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Farming under Drought:

An analysis of the factors influencing farmers' bundling of water conservation practices to mitigate farm-level water scarcity in South Africa

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Summary:

South Africa is a water-stressed country prone to multi-year droughts and water shortages (DWSs) which are being exacerbated by climate change. The DWSs pose unprecedented water challenges to farmers and lead to negative impacts on agricultural production, food security and rural employment. Hence, jeopardizing the national development plan which aims at enhancing the contribution of agriculture to the country's unemployment and poverty reduction strategies. This paper investigates the factors that drive farmers' simultaneous adoption of six water conservation practices (WCPs)—drip and/or sprinkler irrigations (more efficient performing irrigation methods (MEPIDs)), conservation tillage, cover cropping, intercropping, mulching, and growing drought-tolerant crops and the intensity of their adoption. Using a sample of 555 farmers from the Limpopo province of South Africa, we estimate farmers' adoption of these WCPs with a multivariate probit model and for the intensity of their adoption, an ordered probit model is estimated. Our results show that gender, age, education, farm size, off-farm and farm incomes, and access to credit, among other factors, induce the probability and extent of adoption of multiple WCPs. Additionally, we found a positive correlation amongst the combinations MEPIDs and cover cropping, MEPIDs and intercropping, MEPIDs and mulching and drought tolerant crops and intercropping, suggesting complementarity or the bundling of these WCPs. The study, beyond its academic contributions to the literature, provides policymakers with key insights for the design of relevant and effective water management strategies that improve water use efficiency at the farm level. It also offers farmers the guidance to prepare appropriately to cope with the effects of DWSs.

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Farming under drought: An analysis of the factors influencing farmers' bundling of water conservation practices to mitigate farm-level water scarcity in South Africa

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Abstract

South Africa is a water-stressed country prone to multi-year droughts and water shortages (DWSs) which are being exacerbated by climate change. The DWSs pose unprecedented water challenges to farmers and lead to negative impacts on agricultural production, food security and rural employment. Hence, jeopardizing the national development plan which aims at enhancing the contribution of agriculture to the country's unemployment and poverty reduction strategies. This paper investigates the factors that drive farmers' simultaneous adoption of six water conservation practices (WCPs)—drip and/or sprinkler irrigations (more efficient performing irrigation methods (MEPIDs)), conservation tillage, cover cropping, intercropping, mulching, and growing drought-tolerant crops and the intensity of their adoption. Using a sample of 555 farmers from the Limpopo province of South Africa, we estimate farmers' adoption of these WCPs with a multivariate probit model and for the intensity of their adoption, an ordered probit model is estimated. Our results show that gender, age, education, farm size, off-farm and farm incomes, and access to credit, among other factors, induce the probability and extent of adoption of multiple WCPs. Additionally, we found a positive correlation amongst the combinations MEPIDs and cover cropping, MEPIDs and intercropping, MEPIDs and mulching and drought tolerant crops and intercropping, suggesting complementarity or the bundling of these WCPs. The study, beyond its academic contributions to the literature, provides policymakers with key insights for the design of relevant and effective water management strategies that improve water use efficiency at the farm level. It also offers farmers the guidance to prepare appropriately to cope with the effects of DWSs.

Keywords: Climate change, drought, adoption, farmers, multivariate probit, multiple water conservation practices, South Africa

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1. Introduction

South Africa's National Development Plan (NDP) for 2030 requires adequate water of the right quality and quantity to support equitable economic growth and the achievement of the national developmental goals (The National Development Plan 2030, 2012). However, the country is severely water stressed and prone to multi-year droughts and water shortages (DWSs) which are being exacerbated by several factors including climate change, economic industrialization, and population growth. Since the agricultural sector uses about 60 percent of the country's fresh water, farmers suffer the brunt of the shocks of intensified DWSs. These shocks do not only pose unprecedented challenges to farmers, but also place severe negative impacts on the whole agricultural supply chain, food security, and rural employment at large. For instance, the droughts of 2015 through to 2018, in some parts of the country resulted in the loss of large tracts of farmlands and livestock, increased prices of staple food items like maize, and induced the imposition of harsh water restriction measures.

