Climate change and water use: Farmers' preferences for policy options

By

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1 Background

1.1 Introduction

Climate change leads to an increased risk of droughts (Elkouk, et al., 2022; Secci, et al., 2021; Grillakis, 2019), higher temperatures (Mwabumba, et al., 2022; He, et al., 2022), frequency of heatwaves (Ban, et al., 2022; Mukherjee, et al., 2022), and frequency of severe floods (Wang, et al., 2022; Yan, et al., 2022). Climate change has numerous negative consequences on the earth's natural climate cycles, and it makes future climate patterns more unpredictable(Mahato, 2014). The global community has realized the significant threat that it poses to human life, and has therefore been giving more attention to policy action on climate change for the past three decades. According to the Global Risk Report by the World Economic Forum (2019), the failure to respond to climate change effectively is one of the worst risks to the globe in terms of impact and likelihood.

In South Africa, climate change represents a serious threat to farmers (Chersich & Wright, 2019). Jury (2017) observed that the annual average temperature has increased by 0.68°C per year from 1980 to 2014; this is slightly more than the annual average global temperature increase over the past 50 years (0.65°C) (Ziervogel et al., 2014). It is also anticipated that the temperature is going to rise by at least 2°C per century and that there would be a 30% decline in rainfall before the end of this century in Southern Africa (Department of Environmental Affairs, 2017; Arora, 2019). Olabanji *et al.* (2021) identify three non-climatic factors which further aggravate pressure experienced by South African farmers, these include: "high production cost, insufficient arable land, poorly implemented policy initiatives and a lack of technical support." Challenges such as pollution, population growth, and land degradation also negatively affect the water resources of South Africa (McMullen, 2009(Du Plessis, 2017). Climate change further exacerbates the problem(Kusangaya *et al.*, 2014). Currently, available freshwater is already fully allocated, and demand for irrigation and city water is likely to increase(Cullis *et al.*, 2018). As these changes are likely to continue in the future (Ipcc, 2021), the South African economy is likely to be seriously affected. Effective water management becomes vitally important in South Africa, because of the small amount of annual rainfall and especially summer rainfall. It is thus of critical importance for farmers in South Africa to consider these climatic changes to adapt timely and apply mitigation and adaptation strategies (van der Bank & Karsten, 2020; Lawal, et al., 2019; Kusangaya, et al., 2013; Remilekun, et al., 2021).

There are various climate change adaptation and mitigation strategies with which the national community can respond to decrease the risk of all the pressures experienced by farmers (Simpson & Burpee, 2014; Hof, et al., 2009).

1.2 Problem statement

Climate change is posing a threat to water security in South Africa. To respond to these challenges, the SA Government has mobilized resources to develop possible scenarios of changes and adaptation strategies (Department of Environmental Affairs, 2013). The design of policies in an increasingly complex environment is, however, extremely difficult (Peters, 2018), especially for wicked problems such as climate change. "Wicked problems" are defined as social or policy issues that are often complex, difficult to define, and difficult to solve (Rittel, H. & Webber, 1973a). Ecosystems are complex, inherently unpredictable systems (De Fries & Nagendra, 2017; Levin, et al., 2012), and this makes it more difficult to predict the outcome of policy decisions.

The involvement of stakeholders in decision-making processes has the potential to result in more realistic and more effective policies (Sevaly, 2001; Kristjanson, et al., 2009; Dale & Armitage, 2011), and this is especially valuable where levels of complexity and uncertainty are high (Berkes, et al., 2003; Bizikova, et al., 2014). The involvement of stakeholders is critically important in the design of solutions for wicked environmental problems. A good understanding of different stakeholder perspectives can reduce the wickedness of a problem (Head & Xiang, 2016; Rissman & Carpenter, 2015).

Several studies have been conducted to understand farmer perceptions of climate pattern changes and their adaptation strategies (e.g., Archer *et al.*, 2020; Elum *et al.*, 2017; Olabanji *et al.*, 2021b; Rankoana, 2019; Wiid & Ziervogel, 2012), or to analyze the potential effects of climate change on agricultural systems (e.g., Blignaut *et al.*, 2009; Tibesigwa *et al.*, 2017). However, since such studies mostly concentrate on farmer perceptions or their current adaptation strategies, there is a gap in the analysis of stakeholder preferences for public policies that would favor the adaptation of their farming systems. This study is designed to fill this gap.

Information about farmers preferences for different policy options is vitally important in the policy design process to ensure that policies can be implemented and optimize compliance. Thus, on the one hand, this research will provide the foundation to communicate essential information to policymakers that will strengthen their position to influence policy. On the other hand, it will provide clear insights to policymakers on policy options that will provide the most optimal outcomes to achieve the government's goals.

Consequently, this study was designed to elicit stakeholder preferences for public policies that would favour the adaptation of their farming systems based on policy directives (options) contained in the National Water Act (1998). The National Water Act was specifically selected because it is the foundational policy document that all other water policies are based on.

1.3 Research objectives

The main purpose of the research is to study farmers' preferences for public policy measures that would favour the adaptation of their farming systems, by asking them to compare different policy options and ranking them in terms of strength of preference.

The three sub-objectives of the study were:

1. to identify the public policies that are deemed relevant to solve the issue of water management by the agricultural sector under different climatic scenarios;
2. to identify farmers' preferences for these different policies;
3. to characterize the diversity of these preferences.

1.4 Scope

This study will be limited to the Breede Valley in the Province of Western Cape. There is insightful knowledge that can be gathered from the Breede Valley's farmers' first-hand experience that can be used for better policy design (Wiid & Ziervogel, 2012). By analysing different farmers' perceptions of how the water policies are being experienced on the ground/farm-level, stronger resilience could be built against the impacts of climate change (Olabanji *et al.*, 2021a); by grounding the policies in local realities (Wiid & Ziervogel, 2012).

2 Methodology

2.1 Description of the study area

Knowledge about the context of the study area is essential for identifying relevant policies for the survey. Farmers' preferences for policy implementation will be formed by their context. There must be an understanding of the area in which the policy will be applied for the policy to be designed effectively(Peters, 2018). The success of a policy then is highly dependent on how well it fits into the context of the area in which it is applied. This section will aim to give the context of the Breede Valley area.

2.1.1 Climate, rainfall, and water availability

The Breede Valley d,erives its name from the Breede River that flows through the area. The river originates near Ceres at the Skurweberg mountains, after which it flows Southeast through Worcester towards the east coast of South Africa (Flemming & Martin , 2021; Raath, 2015). The Breede Valley lies within a Mediterranean climate zone (Roberts *et al*., 2001) and receives a combination of winter and summer rainfall (Brown *et al*. 2004), most of its water is, however, received in the months of April through to September (Steynor et al., 2009;(Lakhraj-Govender & Grab, 2019) The northern areas of the river receive significantly more rainfall than further downstream (near Robertson and Worcester) (RHP 2011).

Effective water management becomes vitally important in the Breede Valley area, because of the small amount of annual rainfall and especially summer rainfall. The area is already classified as a water scarce area and the demand for water is increasing(Cullis *et al.*, 2018). Robertson, a drier area in the Breede Valley, experiences a mean annual rainfall of 290 mm (Hunter & Bonnardot 2011); compared to the global annual average of 1000 mm(Lamb *et al.*, 2021). The Breede Valley also experiences frequent flooding; there were twelve large floods between 2003 and 2008 alone, and during each year frequent smaller flood events occur during the winter months (Holloway et al. 2010).

2.1.2 Pollution in river

Due to the intensification of agriculture in the Breede Valley area more pesticides and fertilizers have been introduced into the river through runoff, spills, spray or vapour (RHP, 2011). The increase of nutrients in the river causes toxic algal blooms, water anoxia (Weigelhofer et al., 2018), and an increased salinity (Department of Water Affairs and Forestry, 2003). The Department of Water Affairs and Forestry (2003) found that yields in the Breede Valley decreased at a rate of 3% per 10 mS/m salinity increase in irrigation water.

Increase of invasive species in river has reduced water yield significantly (Breede River environment plan)

2.1.3 Population

The Breede Valley grew from a population of 174,198 in 2015 to 193,104 in 2020 (Western Cape Government , 2015; Western Cape Government , 2020), this is a growth rate of 2.2% per annum, somewhat higher than South Africa's annual population growth of 1.4% over the same period(O'neill, 2022). The growing rate of urbanization in the Breede Valley is a concern because it causes declining water quality due to the limited financial resources and technical capabilities to adequately maintain and upgrade wastewater treatment works(Cullis *et al.*, 2018).

There is much potential for further expansions in the Breede Valley, but water is a limiting factor. This has led to many disputes between different farmers in the area about water (du Toit, 2022). This tension mostly has to do with unethical withdrawal of water which leads to decreased stream flow for farmers further down the river. This creates a need for government assistance in the area.

2.1.4 Water governance in the Breede Valley

In South Africa the highest authority of water management is the Department of Water and Sanitation (DWS), followed by the Catchment Management Agencies (CMA), and then the Water User Associations (WUA) / Irrigation Boards (IB). One of the main purposes of the NWA of 1998 was to create more equality in the country (Ncube, 2014). The NWA of 1998 stated that all IBs must be reconstructed to WUAs within 6 months; there are, however, still many IBs. Thus, WUAs and IBs will be used interchangeably in this study as they still serve the same water management function in the Breede Valley.

In the Breede Valley there are 30 WUAs/ IBs. The purpose of the WUAs is to create cooperation between individual water users on a localized level, for the mutual benefit of the individual parties (Ncube, 2014). The Breede Valley area falls under the government of the Breede-Gouritz Catchment Management Agency (BGCMA), a government institution established in 2004. The BGCMA's purpose is to transfer water resource management responsibilities to the regional or catchment level(Ncube, 2014). The irrigation boards were established under the old South African water law, and still operates under the water Act no. 54 of 1956 (Section 71). With the implementation of the new water law, Act 36 of 1998, the government required the irrigation boards be reconstructed into water user associations within 6 months of the commencement of the Act.

