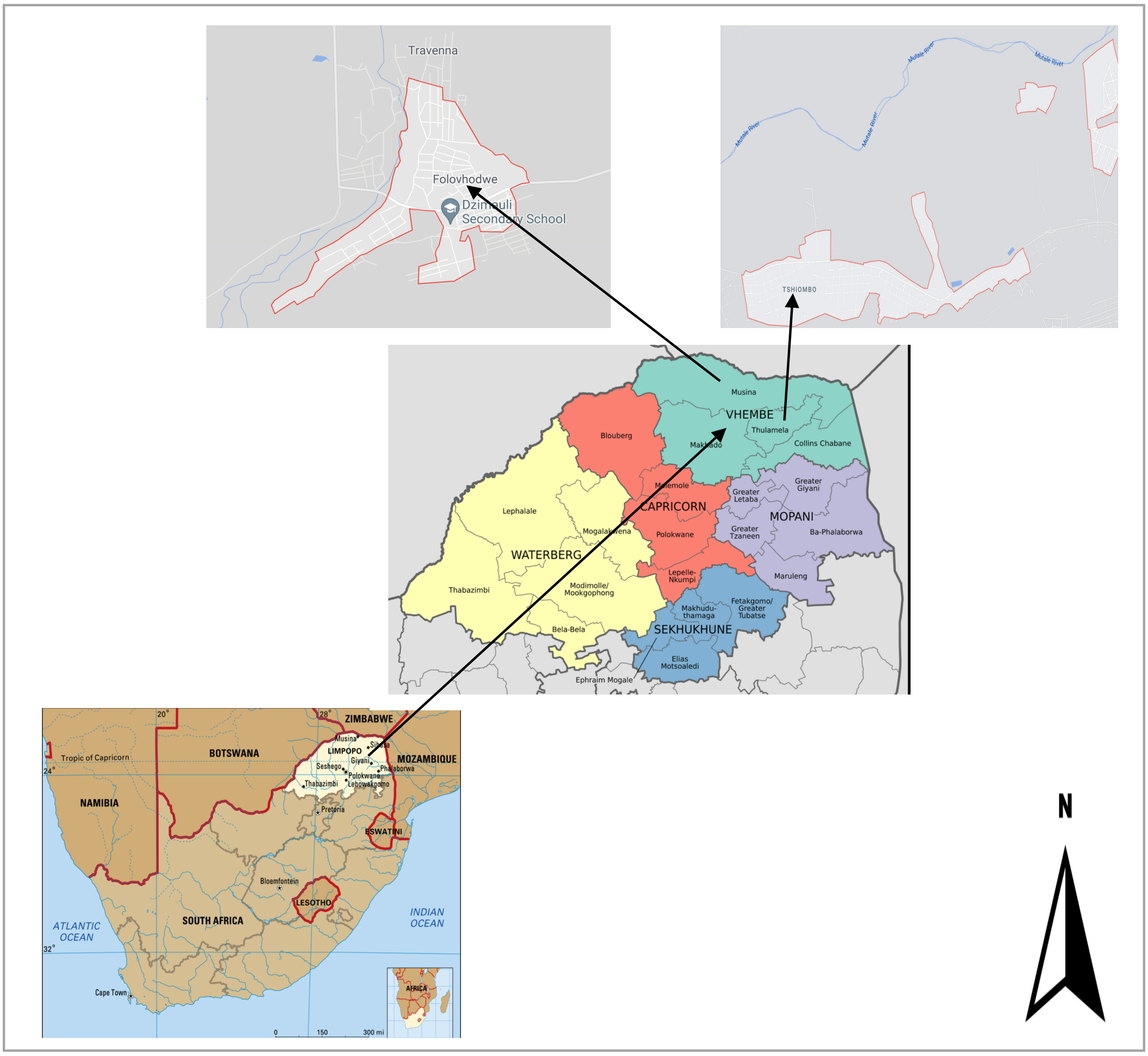

Figure 1: Research area.