In response to the DWSs, there are calls for water conservation in all facets. Farmers are expected to be at the center of the efforts to save, conserve, and promote water use efficiency given the importance of water use in agriculture. Droughts are often unpredictable, therefore preparedness measures are paramount to enabling farmers to cope with their pervasive long-term effects and severity. One plausible anticipatory measure is the adoption of water conservation practices (WCPs) that enhance water use efficiency at the farm level. It is often argued that the adoption of WCPs does not only allow water saving (Dinar and Wolf, 1994; Uygan et al., 2021), but also provides additional benefits such as increases in water-use efficiency (Cai et al., 2003), the preservation and improvement of water quality (Howell, 2001), decreases in tillage requirements, reducing cultivation costs (both in terms of labour and fuel) and increase in agricultural production (Heilig et al., 2000). Furthermore, the adoption of WCPs enables farmers to build defenses against future droughts and maintain their production cycles throughout the year, which in turn guarantees the stability of their income flows and contributes at reducing poverty and inequality within the farming community (Abdulai & Huffman, 2014; Delgado et al., 2011; Food and Agriculture organization of the United Nation [FAO] (2017); McGuire et al., 2013). According to International Rivers (2000), urban and agricultural water use in southern Africa is still highly inefficient and 2.5 billion cubic meters of water could be saved each year if irrigation water usage could be made only 10 percent more efficient. It is against such backdrop that this study finds it imperative to understand the factors that drive farmers' simultaneous adoption of WCPs that aim at improving water use efficiency in the Limpopo River Basin (LRB) of South Africa. The LRB is a shared basin amongst four countries—Botswana, Zimbabwe, Mozambique, and South Africa (Limpopo Basin Permanent Technical Committee [LBPTC], 2010). Agricultural activities constitute a large portion of land use in the LRB, particularly in the South African portion of the basin (LBPTC 2010). It is estimated that over 273,000 smallholder farmers live in the Limpopo province (Statistics South Africa, 2002). Yet agricultural practices in the region may not be sustainable, because, first, the province is a semi-arid to arid region receiving less precipitation (250–500 millimeters of rainfall per year), causing high surface water scarcity and diminishing groundwater levels. Second, the water quality in the LRB is severely deteriorated due to agricultural nonpoint source (agNPS) pollution and siltation caused by poor tillage and land use management practices. These make water use in the basin for agriculture unsustainable in the long run, endangering the province's economic development strategy that identifies agriculture as one of the three pillars of economic growth.

Therefore, the purpose of this study is to identify and analyze the factors that motivate farmers' adoption of multiple WCPs and their interrelationships in mitigating farm level water scarcity to advice policy and enlighten farmers on the need to increase water use efficiency. We are particularly interested in how farmers in the LRB are bundling WCPs to adapt to water scarcity caused by DWSs and promote quality mitigation. Using six WCPs[4], we first determine the factors that motivate farmers to adopt multiple WCPs (bundles of WCPs) instead of only a given conservation practice. Second, we determine the interrelationships amongst the existing WCPs, paying particular attention to those that are complementary. Finally, we determine the intensity of the adoption (number of practices adopted) of WCPs by farmers. We estimate farmers' adoption of these WCPs with a multivariate probit (MVP) model and for the intensity of their adoption an ordered probit model (OPM) is estimated. We use data collected from 555 farmers in the Limpopo province.

Our results show that female farmers are less likely to adopt mulching compared to their male counterparts. The rest of the WCPs are insignificant for gender, even though some have the required a priori expected signs. Education also plays a role in the adoption of the WCPs.

[4] (1) Drip and/or sprinkler irrigation (MEPIDs), (2) conservation tillage, (3) cover crops, (4) mulching, (5) intercropping techniques (intercropping and agroforestry) and (6) growing drought tolerant crops.