Figure 1: Map of study area (source: SA Venue)

The different areas that were included in the study:

- Overhex
- Nuy
- Slanghoek
- Robertson
- Scherpenheuwel
- De Doorns

The different WUAs / IBs that were included in the study:

- Jan du Toit (IB)
- Moordkuil (IB)
- Moddergat (IB)
- Olifantsberg (IB)
- Smalblaar (IB)
- Stettyn (IB)

- Doornrivier (IB)
- Bo-Doorns (IB)
- Grooteiland-klipdrift (IB)
- Bossieveld (IB)
- Brandwacht (IB)
- Holsloot (WUA)
- Worcester East (WUA)

2.2 Construction of the survey instrument

A questionnaire was developed and distributed to 100 farmers in the study area. The policy measures were selected from concepts of the National Water Act of 1998. The farmers' preferences are specifically relevant to the study area, and a good understanding of the context of the study area was therefore needed in order to design a questionnaire that is relevant for the study area.

The first step in the development of the questionnaire was discussions with stakeholders, in order to have a better understanding of the context of the study area. These stakeholders' were identified by making use of the Prospex CQI method (Gramberger *et al.*, 2014). Various levels of power interact with each other in the South African hierarchy of water management. The National Water Act provides for a balance of responsibilities, ranging from the Minister and Director General at the national level, to Catchment Management Agencies (CMAs) at the basin level and Water User Associations at a sub-basin level. Stakeholders from each of these levels were contacted to assist with the development of the questionnaire. The stakeholders that were involved in these discussions include members of: Western Cape Department of Agriculture, South African Association for Water Use Associations, Agri Western Cape, the BGCMA, the Hex-river Irrigation Board, and the Robertson Water User Association. The information gathered through the discussions were used to identify certain problems in the area.

The second step was a comprehensive study of the NWA of 1998 to identify policy measures that can be implemented in the area. The NWA of 1998 was chosen as the best document to draw the policy measures from as it is the foundational Act that all other water related national, provincial, and municipal policies are based on. After the commencement of Act 36 of 1998, many policies and programmes were introduced by the Government with the aim of promoting water management. Adom & Simatele (2021) argues that these policies are now "outdated, compartmentalized, complex, and lack robust water governance." In this regard, the NWA was used to formulate policy measures that are timely and relevant for the specific study area.

The third step was the selection of a relevant and feasible method to rank potential policies. Stated preference (SP) methods can be used to measure people's preferences for goods, services, or policies and their characteristics (e.g., Hensher *et al.*, 2015). The relevance of these methods have been broadly discussed, but the methods are now in wide use (Johnston *et al.*, 2017). Among the different SP methods, we found the Best-Worst Scaling (BWS) approach (Louviere, Jordan J *et al.*, 2015) as the most appropriate. BWS requires survey respondents to select their most preferred and least preferred options from a constructed choice sets and deduct people's preferences from these stated choices. BWS is categorized into three types: Case 1 (object case), Case 2 (profile case), and Case 3 (multi-profile case). The object case, subsequently OBWS, corresponds to studies where the items being ranked, called objects but in our case we would call policy are not described by attributes that vary (Louviere, Jordan J *et al.*, 2015). The purpose of the OBWS is to rank each item on a latent subjective scale. In contrast, with the profile case, subsequently PBWS, the policies are described by a common set of attributes and levels and the descriptions are called profiles. The profiles are presented to respondents one at a time and respondents choose, respectively, the best and worst attribute levels in each profile. In other words, participants do not make holistic profile choices, i.e., they do not have to choose between different profiles, but for a given profile, have to designate the features that they prefer most or least. Finally, the multi-profile case, or MPBWS, corresponds to a survey were respondents have to compare several profiles and state which profiles they would consider as best and worst. In that sense the MPBWS is similar to a Discrete Choice Experiments (DCEs) during which respondents only choose their best option. After considering the different BWS approaches, we opted for a PBWS approach. First, we considered s an easier task for participants to evaluate only one profile at a time instead of choosing among two or more profiles. Second, PBWS also allow to evaluate preferences for large thematic areas (which will be considered as attributes), and some specific aspects of the policies (which will be considered as levels for this particular attribute). In other words, we will be able to consider what thematic areas are considered most/least important as well as ranking more specific policy statements. Third, it was also shown that PBWS allowed to estimate attribute impact and to estimate all levels for all attributes on a common scale (Louviere, Jordan J *et al.*, 2015).

Based on the selection of the PWBS approach to evaluate farmers's preferences, the fourth step was to select a limited number of policy measures to be evaluated by farmers. We had to limit the numbers of measures to evaluated is to reduce the possible cognitive burden on farmers interviewed. Based on initial discussions with selected experts and farmers, we selected four thematic areas in which policy and governance could affect farmers and their capacity to adapt to climate change: management of water infrastructures, institutional arrangements, regulation of extractions and management of water pollution. Within each thematic area, three policy statements were adapted from statements found in the NWA document. The twelve statements are presented in Table 1.

Table 1 : Policy statements selected for ranking. The statements are structured into four thematic areas: infrastructures, institutions, extraction and pollution

Policy group	Policy statement
Institutions	The BGCMA should be responsible for irrigation water allocation across its farmers.
	Each water user association (WUA) should be responsible for irrigation water allocation across its farmers.
	Ensure efficient and transparent governance systems between the different tiers of regulatory and management activities.
Pollution	BGCMA must engage in clean-up activities in the event of pollution.
	Technical assistance/information for on farm pollution.
	Enforce penalties on farmers that engage in activities potentially leading to water pollution.
Extractions	Introduce financial support mechanisms (e.g., some form of subsidy) to invest in water saving technologies.
	Technical assistance/information for on farm extraction activities.
	Enforce penalties on farmers that extract more water than allocated or does not have a functional water metering system.
Infrastructure	Ensure appropriate and timely infrastructure development and maintenance that keeps up with the needs of water users.
	Maintain water available to agriculture to its current levels.
	Increase water available to agriculture by building more dams.

In the fifth step, we built the profiles to be presented to farmers using the methodology described in Aizaki and Fogarty (2019) and summarized in **Error! Reference source not found.**.

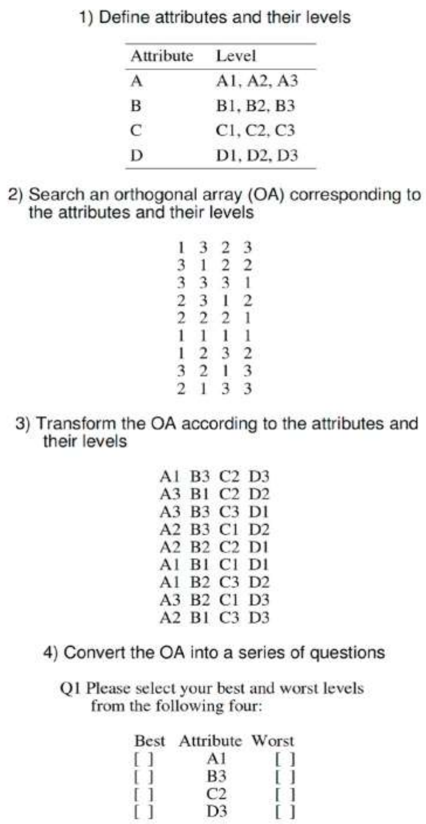

Figure 2 : An example of construction of a PBWS profile (source : Aizaki and Fogarty (2019))

The profiles had four thematic areas (attributes), and each thematic areas had 3 statements (levels). We selected a 3^4 orthogonal array to construct the profiles using the R package DoE.base (Grömping, 2018) and then used the package support.BWS2 (Aizaki & Fogarty, 2019). As a result, we created nine profiles to be evaluated. An example of profile is presented in Table 2.

The respondents had to choose one of the four as the most effective policy measure, and one as the least effective policy measure. It was optional for the respondent to provide reasons for their answers, but they were only required to choose the already identified policy options that they most/least preferred. The respondent was then also asked if he/she would promote the policy option that he selected as the most effective to help farmers adapting to climate change and water scarcity issues.

Table 2 : An example of profile

Most		Least
[ ]	The BGCMA should be responsible for irrigation water allocation across its farmers	[ ]
[ ]	Enforce penalties on farmers that engage in activities potentially leading to water-polluting	[ ]
[ ]	Technical assistance/information for on farm extraction activities	[ ]
[ ]	Ensure appropriate and timely infrastructure development and maintenance that keeps up with the needs of water users	[ ]

Each participant of the survey received the following:

- A consent form that must be signed by the participant
- An introduction letter that gives background to the study
- A section that explains how the questionnaire must be answered and the questionnaire
- A section to fill in demographic information
- An e-mail address / address to return the questionnaire

The full questionnaire is presented in Annex.

2.3 Sampling

Probability sampling gives an equal chance of inclusion to all known units of a population. Non-probability sampling is where this mechanism of probability sampling is absent, and participants are chosen based on subjective methods (Vehovar, et al., 2016; Etikan, et al., 2015). Probability sampling is the best way of doing sampling(Vehovar *et al.*, 2016), but there are more time and higher costs involved, as well as a lower response rate with this method(Yang & Banamah, 2013).

Non-probability sampling is not an “acceptable alternative” to probability sampling, but probability sampling has no advantage when the response rate is low (Yang & Banamah, 2013). Etikan, et al. (2015) identifies three reasons why a researcher would consider using non-probability sampling methods: “there may not be greatgr concern in drawing inferences from the sample to the population, it is cheaper than probability sampling, and can often be implemented more quickly.”

Due to limitations of time and financial budget this study will make use of non-probability sampling. A disadvantage of non-probability sampling is that it could possibly be a bad representative of the population. However, in this study this is not likely to be the case. Farmers with different farm sizes, with different farming commodities, of different ages, and different education levels is included.

The non-probability methods that were used are quota and purposive sampling methods.

The sampling frame of the study consists of all of the members of the different Water User Associations (WUAs) and Irrigation Boards (IBs). Contact details of the different WUAs and IBs have been provided by the Breede-Gouritz Catchment Management Agency (BGCMA). Farmers from the different WUAs and IBs. Budget limitations and time allowed for 100 questionnaires to be given to farmers. The budget and time limitations resulted in the choice to do convenience sampling. Farmers in the Breede Valley that was the closest travelling area were identified and contacted.

2.4 Analysis of the responses

Aizaki and Fogarty (2019) described two complementary approaches to analyze the responses: the counting approach and the modeling approach.

2.4.1 The counting approach

The counting approach calculates the scores B_{in} based on the number of times the level i was selected as the most effective and W_{in} the number of times the level i was identified as the least effective among all the questions for respondent n. Then a best-minus-worst (BW) score is defined as: $BW_{in} = B_{in} - W_{in}$. Finally, the standardized BW score is defined as $std.BW_{in} = \frac{BW_{in}}{f_i}$, where

f_i is the frequency with which level i appears across all questions. These scores reveal respondents' preferences for levels.