Literate farmers are more likely to adopt more efficient performing irrigation methods (MEPIDS) compared to their non-literate counterparts. Furthermore, farm ownership, market access, off-farm and farm incomes have positive effects on the adoption of MEPIDS. Additionally, a positive correlation is evident for cover cropping and MEPIDS, intercropping and MEPIDS, mulching and MEPIDS, intercropping and conservation tillage, intercropping and cover cropping and growing drought tolerant crops and intercropping suggesting significant bundling of these WCPs. Our study contributes to the literature first, by enhancing the understanding of the factors that influence the simultaneous adoption of the WCPs that mitigate water scarcity at the farm level. It is also the first testament of bundling of WCPs in South Africa to the best of our knowledge. The bundling of WCPs is novel and provides better efficient use of scarce water resources. Second, beyond its academic contributions, our study provides policymakers with key insights for the design of relevant and proactive water management strategies that improve water use efficiency at the farm level. Lastly, it holds important lessons for farmers in South Africa and other water risk hotspots across the world.

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

2. Review of Related Literature

Farmers tend to adopt technologies and conservation practices that may help them increase their expected profit (Ellis, 1993; de Graaff et al., 2008). A wide range of empirical literature studied the factors that drive or constrain adoption of agricultural innovation (Dinar & Yaron, 1992; Koundouri et al., 2006). In general, the literature shows the adoption of WCPs as a function of a multitude of factors: personal and demographic characteristics, social capital, the natural environment, technical characteristics, institutional characteristics, family and farm characteristics, cost of production, and risk factors among other factors (Abdulai et al., 2011; Alam, 2015; Bjornlund et al., 2009; Chen et al., 2014; Nikouei et al., 2012; Wang et al., 2015). Specifically, these studies investigate the factors that influence the adoption of WCPs (Amsalu & de Graaff, 2007; Bjornlund et al., 2009; Foltz, 2003; Jara-Rojas et al., 2012; Alotaibi & Kassem, 2021; Kerse, 2018; Nyirahabimana et al. 2021; Sileshi et al., 2019) and the adoption of climate smart agriculture technologies (Deressa et al., 2009; Diallo et al., 2020; Dung 2020; Kurgat et al., 2020; Maguza-Tembo et al., 2017; Mulwa et al., 2017; Teklewold et al., 2013; Tran et al., 2020; Zakaria et al., 2020) amongst others in response to farmers' adaptative strategies to droughts and climate change.

Other studies have also investigated barriers to water conservation (Kulkarni 2011; Ward et al., 2007), choices of irrigation technologies to conserve water (Caswell & Zilberman, 1985), and conservation practices programmes to protect water quality in agricultural watersheds (Osmond et al., 2012). In Table A1 of Appendix A1, we provide an overview of key related studies that explored the factors determining farmers' adoptions of drought and climate change adaptative strategies in selected countries. However, a recent strand of new literature that is of interest to us is those on the adoption of bundles of technologies and management practices to adapt to climate change. Bundling or combining technologies take place when farmers use several technologies and management practices that complement each other instead of adopting one technology or management practice independently (Reints et al., 2020). According to Fleischer et al. (2011) and Wang et al. (2010), the adoption of bundles may provide farmers with more flexibility which may result in better resilience and higher profits. Specifically, Fleischer et al. (2011) used discrete choice analysis to simulate how Israeli farmers bundle the choice of crop species, technology, in response to climate to simultaneously decide what crop to grow, what type of irrigation to use, and whether or not to use cover in response to changes in climate and long-term availability of water. The study concludes that the shift between bundles provides adaptation capacity and enables farmers to be better prepared to handle climate change impacts and maximize their profits. Wang et al. (2010) contribute to the literature on bundling by simulating how farmers' crop choice outcomes might change in response to climate change in China. The crux of this study is how farmers have adapted to the different range of climates across China using different cropping patterns with different water requirements. The study's results show that, depending on the region, certain crop bundles provide farmers flexibility in dealing with climate change impacts on water scarcity. The nine major crops the paper specifically examined are wheat, rice, maize, soybean, potato, cotton, oil crops, sugar and vegetables. Their analysis reveals that climate change will cause some crops to increase in some regions and fall in others across China. For Reints et al. (2020), their contribution to the literature on bundling is on how avocado growers in California adopt bundles of different management practices and irrigation technologies to deal with water scarcity. The authors used Kohonen Self-Organizing Maps (KSOM) (Kohonen, 2013) and logit models to identify the most common bundles of technologies and management practices that growers are using to deal with water scarcity. One important conclusion from their study is that regional climates and water conditions matter. Therefore, farmers will need to have more flexibility in their approach to water management to mitigate climate change and reductions in irrigation water quantity and quality. In areas with less water availability, growers with ability to select from many different discrete management outfits that manage water with less complex irrigation systems may benefit from simplifying their irrigation systems in order to facilitate maintenance and improve water-use efficiency.