The cluster analysis approach is an extension of the counting approach as it uses the individual scores computed in the counting approach. We conducted a principal component analysis of the individual scores for the twelve policy statements. Then, we used the PCA coordinates of the policies on the first 4 dimensions to run a hierarchical cluster analysis. To characterize the groups obtained and their specific preferences, we calculated the mean of the standardized scores for each cluster.

2.4.2 The modeling approach

The theoretical framework of the modeling approach is based upon random utility theory (RUT) (Marley, A. A. & Louviere, 2005; Mcfadden, 1973, 1974) and the Lancasterian consumer theory (Lancaster, 1966). In accordance with these theories, we assume that the utility $U_{n,i}$ of individual *n,* when choosing alternative *i,* can be represented as a linear function of its attribute:

$$U_{n,i} = \beta . X_{n,i} + \varepsilon_{n,i} = v_{n,i} + \varepsilon_{n,i} \qquad (1)$$

where $X_{n,i}$ is a vector of observed attributes related to the alternative *i* presented to individual *n,* β is a vector of preference parameters which explain choices, and $\varepsilon_{n,i}$ is an error term to account for possible choice errors and unobserved influences.

In the case of PWBS, the alternatives are the four families of policies, i.e., institution, pollution, extraction, infrastructure, and the levels are the different policy statements attached to each family as presented in Table 1. If we consider a person who chose its most efficient policy choice, and if the unobserved term $\varepsilon_{n,i}$ is assumed to be independent and identically distributed extreme value variates, it can be shown that the probability of making this choice is (Louviere, J. J. *et al.*, 2000):

$$Prob(most_n = i) = \frac{exp\ (\mu.\beta.X_{n,i})}{\sum_{p \subset A} exp\ (\mu.\beta.X_{n,p})} \qquad (2)$$

where A is the set of policy options presented and μ is the scale factor for a particular data set. Because μ cannot be identified, for standard applications, this scale is often arbitrarily fixed to one (Louviere, J. J. *et al.*, 2000; Swait & Louviere, 1993).

Since respondents were asked to state their most efficient and least efficient policies, we can incorporate two choices for each person, *i.e.*, the choice of the most efficient policy and the choice of the least efficient one. At this stage, we had to make an assumption about how respondents made these two choices. For PBWS choices, there are three possible models: paired, marginal, and marginal sequential (Aizaki & Fogarty, 2019; Louviere, Jordan J *et al.*, 2015). The paired model assumes that the difference in utility between the two levels represents the greatest utility difference among all k × (k - 1) = 4 × 3 = 12 utility differences. In our case, if a respondent selects IF1 as the best level and E2 as the worst, the paired model assumes that the respondent calculates twelve utility differences as per the twelve possible pairs, and that the difference in utility between IF1 and E2 is the maximum difference across all twelve utility differences. The marginal model assumes that the utility for policy statement *i* provides the maximum utility among the four statements and that policy statement j provides the minimum utility among the same four statements. In our case, if a respondent selects IF1 as the best level and E2 as the worst from the four levels (IF1, E2, P2, and I3) it means that the utility for IF1 is the maximum among the four utilities (IF1, E2, P2, and I3), and the utility for E2 is the minimum among the same four. The marginal sequential model assumes that the utility for level i provides the maximum utility among the 4 policy statements, and that policy statement j provides the minimum utility among the remaining 4 – 1 = 3 levels, i.e., the respondent first considers the best option among four, and then considers the worst option among the remaining three options. So, in our case, assuming the best is chosen before the worse, the marginal sequential model assumes, there are four possible best levels and three possible worst levels in the profile. Following our example, if a respondent selects IF1 as the best level and E2 as the worst from the four levels (IF1, E2, P2, and I3), it means that the utility for IF1 is the maximum among the four utilities (IF1, E2, P2, and I3), and the utility for E2 is the minimum among the three remaining policies (E2, P2, and I3).

In our case, we made the reasonable hypothesis that farmers chose first the most efficient policies and then selected the least efficient policies from the remaining three policies. As a consequence, we used a marginal sequential model. With the sequential marginal model, the probability of getting the best worst pair (i, j) is calculated as (Aizaki & Fogarty, 2019; Louviere, Jordan J *et al.*, 2015):

$$Prob(\mathrm{most_n} = i, \mathrm{least}_n = j) = \frac{\exp\,(\mu_m.\beta.X_{n,i})}{\sum_{p\subset A}\exp\,(\mu_m.\beta.X_{n,p})} \times \frac{\exp\,(-\mu_l.\beta.X_{n,i})}{\sum_{q\subset A-i}\exp\,(\mu_l.\beta.X_{n,i})} \quad (3)$$

Where $A - i$ represents the set of remaining alternatives after i was chosen as the most efficient policy, and μ_m and μ_l are the scales associated with the utilities of respectively the most and the least efficient policies. When compared to the model 8 developed in Aizaki and Fogarty (2019), we have added the hypothesis that respondents would have different level of difficulties in selecting the most efficient and the least efficient policies. This is materialized by the estimated parameters μ_m and μ_l. In fact, it can be shown that the response variance for best or worst choices are inversely related to the scale parameter μ. As a consequence, the parameter μ can be interpreted as measures of the lack of certainty of respondents when making choices (Swait & Louviere, 1993). For the analysis, the attribute variables were effect-coded with the pollution attribute selected as the base attribute. The level variables were also effect-coded, and the first level in each attribute was chosen as the base level.

The parameters related to pollution, extraction, infrastructure and institutions will be interpreted as the relative preference for the thematic areas, independently the specific policy statements in that thematic. This is an important information as policymakers may be interested in comparing the absolute impact of family of policy. An example would be testing the hypothesis that "changing institution is seen as more efficient than changing infrastructure" — a statement purely about policy family, with no reference to the specific policy considered (the levels). PBWS are specifically adapted to answer this type of answer since we are asking to compare alternative within one single profile. As a result, the reference case is a single attribute level, not an entire scenario. By estimating all of an attribute's levels on the same scale, it allows the researcher to estimate the average utility for each attribute across all its levels — in the literature, this is defined as attribute impact[1] (Flynn *et al.*, 2007). Because of the effect coding, the attribute impacts are estimated as deviations to the global mean. We cannot estimate the absolute impact of each attribute but, a particular interesting point of the PBWS formulation, is that they are built on the same scale and are directly comparable (Louviere, Jordan J *et al.*, 2015).

The model developed in Equation (3) can be considered as an extension of the conditional logit to the PBWS case. It provides some population preference coefficients about the different policies, but does not allow for the analysis of the heterogeneity of these preferences in the population.

To analyze this heterogeneity, we developed a latent class logit model adapted to PBWS. The latent class models are also based upon a utility-based theoretical framework (Marley, A. A. & Louviere, 2005). With a standard latent class model, we can assign each individuals a probability of belonging to one of the C classes of homogenous preferences. It uses two sub-models to calculate the probability that an individual will choose a specific alternative. The first sub-model estimates the probability that each individual will belong to classes, while the second sub-model estimates the class probabilities of choosing one alternative conditional on the preference parameters of each class. The probability of observing the respondent classifying the statement *i* as most efficient policy, and the statement j as the least efficient policy forms the basis for the construction of the likelihood function of the model to be estimated:

$$Pr(most_n = i, least_n = j) = \sum_{c=1}^{C} Pr(most_n = i,\ least_n = j | n \in c) \times Pr(n \in c) \qquad (4)$$

The probability π_c that respondent *n* belongs to class *c* is represented by a multinomial logit:

$$\Pr(n \in c) = \pi_c = \frac{exp(\theta_c' . Z_n)}{\sum_{c'=1}^{C} exp\,(\theta_{c'}' . Z_n)}; \quad c = 1, \ldots, C \qquad (5)$$

[1] Note that the attribute impact is not equal to "attribute importance" or "attribute weight". Although the weight of an attribute would be interesting to capture, it is usually impossible to disentangle these weights from the preference scale (Marley, A. a. J. *et al.*, 2008).

where Z_n is a vector of observable characteristics of individuals related to class membership, and θ_c is a vector of parameters to be estimated representing the effects of the characteristics of the probability to belong to the class c (Greene & Hensher, 2003).

For each class, the utility of a policy instrument can be represented by:

$$U_{n,i|\, n\in C} = \beta_c . X_{n,i} + \varepsilon_{ni} \tag{6}$$

As a consequence, the probability that an individual *n* belonging to a specific class $c \in \{1, \dots, C\}$ will choose one statement i as the most efficient can be written as (Greene & Hensher, 2003):

$$Pr(most_n = i \mid n \in c) = \frac{exp\,(\mu_c\, \beta_c\, X_{n,i})}{\sum_{p\subset A} exp\,(\mu_c\, \beta_c . X_{n,p})} \tag{7}$$

where β_c is a vector of utility parameters, and μ_c the scale parameter specific to class *c*.

When considering both the most and least efficient choices, equation 7 should be adapted to consider both choices:

$$Pr(most_n = i,\ worst_n = j \mid n \in c) = \frac{exp\,(\mu_{m,c}\, \beta_c\, X_{n,i})}{\sum_{p\subset A} exp\,(\mu_{m,c}\, \beta_c . X_{n,p})} \times \frac{exp\,(\mu_{l,c}\, \beta_c\, X_{n,j})}{\sum_{p\subset A-i} exp\,(\mu_{l,c}\, \beta_c . X_{n,p})} \tag{8}$$

For the purpose of identification, the parameters $\mu_{m,c}$ are fixed to one, so only the parameter $\mu_{l,c}$ are estimated.

If we gather the two sub-models (equations 5 and 8), we can build up the likelihood function using equation 4:

$$Pr(most_n = i,\ worst_n = j \mid n \in c) = \sum_c \left[\frac{exp(\theta_c' . Z_n)}{\sum_{c'=1}^{C} exp\,(\theta_{c'}' . Z_n)} \left\{\frac{exp\,(\mu_{m,c}\, \beta_c\, X_{n,i})}{\sum_{p\subset A} exp\,(\mu_{m,c}\, \beta_c . X_{n,p})} \times \frac{exp\,(\mu_{l,c}\, \beta_c\, X_{n,j})}{\sum_{p\subset A-i} exp\,(\mu_{l,c}\, \beta_c . X_{n,p})}\right\}\right] \tag{9}$$

Finally, the latent class approach does not allow to simultaneously choose the number of classes and the preference parameters. As suggested in the literature, we ran models with varying numbers of preference classes from two to four. Standard procedures (Log Likelihood, plausibility and significance of classes) and information criteria scores (AIC and BIC) were used to select the optimal number of classes within the data.

Overall, this formulation allows us to identify homogenous classes of preferences (i.e., the farmers that have identical preferences about policy instruments), and to study the socio-economic factors that influence the probability to belong to each class. As such, this should be considered to the cluster approach presented in the counting approach.

On the technical part, we estimated the BWS-adapted conditional logit and latent class models using the R package Apollo (Hess & Palma, 2019). Because of non-linearity for the latent class model, we ran the model with 100 different starting points using algorithms that have been proposed in the literature to dynamically eliminate unpromising candidates and included in the Apollo package (function apollo_searchStart).

3 Results and Discussion

3.1 Sociodemographic characteristics of respondents

	Total
Gender:	
Male	98
Female	2
Age:	
18-25	6
26-35	14
36-45	19
46-55	20
56-65	21
65+	17
Education:	
Primary School	0
High School	25
Diploma	42
Degree	21
Post graduate degree	8
Size of Farm under irrigation	
0-50	14
51-100	29
101-150	20
151-200	19
201-250	3
251-300	3
301-350	0
351-400	3
401-450	0
450-500	3
501-550	4
551-600	1
Number of permanent farm workers:	
0-20	36
21-40	35
41-60	14
61-80	8
81-100	2
101-120	0
121-140	3
141-160	1
Number of seasonal farm workers:	
0-20	27
21-40	13
41-60	9
61-80	31

81-100	9
101-120	4
121+	1
Main decision maker?	
Yes	93
No	6

3.2 The counting approach

The aggregate preferences for the thematic areas (the attributes) that were considered as most effective to help farmers adapt are presented in Table 3. The distribution of these scores across the sample are shown in Figure 3.

Table 3 : Aggregate preferences for the thematic areas

Thematic area	Most effective	Least Effective	BW	Std.BW
Infrastructure	484	100	384	0.43
Institutions	230	163	67	0.07
Extraction	143	252	-109	-0.12
Pollution	43	385	-342	-0.38

The results suggest a strong preference for policies that addressed issues related to the management of water infrastructures and to a much lesser extent to the institutions. The management of extraction and pollution are seen as the least effective instruments.

The distribution of the scores across the sample suggest a relative consensus for the infrastructure as being the most effective and pollution as the least effective. In contrast, the histogram suggests more divided opinion regarding the effectiveness of institutions and extraction measures.

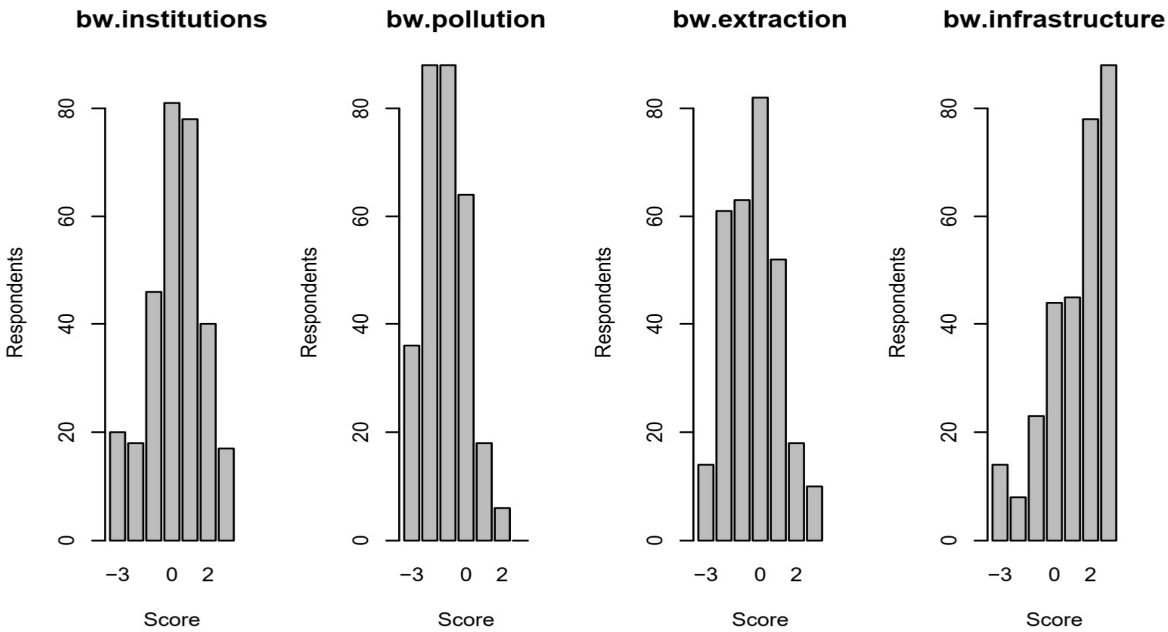

Figure 3: Histograms of the scores for the four thematic areas

The aggregate preferences for the policy statements (the levels) that were considered as most or least effective to help farmers adapt are presented in Table 4. The distribution of these scores across the sample are shown in Figure 4.

Table 4 : Aggregate preferences for the policy statements

Policy statement	B	W	BW	Std.BW
Ensure appropriate and timely infrastructure development and maintenance that keeps up with the needs of water users	191	10	181	0.60
Increase water available to agriculture by building more dams	202	28	174	0.58
Each Water User Associations (WUA) should be responsible for irrigation water allocation across its farmers	108	25	83	0.28
Maintain the water available to agriculture to its current levels	91	62	29	0.10
Introduce financial support mechanisms (e.g., some form of subsidy) to invest in water saving technologies	79	56	23	0.08
Ensure efficient and transparent governance systems between the different tiers of regulatory …	72	63	9	0.03
Enforce penalties on farmers that extract more water than allocated or does not have a functional water metering system	49	71	-22	-0.07
The BGCMA should be responsible for irrigation water allocation across its farmers	50	75	-25	-0.08
BGCMA must engage in clean-up activities in the event of pollution	16	105	-89	-0.30
Enforce penalties on farmers that engage in activities potentially leading to water-polluting	17	117	-100	-0.33
Technical assistance/information for on farm extraction activities	15	125	-110	-0.37
Technical assistance/information for on farm pollution	10	163	-153	-0.51

The results also suggest a strong preference for policies related infrastructure management. The farmers are strongly in favour of supply-side types of policies, with the two highest scores given to and the timely development and maintenance of infrastructures, and the the increase of water available to agriculture. In that respect, the simple maintenance of current levels of water available to agriculture is seen as much less effective (standardized score of 0.1 vs. 0.58 for an increase of water available).

In terms of water allocation and institutions, farmers favoured more policy in which allocation of water among farmers is done by the WUAs much more than an allocation done at the level of the BGCMA.

For the management of extractions and pollutions of water resources, farmers were more in favour of “carrot” type of policies, e.g., introducing financial support mechanisms to invest in water saving technologies, than “stick” type of policies, e.g., penalties for farmers extracting more than their allocation, or farmers polluting. However, except for penalties for polluting activities, both carrot and stick instruments regarding the use of water were situated in the middle range indicating a relative neutrality about their effectiveness (not the most effective not the least effective either…).

Finally, the measures perceived as the least effective were the provision of technical assistance or information on how to reduce pollution or control their extracting activities. It suggests that farmers are not lacking information or skills about technologies.

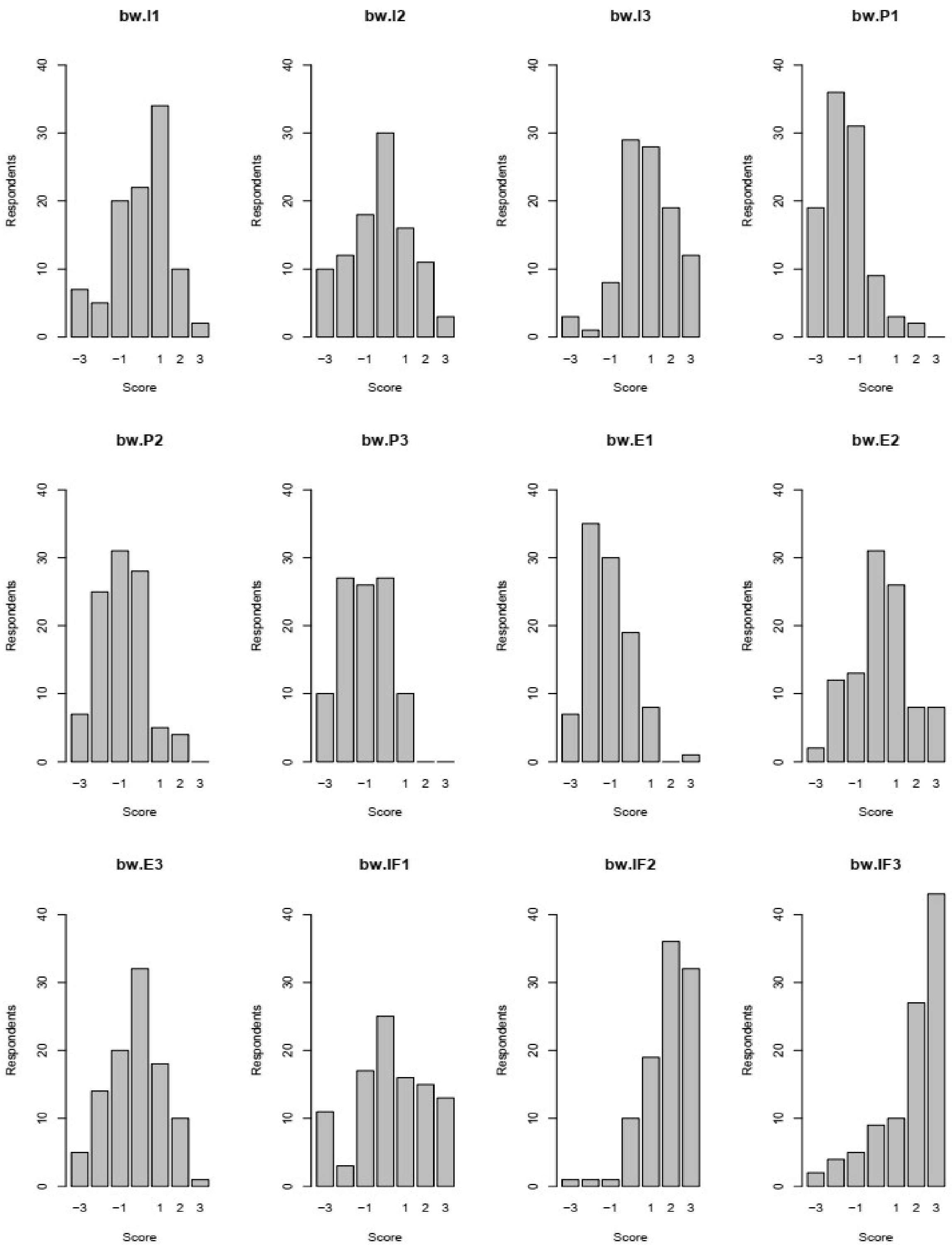

Figure 4 : Histograms of the scores for the 12 policy statements

The distribution of the scores across the sample also suggest that some of the policy statements are consensual (such as IF2 and IF3), while some others divide the population between farmers who perceive it as effective and those who perceive as ineffective (e.g., IF1: The BGCMA should be responsible for irrigation water allocation across its farmers or E2: Technical assistance/information for on farm extraction activities).