The review of the literature shows that, first, no study exists in the literature of farmers simultaneous adoption of the unique six WCPs we investigate in this study. Second, despite the importance of water conservation in agriculture, few studies (Baiyegunhi, 2015; Gbetibouo et al., 2010; Kohler, 2016; Mogogana, et al., 2018 among others) have investigated the subject in South Africa. Although important, these studies fall short in providing us with a comprehensive picture of the factors motivating farmers' adoption of multiple WCPs. According to Marenya and Barrett (2007), farmers often face multiple innovations. They consider the way these different technologies interact and take these interdependencies into account in their adoption decisions. Ignoring these interdependencies can lead to biased estimates and inconsistent policy recommendations. The important differences between our study and those reviewed, is that first, we focus attention on South Africa, where no studies of the bundling of WCPs have been conducted. Our choice of six WCPs is unique and enriches the discussions and understanding of the WCPs that mitigate farm level water scarcity. Second, our use of the MVP and OPM methodologies differentiate the current study from most of the previous studies on WCPs. Most previous studies used the univariate models of adoption which biases their estimates and policy implications as highlighted in (Marenya & Barrett, 2007).

3. An Overview of the Study Area

The study is conducted in two farming communities—Folovhodwe and Tshiombo, both in the Vhembe District of the Limpopo Province in South Africa. Folovhodwe is in the Musina municipality and Tshiombo is in the Thulamela municipality. These two farming communities are located on important tributaries of the Limpopo River. Folovhodwe is located on the Nwanedi River, which houses the Nwanedi Irrigation Scheme. As per the 2011 Census, Folovhodwe had a population of 2806 people, who are largely farmers (Census, 2011). On the other hand, the Tshiombo Irrigation Scheme which is among the largest in the Limpopo Province is in Tshiombo. It is in the western end of the Tshiombo valley on the south bank of the Mutale River (Lahiff, 1997). As per the 2011 Census, Tshiombo had a population of 1,415 people also, largely farmers (Census, 2011). Agricultural activities predominantly consist of citrus fruits, banana, vegetables, melons, corn (maize), sweet potatoes/potatoes, tobacco, peanuts (groundnuts) and spices grown in the area. Figure 1 provides a map of the study area.