3.3 The cluster analysis approach

The results of a principal component analysis of the standardized scores for the levels is presented in Figure 5 and Figure 6.

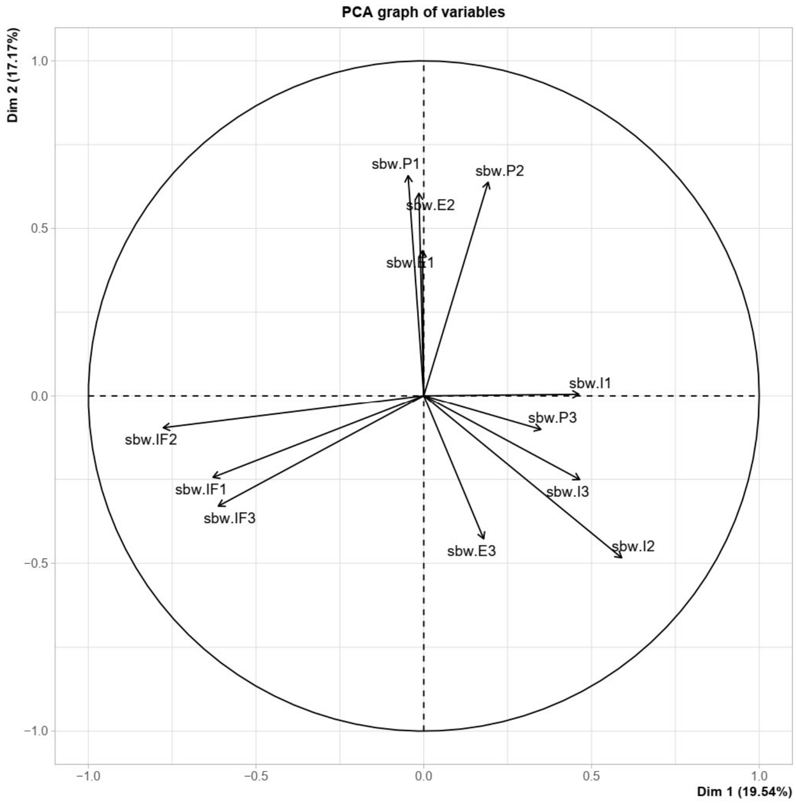

Figure 5: Principal Components of the standardized scores for levels (Dimension 1 x Dimension 2)

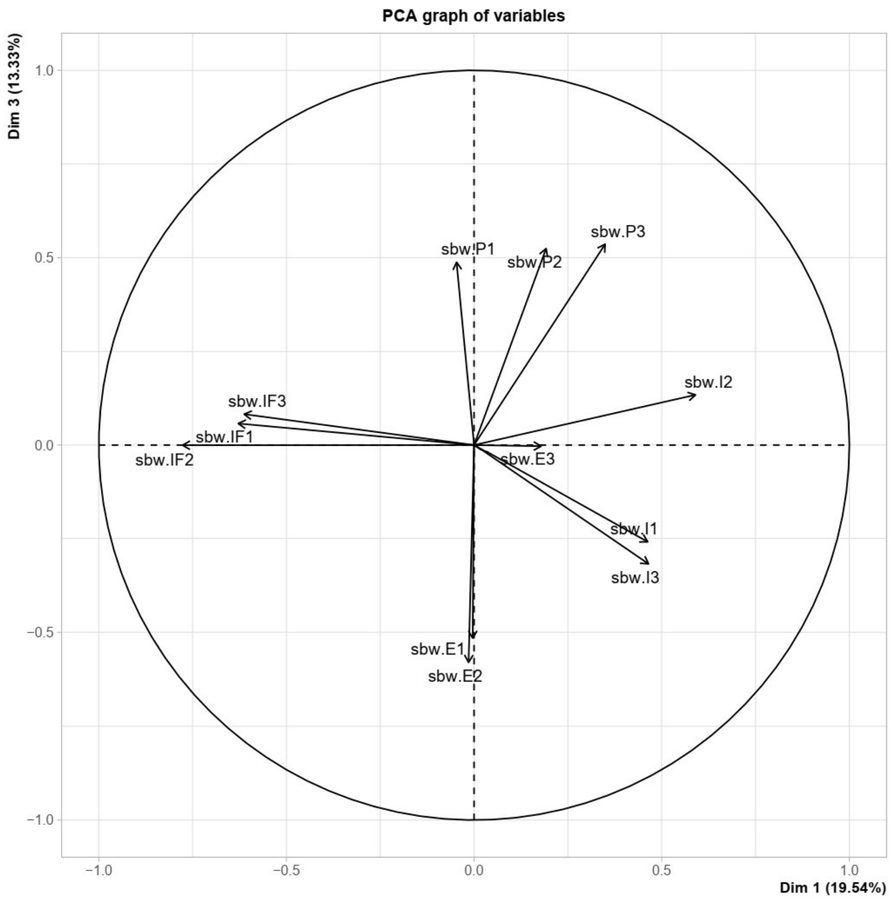

Figure 6 : Principal Components of the standardized scores for levels (Dimension 1 x Dimension 3)

The two graphs suggest the presence of different views regarding the best policy instruments. The axis 1 of the PCA opposes Infrastructure (IF1, IF2, IF3) to Institutions (I1, I2, I3), while the axis 3, opposes Extraction to Pollution instruments. Altogether, these three axes represented 50% of the variance contained in the data.

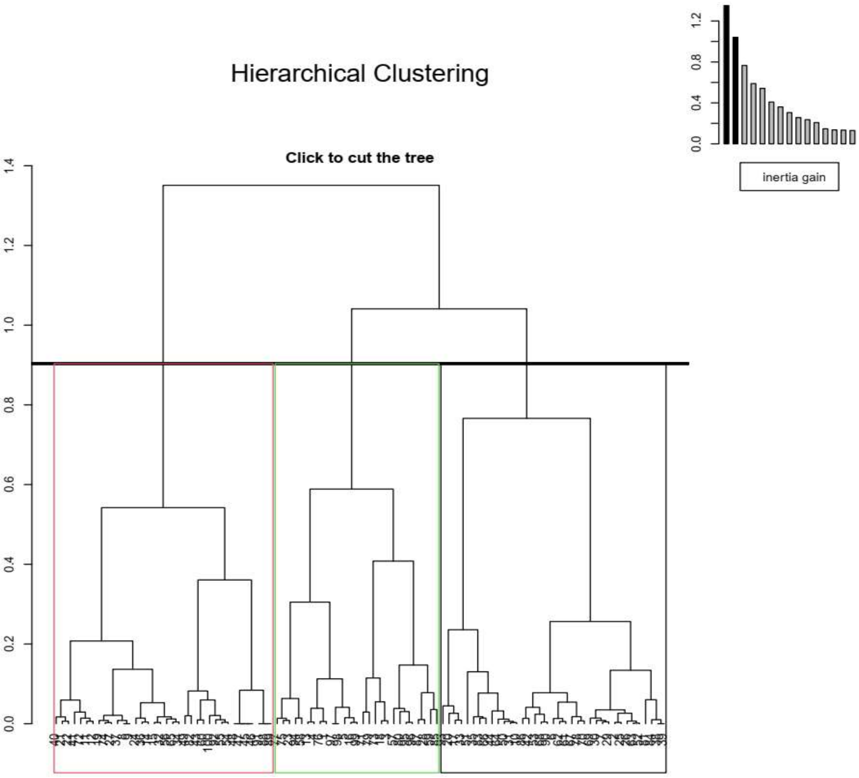

Figure 7 : Hierarchical tree of the hierarchical cluster analysis

The results of a hierarchical cluster analysis suggest the presence of three distinct clusters (Figure 7). Their representation into the factorial space is shown in Figure 8.

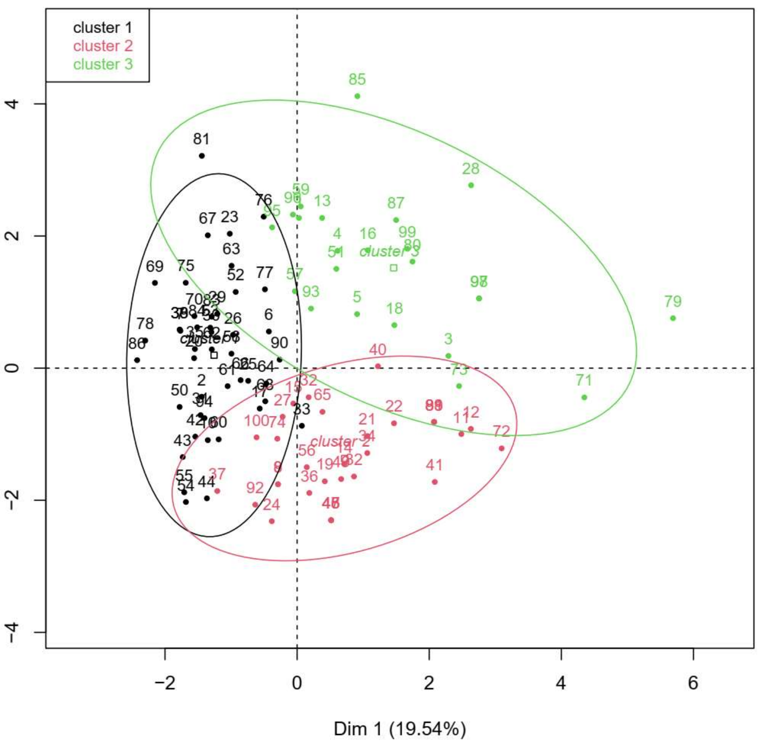

Figure 8 : Representation of clusters using hierarchical clustering into the factorial space

We calculated the mean standardized scores of the policies for the three clusters (Table 5). They suggest that cluster 1 favor infrastructure policies, that cluster 2 favor institutional policies (but still want to increase the supply of water to agriculture) and cluster 3 favor economic incentives to invest in water saving technologies and the decision-making at the WUA level. In other terms, these three groups favor different policy mix.

Table 5 : Mean value of policy statements scores for the three clusters

	Policy statements	Cl1	Cl2	Cl3
IF1	Maintain the water available to agriculture to its current levels	**0.385**	-0.0521	-0.261
IF2	Ensure appropriate and timely infrastructure development and maintenance that keeps up with the needs of water users	**0.844**	0.542	0.217
IF3	Increase water available to agriculture by building more dams	**0.8**	**0.688**	0
E1	Technical assistance/information for on farm extraction activities	-0.304	**-0.625**	-0.13
E2	Introduce financial support mechanisms (e.g., some form of subsidy) to invest in water saving technologies	0.111	-0.115	**0.275**
E3	Enforce penalties on farmers that extract more water than allocated or does not have a functional water metering system	-0.141	0.0521	-0.116
P1	Technical assistance/information for on farm pollution	-0.467	**-0.771**	-0.232
P2	BGCMA must engage in clean-up activities in the event of pollution	-0.348	**-0.49**	0.0725
P3	Enforce penalties on farmers that engage in activities potentially leading to water-polluting	-0.407	-0.323	-0.203
I1	Ensure efficient and transparent governance systems between the different tiers of regulatory …	-0.156	0.229	0.116
I2	The BGCMA should be responsible for irrigation water allocation across its farmers	-0.407	**0.323**	-0.0145
I3	Each Water User Associations (WUA) should be responsible for irrigation water allocation across its farmers	0.0889	**0.542**	**0.275**

3.4 The modelling approach

3.4.1 The BWS conditional logit

The results of the BWS conditional logit model are reported in Table 6. All the parameters are significantly different from zero and the model adjusted rho square indicated a relatively good fit. The scale parameter for the least efficient policy choice ($\mu_l = 0.4$) was positive and highly significant. Since μ_m was fixed to one, μ_l should be interpreted as relative to μ_m. In particular, this suggests that the choice of the least efficient policy is much less consistent than the choice of the most efficient policy. The lesser consistency could be linked to the greater difficulty of choosing between the less effective policies.

The results indicate a strong preference for policy related to infrastructure and to a lesser extent related to institutions that govern water. They are similar to the results obtained with the counting approach.

The parameters related to infrastructure policies suggest a strong preference for increasing the water made available to agriculture (IF2 or IF3). The mere maintenance of current water allocations to agriculture is not seen as adequate.

The parameters related to extraction policies suggest a strong preference for some form of financial support to invest in new technologies. On the other hand, the provision of technical assistance or information regarding these technologies was not seen as useful. The enforcement of penalties for farmers extracting more than their allocated share was also perceived as useful. Both carrot and stick types of policies were preferred, but with a preference for a carrot approach. The results of the counting and cluster approach are consistent with these results.

Table 6 : Parameter estimates of a best-worst conditional logit model with a different scale parameter for the worst choice.

Parameter	Description	Estimate	Robust SE	Robust t ratio
Policy family impacts				
Pollution[a]	Impact of pollution related policies	-1.620		
Extraction	Impact of extraction related policies	-0.155	0.092	-1.690
Infrastructure	Impact of infrastructure related policies	1.278	0.106	12.057
Institutions	Impact of institutions related policies	0.497	0.134	3.713
Policy preference scales				
I1	Ensure efficient and transparent governance…	-0.222		
I2	The BGCMA should be responsible for irrigation…	-0.462	0.128	-3.603
I3	Each Water User Associations (WUA) should…	0.684	0.120	5.717
E1	Technical assistance/information for on farm extraction…s	-1.211		
E2	Introduce financial support mechanisms …	0.827	0.133	6.207
E3	Enforce penalties on farmers that extract more water…	0.385	0.172	2.236
P1	Technical assistance/information for on farm pollution	-0.782		
P2	BGCMA must engage in clean-up …	0.431	0.141	3.050
P3	Enforce penalties on farmers that engage …	0.351	0.184	1.902
IF1	Maintain the water available to agriculture …	-1.050		
IF2	Ensure appropriate and timely infrastructure…	0.477	0.095	5.001
IF3	Increase water available to agriculture by building…	0.573	0.130	4.411
Scale worst		0.408	0.063	6.487
Log likelihood initial		-2236		
Log likelihood final (whole model)		-1839		
Pseudo Rho-squared		0.178		
AIC		3702		

a Attributes (policy families) and levels (policy statements) are effect coded. The parameter of Pollution, IF1, E1, P1 and IS1 were calculated as the negative of the sum of the other related parameters.

The parameters related to the management of pollution again are showing the same pattern, with an equal preference for carrot and stick approaches and a rejection of technical assistance or provision of information.

Finally, the parameters related to institutions suggest that farmers strongly support that water allocation decisions should be taken by the WUAs.

Overall, these results are compatible with the findings of the counting approach.

3.4.2 The BWS latent class approach

To select the number of classes of the BWS latent class model, we ran models with varying numbers of preference classes from two to four. Standard procedures (Log Likelihood, plausibility and significance of classes) and information criteria scores (AIC and BIC) were used to select the optimal number of classes within the data. In our case, the models with three and four classes identified some classes with very small probabilities or with most of the estimated parameters were not significantly different from zero. As a consequence, we decided to use a model with two different preference classes as the model we will comment.

The estimated parameters of this model are reported in Table 7. The use of a latent class improved the model fit as can be seen with the improvement of the AIC and the improvement of the log likelihood by 61 while increasing the number of parameters by 21. The scale parameters for the least efficient policy choice were not significantly different between the two classes and were of the same magnitude than the one obtained with the BWS conditional logit model. The two classes had similar patterns with regard to family of policies impacts (average utilities). The average utilities were negative for pollution and extraction related policies, and positive for institutions and infrastructure related policies. However, the magnitude of the coefficients was much higher for the first class than for the second class. In addition, the first class had a relatively greater aversion against extraction related policies than the second class.

For pollution related policies (P1, P2, P3), the two classes differed in their preferences for P2 and P3. The first class favored more the enforcement of penalties on farmers that engage in polluting activities, while the second class favored more the BGMA intervention in cleaning up activities. Both classes tended to see technical assistance/information as the least effective policy. The first class would favor “stick” kind of policies. The second class would tend to rely on the state or the basin authorities for taking care of the public good.

For water extraction policies (E1, E2, E3), the two classes again differed in what type of policies would be the most efficient. Again, the first class would strongly favor “stick” kind of policies, and the second class favor state interventions via financial mechanisms to support technological changes. Again, both classes did not see training and information diffusion as efficient methods.

Table 7 : Estimated parameters of the BWS-Latent Class model

	Class A			Class B		
	Estimate	Robust SE	p (2-sided)	Estimate	Robust SE	p (2-sided)
Policy family impacts						
Pollution[a]	-2.901	0.830	0.000	-1.100	0.140	0.000
Extraction	-2.327	0.717	0.001	-0.134	0.094	0.152
Institutions	1.828	0.720	0.011	0.259	0.124	0.036
Infrastructure	3.399	0.769	0.000	0.976	0.106	0.000
Policy preference scales						
P1[a]: Technical assistance/information for on farm pollution	-1.957	0.594	0.001	-0.656	0.220	0.001
P2: BGCMA must engage in clean-up …	-0.304	0.641	0.635	0.481	0.143	0.001
P3: Enforce penalties on farmers that engage …	2.261	0.928	0.015	0.175	0.215	0.416
E1[a]: Technical assistance/information for on farm extraction…s	-3.360	1.142	0.002	-0.942	0.172	0.000
E2: Introduce financial support mechanisms …	-1.276	0.422	0.003	0.957	0.133	0.000
E3: Enforce penalties on farmers that extract more water…	4.636	1.246	0.000	-0.016	0.173	0.929
I1[a]: Ensure efficient and transparent governance…	-1.153	0.406	0.002	-0.070	0.134	0.298
I2: The BGCMA should be responsible for irrigation…	0.227	0.282	0.421	-0.648	0.163	0.000
I3: Each Water User Associations (WUA) should…	0.927	0.411	0.024	0.718	0.137	0.000
IF1[a]	-1.720	0.462	0.000	-1.010	0.151	0.000
IF2	0.109	0.279	0.698	0.542	0.114	0.000
IF3	1.611	0.406	0.000	0.468	0.150	0.002
Scale worst class	0.452	0.164	0.006	0.433	0.085	0.000
Delta class A	-4.112	1.215	0.001			
Age : 36-45	-0.275	1.217	0.821			
Age : 46-55	0.667	1.195	0.577			
Age : 56+	-0.451	0.924	0.625			
Irrigated Area (/100 ha)	0.551	0.189	0.004			
Household size	0.082	0.240	0.731			
Education : Degree	2.020	1.270	0.112			
Education : Diploma	1.520	1.202	0.206			
Education : PostGrad	1.588	1.344	0.238			
Unconditional Probability	0.188			0.812		
LogLikelihood 0 (no variables)	-2236.42					
Log Likelihood model	-1777.91					
AIC	3621.82					

[a] Attributes (policy families) and levels (policy statement are effect coded. The parameter of pollution, IF1, E1, P1 and IS1 were calculated as the negative of the sum of the other parameters. The standard errors of the calculated parameters were estimated using the delta method.

For institutions related policies, the two classes differ essentially in the role of BGCMA, where the second perceive more negatively the involvement of BGCMA. Both classes did not see an improvement in the transparencies of the decisions and governance as useful.

With regard to infrastructure, although there were differences in the magnitude of the parameter estimates, there were no strong differences between the classes in terms of the ranking of the three policies.

In an attempt to summarize the two classes suggested by the model. The first class could be pictured as farmers more inclined to enforcement (stick) policies, especially with regard to polluting and extracting activities, and not to rely on government support. The probability to belong to this group was around 20% of the sampled population. Among the socio-demographic indicators, only the irrigated area had a significant impact on this probability, with greater irrigated area increasing the probability to belong to this group. The second class could be associated with farmers more inclined to ask for more government support, as for example some financial mechanisms to help consuming less water. The probability of belonging to that group was around 80% of the sampled population. However, both classes are strongly supporting the idea that more should be done in terms of infrastructures to maintain or even increase the water made available to farmers.

4 Conclusion

The main purpose of the study was to analyze South African farmers' preferences for public policies that would favour the adaptation of their farming systems based on policy directives (options) contained in the National Water Act. As these preferences may vary among farmers, we also analysed the diversity of these preferences in a population of farmers. We conducted a best-worst scaling survey with 100 farmers of the Western Cape province where farmers had to choose what they considered as the most efficient and the least efficient policies among sets of four types policies: pollution management, water extractions management, institutions to manage water, water infrastructure. The data collected were analysed using two complementary approaches: a counting approach and a modelling approach.

Both approaches gave consistent results regarding farmers preferences and their diversity. Farmers of the study area are strongly in favour of policies that maintain or even increase water availability for farming activities. They see this as the most efficient policies to help them adapt to potential climate change impact. Institutions and their management are also considered as efficient tools, and they see an important role water user association in the management of water, especially for the allocation of water among users. Pollution and extraction related policies are seen as much less efficient to help them adapt. However, farmers have divided opinions about these policies. On the one hand, a small proportion of farmers saw a potential in the enforcement of sanctions (fines) against farmers who do no respect their extraction quotas or pollute scarce water resources. On the other hand, a majority (80%) of farmers were in favour of Government financial mechanisms to help them adapt their practices. Both cluster analysis associated based in the counting approach, and the latent class models based on the random utility approach give similar results. Overall farmers are more in favour of carrot types of instruments than sticks types of instruments. We did not find an important diversity of point of views.

The PBWS approach proved an interesting way to quantify farmers preferences as it allowed to cover a large spectrum of policies with a relatively limited number of choices to be made by interviewed farmers. However, further research is probably needed with a larger and more diverse sample. In particular, the sample of 100 farmers could be considered as rather small for the analysis of logistic regressions. In addition, it was difficult to reach all types of farmers and the sample is probably biased. As such the probabilities of belonging in one of the two classes should be taken with caution.

Overall, water supply and increased reliance of irrigation water is seen as a key mechanism to adapt to the climate change impacts. While this makes sense from the point of view of the farmers interviewed since they are mostly relying on irrigation for their crop production, other water users are also likely to have increasing water needs. This is likely to lead to increasing conflicts over the allocation of water among different types of water users. However, the potential role of BGCMA in allocating water among water users does not seem consensual. The role of governments (provincial or central) could also be central in helping farmers in their adaptation to CC. In particular, the provision of financial mechanisms to help them invest in alternative systems is considered as efficient types of policies by farmers.

Adaptation of farmers is likely to have to rely on farmers more efficient use of less water. While some farmers are ready to adapt their systems to more efficient water use, provided they receive some financial help from the governments, they seem much less ready to give up water for other sectors. Instead, they would, in their majority, favour policies that increase water available to farmers. Policymakers and farmers will need to address this gap between what farmers want (or see as the major tool for adaptation to CC) and the increasing demand for water by non-agricultural sectors.

Annexes:

Annex 1. Terms of References

1. Background

In South Africa, Ziervogel et al. (2014) were already reporting in 2014 that annual average temperatures had increased by 1.5 times the observed global average of 0.65°C over the past five decades, and extreme weather events such as drought had increased in frequency. As these changes are likely to continue in the future (Ipcc, 2021), the South African economy is likely to be seriously affected.

The agricultural sector is only contributing to 3% of GDP and 7% of total employment. However, it creates many spillovers on the South African economy. As such, it is considered a critical sector for future growth and employment (Arndt *et al.*, 2021; Blignaut *et al.*, 2009). Among the anticipated impacts, an increased number of extreme climatic events (floods, droughts, etc.), the management of land and water resources will be more complex. Currently available freshwater is already fully allocated, but demand for irrigation water is likely increase and so is the demand for water by cities. To respond to this challenge, the SA Government has mobilized resources to develop possible scenarios of changes and adaptation strategies (Department of Environmental Affairs, 2013). On the research side, several studies have already been conducted to understand farmers' perceptions of changes in the climatic patterns and their adaptation strategies (e.g., Archer *et al.*, 2020; Elum *et al.*, 2017; Olabanji *et al.*, 2021b; Rankoana, 2019; Wiid & Ziervogel, 2012), or to analyze the potential effects of climate changes on agricultural systems (e.g., Blignaut *et al.*, 2009; Tibesigwa *et al.*, 2017).

The management of land and water resources under climate change could be considered a "wicked problem" where wicked problems are defined as the social or policy issues that are often complex, difficult to define and difficult to solve (Rittel, H. W. & Webber, 1973b). Following from the wicked problems literature (Carter, 2019; Defries & Nagendra, 2017; Kumlien & Coughlan, 2018), stakeholder involvement is critically important in designing long-term solutions to resources management challenges (Camillus, 2008). In particular, a better understanding of the diverse stakeholder perspectives contributes to reducing the wickedness of resource management challenger (Head & Xiang, 2016; Rissman & Carpenter, 2015).

However, since studies mostly concentrate on farmers' perceptions of the effects of climate change or their current adaptation strategies, there seems to be a gap in the analysis of the point of views of the main stakeholders regarding the public policies that would favor adaptations of their farming systems. The purpose of the study is to fill this gap.

The objectives of the project will be:

4. to identify the public policies that are deemed relevant to solve the issue of water management by the agricultural sector under different climatic scenarios (current, under preparation, or that the consultant would find adequate after discussion with the main stakeholders);
5. to identify farmers' preferences for these different policies;
6. to characterize the diversity of these preferences.

As there is a great diversity of agro-ecological contexts in South Africa, the present study will be limited to the municipalities of Drakenstein and Breede Valley in the Province of Western Cape.

Tasks

The proposed study will include three complementary tasks:

1. Stakeholders identification and interviews to identify issues and related public policies
2. At least 120 farm household surveys in order to investigate the preferences of farmers for the identified public policies (final methodology: Q-methodology, Best-Worst Scaling, etc. and final sampling strategy to be decided after the stakeholder interviews);
3. Analysis of the farm household survey and reporting

Outputs

1. A research report that will include methodology employed and main findings (stakeholder identified, policies considered, and a first assessment of the diversity of farmers' preferences.
2. Preparation of research article.

Annex 2. Questionnaire

Stellenbosch
UNIVERSITY
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UNIVERSITEIT

AGRISCIENCES
EYENZULULWAZI NGEZOLIMO
AGRIWETENSKAPPE

Department of Agricultural Economics
Departement Landbou Ekonomie

STELLENBOSCH UNIVERSITY

CONSENT TO PARTICIPATE IN RESEARCH

You are invited to take part in a research project. Please take some time to read the information below which will explain the details of this research project.

Please feel free to contact the researchers about any part of this project that you do not fully understand. It is very important that you are completely satisfied that you clearly understand what this research is about and how you could be involved.

Your participation is completely voluntary, and you are free to decline to participate. In other words, you may choose to take part, or not. Saying no will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part initially.

The Research Ethics Committee: Social, Behavioural and Education Research at Stellenbosch University has approved this study (Project ID #: 24373).

1. WHO IS CONDUCTING THIS STUDY?

This research study is conducted by Wilhelm Naudé, André Jooste, and Eric Mungatana.

The researchers are from the Department of Agricultural Economics at Stellenbosch University.

2. WHY DO WE INVITE YOU TO PARTICIPATE?

You are invited to participate in the study because your opinions and preferences about public policy implementation is important. Your opinions are based on first-hand experience and knowledge on ground level, which makes it valuable information that should be considered in policy creation and implementation by the government.

3. WHAT IS THIS RESEARCH PROJECT ABOUT?

This study's aim is to conduct research on farmers preferences for public policies that would favour adaptation to mitigate climate change in their farming systems. This is in response to the observation that climate change is exacerbating water scarcity in South Africa. It is government's mandate to create and implement policies that are relevant to solve the issue of water management and to mitigate against water scarcity. To the best of our knowledge, no research has been done in South Africa on the farmers' preferences and opinions on these different policies. The purpose of the study is to fill this gap. The results will give an informed idea of what policies farmers think would help them the most with successful water management.

4. WHAT WILL BE ASKED OF ME?

If you agree to take part in this study, you will be asked to complete a questionnaire where you will give your personal preferences for public water policy implementation. You will be asked to sit in at a meeting that will be held in your farming community that will last between 15-25 minutes. Only one meeting will be held and no further participation will be required/ requested from you.

5. ARE THERE ANY RISKS IN MY TAKING PART IN THIS RESEARCH?

There are no risks involved to take part in this study. You will not be asked to share any sensitive/ personal information.

6. WILL I BENEFIT FROM TAKING PART IN THIS RESEARCH?

By taking part in this study you could play a role in better designed water policies and regulations, as well as better implementation thereof. This would be beneficial to your farming activities and it would benefit the society as a whole.

7. WILL I BE PAID TO TAKE PART IN THIS STUDY AND ARE THERE ANY COSTS INVOLVED?

No, you will not be paid for completing the questionnaire. The costs that would be involved for you are the time that it will require to complete the questionnaire and the transport cost to the location in the community where you will complete the questionnaire.

8. WHO WILL HAVE ACCESS TO MY INFORMATION?

Any information you share during this study and that could possibly identify you as a participant will be protected. Your information will be kept confidential and will be stored on a password-protected device. Only the primary researcher will have access to the data, it will not be shared with any other person or third party. The results of the study will be published, but none of the participants' names will be mentioned.

9. HOW DO I MAKE CONTACT WITH THE RESEARCHERS?

If you have any questions or concerns about this study, please feel free to contact the researcher, Wilhelm Naude at 21589682@sun.ac.za, and/or the study supervisor Andre Jooste at 021 808 4899 or e-mail at joostea@sun.ac.za.

10. RIGHTS OF RESEARCH PARTICIPANTS

If you have questions, concerns, or a complaint regarding your rights as a research participant in this research project, please contact Mrs Clarissa Robertson [cgraham@sun.ac.za; (+27) 021 808 9183] at the Division for Research Development.

DECLARATION OF CONSENT BY THE PARTICIPANT

As the participant, I declare that:

- I have read this information and consent form, or it was read to me, and it is written in a language in which I am fluent and with which I am comfortable.
- I have had a chance to ask questions and I am satisfied that all my questions have been answered
- I understand that taking part in this study is voluntary, and I have not been pressurised to take part.
- I may choose to leave the study at any time and nothing bad will come of it – I will not be penalised or prejudiced in any way.
- I agree that the interview with me can be [video-recorded / audio-recorded].

By signing below, I ________________________________ *(name of participant)* agree to take part in this research study, as conducted by _____ *(name of principal investigator).*

____ ______________________

Signature of Participant **Date**

DECLARATION BY THE RESEARCHER

As the **researcher,** I hereby declare that the information contained in this document has been thoroughly explained to the participant. I also declare that the participant has been encouraged (and has been given ample time) to ask any questions. In addition, I would like to select the following option:

	The conversation with the participant was conducted in a language in which the participant is fluent.
	I did/did not use an interpreter. (If an interpreter is used then the interpreter must sign the declaration below.)

______________________________ ______________________

Signature of Principal Investigator **Date**

______________________________ ______________________

Signature of Interpreter (if applicable) **Date**

Introduction to study

Dear respondent,

You are invited to participate in a research study conducted by Wilhelm Naudé, a Masters student from the Department of Agricultural Economics at the University of Stellenbosch. The purpose of this study is to investigate farmers' preferences for water policy design in the Breede Valley area.

Participation in this survey involves responding to questions that will be asked and this should take less than half an hour. The questions requires you to provide your preferences for policy implementation. Demographic questions will also be asked, such as gender, age etc.

You are invited to participate in the study because your opinions and preferences about public policy implementation are important. Your opinions are based on first-hand experience and knowledge on ground level, which makes it valuable information that should be considered in policy creation and implementation by the government.

The purpose of the research is to conduct a study on farmers' preferences for public policies that would favor adaptation of their farming systems. This is in response to the observation that climate change is exacerbating water scarcity in South Africa. It is the government's mandate to create and implement policies that are relevant to solve the issue of water management and to mitigate against water scarcity. To the best of my knowledge, no research has been done in South Africa on the farmers' preferences and opinions on these different policies. The purpose of the study is to fill this gap.

Information pertaining to farmers preferences for different policy options is vitally important in the policy design process to ensure that policies can be implemented and optimize compliance. Thus, on the one hand, this project will provide the foundation to communicate essential information to policy makers that will strengthen their position to influence policy. On the other hand, it will provide clear insights to policy makers on policy options that will provide the most optimal outcomes to achieve government's goals.

Research question, aims, and objectives

The specific objectives of the study is:

1. to identify the public policies that are deemed relevant to facilitate the private sectors response to water management by the agricultural sector under different climatic scenarios;
2. to identify farmers' preferences for these different policies &
3. to characterize the diversity of these preferences.

Section A

The water users association you belong to: ______________________________

The area in which your farm is located: _________________________________

The commodities with which you farm: _________________________________

Section B: Presentation of the relevant policy

This research pertains to the policy directives (options) included in the National Water Act of 1998. Broadly, the policy directives (options) included in the Act can be categorised as follows:

Policy group	Policy statement
Institutions	The BGCMA should be responsible for irrigation water allocation across its farmers.
	Each water user association (WUA) should be responsible for irrigation water allocation across its farmers.
	Ensure efficient and transparent governance systems between the different tiers of regulatory and management activities.
Pollution	BGCMA must engage in clean-up activities in the event of pollution.
	Technical assistance/information for on farm pollution.
	Enforce penalties on farmers that engage in activities potentially leading to water pollution.
Extractions	Introduce financial support mechanisms (e.g., some form of subsidy) to invest in water saving technologies.
	Technical assistance/information for on farm extraction activities.
	Enforce penalties on farmers that extract more water than allocated or does not have a functional water metering system.
Infrastructure	Ensure appropriate and timely infrastructure development and maintenance that keeps up with the needs of water users.
	Maintain water available to agriculture to its current levels.
	Increase water available to agriculture by building more dams.

Section C: The Best-Worst Scale Experiment

In this section 13 statements on water policy implementation were formulated. These 13 statements were then mixed into 9 different combinations. The exercise will be completed by choosing policy options you would **select as the most effective** to help farmers adapting to climate change and water scarcity issues. In addition, you must **select the policy options would be the least effective** to enable farmers to adapt to climate change and water scarcity issues.

Question 1

Most effective	**Policy preference**	**Least effective**
	The BGCMA should be responsible for irrigation water allocation across its farmers.	
	Enforce penalties on farmers that engage in activities potentially leading to water pollution.	
	Technical assistance/information for on farm extraction activities.	
	Ensure appropriate and timely infrastructure development and maintenance that keeps up with the needs of water users.	

Notwithstanding the policy options provided in the table above (i.e. there might be other options not mentioned in the table), would you actively <u>promote the policy option you selected</u> as the one that will be the most effective to help farmers adapting to climate change and water scarcity issues. *(Guide: If you think there are other policy options available that will be better that your choice of most effective policy option in the above table then the answer is No. If you think)*

Yes - ☐

No - ☐

Question 2

The same exercise will now be done with a different combination of preferences.

Most effective	**Policy preference**	**Least effective**
	The BGCMA should be responsible for irrigation water allocation across its farmers.	
	BGCMA must engage in clean-up activities in the event of pollution.	
	Introduce financial support mechanisms (e.g. some form of subsidy) to invest in water saving technologies.	
	Maintain water available to agriculture to its current levels.	

Notwithstanding the policy options provided in the table above, would you actively promote the policy option you selected as the one that will be most effective to help farmers adapting to climate change and water scarcity issues.

Yes - ☐

No - ☐

Question 3

The same exercise will now be done with a different combination of preferences.

Most effective	**Policy preference**	**Least effective**
	The BGCMA should be responsible for irrigation water allocation across its farmers.	
	Technical assistance/information for on farm pollution.	
	Enforce penalties on farmers that extract more water than allocated or does not have a functional water metering system.	
	Increase water available to agriculture by building more dams.	

Notwithstanding the policy options provided in the table above, would you actively promote the policy option you selected as the one that will be most effective to help farmers adapting to climate change and water scarcity issues.

Yes - ☐

No - ☐

Question 4

The same exercise will now be done with a different combination of preferences.

Most effective	**Policy preference**	**Least effective**
	Ensure efficient and transparent governance systems between the different tiers of regulatory management activities.	
	Technical assistance/information for on farm pollution.	
	Technical assistance/information for on farm extraction activities.	
	Maintain the water available to agriculture to its current levels.	

Notwithstanding the policy options provided in the table above, would you actively promote the policy option you selected as the one that will be most effective to help farmers adapting to climate change and water scarcity issues.

Yes - ☐

No - ☐

Question 5

The same exercise will now be done with a different combination of preferences.

Most effective	Policy preference	Least effective
	Each water user association (WUA) should be responsible for irrigation water allocation across its farmers.	
	BGCMA must engage in clean-up activities in the event of pollution.	
	Technical assistance/information for on farm extraction activities.	
	Increase water available to agriculture by building more dams.	

Notwithstanding the policy options provided in the table above, would you actively promote the policy option you selected as the one that will be most effective to help farmers adapting to climate change and water scarcity issues.

Yes - ☐

No - ☐

Question 6

The same exercise will now be done with a different combination of preferences.

Most effective	Policy preference	Least effective
	Ensure efficient and transparent governance systems between the different tiers of regulatory and management activities.	
	BGCMA must engage in clean-up activities in the event of pollution.	
	Enforce penalties on farmers that extract more water than allocated or does not have a functional water metering system.	
	Ensure appropriate and timely infrastructure development and maintenance that keeps up with the needs of water users.	

Notwithstanding the policy options provided in the table above, would you actively promote the policy option you selected as the one that will be most effective to help farmers adapting to climate change and water scarcity issues.

Yes - ☐

No - ☐

Question 7

The same exercise will now be done with a different combination of preferences.

Most effective	Policy preference	Least effective
	Each Water User Association (WUA) should be responsible for irrigation water allocation across its farmers.	
	Technical assistance/information for on farm pollution.	
	Introduce financial support mechanisms (e.g. some form of subsidy) to invest in water saving technologies.	
	Ensure appropriate and timely infrastructure development and maintenance that keeps up with the need of water users.	

Notwithstanding the policy options provided in the table above, would you actively promote the policy option you selected as the one that will be most effective to help farmers adapting to climate change and water scarcity issues.

Yes - ☐

No - ☐

Question 8

The same exercise will now be done with a different combination of preferences.

Most effective	Policy preference	Least effective
	Each Water User Associations (WUA) should be responsible for irrigation water allocation across its farmers.	
	Enforce penalties on farmers that engage in activities potentially leading to water pollution.	
	Enforce penalties on farmers that extract more water than allocated or does not have a functional water metering system.	
	Maintain the water available to agriculture to its current levels.	

Notwithstanding the policy options provided in the table above, would you actively promote the policy option you selected as the one that will be most effective to help farmers adapting to climate change and water scarcity issues.

Yes - ☐

No - ☐

Question 9

The same exercise will now be done with a different combination of preferences.

Most effective	Policy preference	Least effective
	Ensure efficient and transparent governance systems between the different tiers of regulatory and management activities.	
	Enforce penalties on farmers that engage in activities potentially leading to water pollution.	
	Introduce financial support mechanisms (e.g. some form of subsidy) to invest in water saving technologies.	
	Increase water available to agriculture by building more dams.	

Notwithstanding the policy options provided in the table above, would you actively promote the policy option you selected as the one that will be most effective to help farmers adapting to climate change and water scarcity issues.

Yes - ☐

No - ☐

In general, how clear were the instructions provided to you to undertake the choice questions?

Very clear	Clear	Neither clear nor unclear	Unclear

In general, how difficult was it for you to make a choice? Please select one choice

Very difficult	Difficult	Neither easy nor difficult	Easy	Very easy

Section C: Demographic questions

Gender:	Male	Female

Age:	

Education:	Primary School	High School	Diploma	Degree	Post Grad Degree

Size of household	1	2	3	4	5	6	7+

Size of farm under irrigation (ha):	

Number of farm workers (permanent):	
(seasonal):	

Are you the main decision maker in your household	Yes	No

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