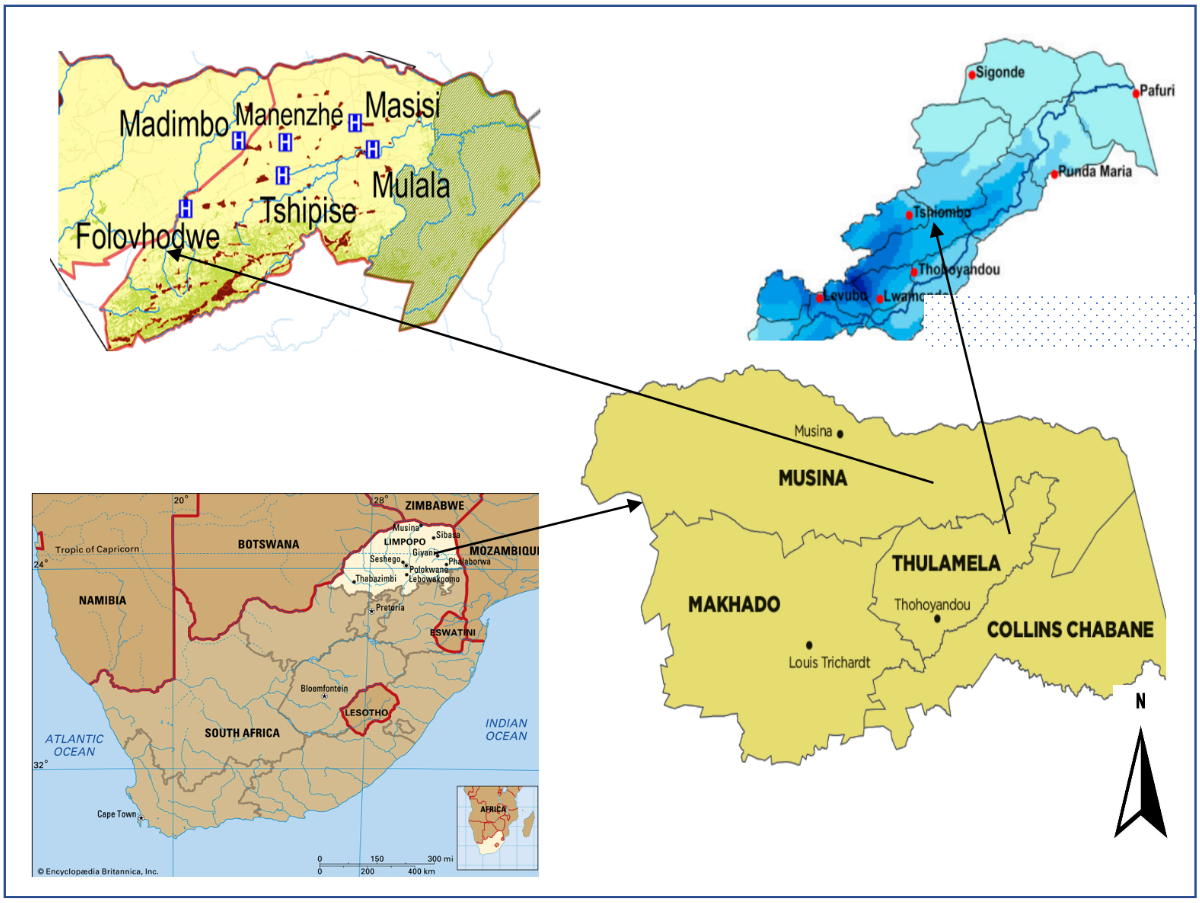

Figure 1: Study Area

4. Methodology

4.1 Multivariate probit (MVP) model

We employ the MVP model which allows us to simultaneously capture the influence of a set of explanatory variables on each of the different WCPs, while allowing for the potential correlation between unobserved disturbances. Through these correlations, the possibility of whether the different WCPs are complements (positive correlation) or substitutes (negative correlation) is determined (Belderbos et al., 2004).

Following Teklewold et al. (2013), the observed outcome of the adoption of these WCPs follow a random utility formulation. A farmer is more likely to adopt a particular WCP if the benefits from its adoption are higher than its non-adoption. Consider the case where the i^{th} farmer ($i = 1, \ldots, N$) faces the decision of whether to adopt or not to adopt the j^{th} WCP on their plot of farm $f(f = 1, \ldots, F)$. If U_0 represents the utility to the farmer when no adoption is made, and U_j the utility of adopting the j^{th} WCP with ($j = me, ct, cc, mu, in, dt$), denoting the choice of more efficient performing irrigation methods (me), conservation tillage (ct), cover cropping (cc), mulching (mu), intercropping (in), and growing drought tolerant crops (dt). The i^{th} farmer decides to adopt the j^{th} conservation practice if $Y_{ifj}^* = U_j^* - U_0 > 0$. The net benefit Y_{ifl}^* that the farmer derives from the j^{th} WCP is a latent variable that is influenced by observed characteristics of the farmer, the farm and other factors that influence farmers' adoption decisions. The MVP model is thus specified as follows:

$$Y_{ifj}^* = X_{if}'\beta_j + \varepsilon_{if} \qquad (j = me, ct, cc, mu, in, dt) \qquad (1)$$

where X_{if} denotes the observed characteristics of the farmer, the farm and other factors that influence farmers' adoption decisions, β_j is a vector of parameters to be estimated and ε_{if} is the unobserved characteristics. Given the latent nature of Y_{ifj}^*, the estimations are based on observable binary discrete variables Y_{ifj}, which indicate whether or not a farmer adopts some particular WCPs. Using the indicator function, the unobserved preferences in Equation (1) translate into the observed binary outcome for each WCP choice as follows:

$$Y_{ifj} = \begin{cases} 1 & if\ y_{ifj}^* > 0 \\ 0 & if\ y_{ifj}^* \leq 0 \end{cases} \qquad (j = me, ct, cc, mu, in, dt) \qquad (2)$$

If the adoptions of the WCPs are assumed to be interdependent or if the adoption of several WCPs is possible, the error terms in Equation (1) jointly follow a multivariate normal (MVN) distribution with zero conditional mean and variance normalized to unity (for identification of parameters). That is $(u_{me}, u_{ct}, u_{cc}, u_{mu}, u_{in}, u_{dt}) \sim MVN(0, \psi)$ and the symmetric covariance matrix ψ is given by

$$\psi = \begin{bmatrix} 1 & & & & & \\ \rho_{ctme} & 1 & & & & \\ \rho_{ccme} & \rho_{ccct} & 1 & & & \\ \rho_{mume} & \rho_{muct} & \rho_{mucc} & 1 & & \\ \rho_{inme} & \rho_{inct} & \rho_{incc} & \rho_{inmu} & 1 & \\ \rho_{dtme} & \rho_{dtct} & \rho_{dtcc} & \rho_{dtmu} & \rho_{dtin} & 1 \end{bmatrix} \quad (3)$$

where ρ is the pairwise correlation coefficient of the error terms of any two potential WCPs. Therefore, the off-diagonal elements in the covariance matrix represent the unobserved correlation between the stochastic components of the different types of WCPs. This specification with non-zero off-diagonal elements allow for correlation across the error terms of several latent equations. If these correlations in the covariance matrix are non-zero, it justifies our use of the MVP model instead of a UVP for each individual WCP. These assumptions mean that Equation (2) provides an MVP model that jointly represents decisions to adopt particular WCPs or not. The six WCPs enter the MVP model as dependent variables.

4.2 Ordered probit model (OPM)

The OPM is estimated to gauge the intensity of adoption of WCPs among farmers. We define the intensity of adoption as the number of WCPs adopted on a farmland as the dependent variable. It takes values from 0 to 6 (where 0 is the non-adoption of any WCP*,* 1 means a farmer adopts 1 WCP, 2 means a farmer adopts 2 WCPs, and so on). Defining the intensity of adoption as the number of WCPs adopted, implies a Poisson regression model could have been used since the dependent variable—the intensity of adoption—is a count variable. However, the Poisson model's assumption that the probability of adopting any of the WCPs is the same contradicts our assumption of interdependence amongst the WCPs. This is because the probability of adopting the first WCP might differ from the probability of adopting the second WCP and so on, since it is believed that with the adoption of the first WCP, the farmer gains some information which influences the adoption of other WCPs, hence our use of the OPM. The OPM is specified as follows.

$$y^* = x'\beta + \varepsilon \quad (4)$$

β is a vector of parameters we wish to estimate. y^* is unobserved, but the relationship between y^* and the observed variable y is:

$$y = \begin{cases} 0 \text{ if } y^* \leq 0 \\ 1 \text{ if } 0 < y^* \leq \gamma_1, \\ 2 \text{ if } \gamma_1 < y^* \leq \gamma_2 \\ \vdots \\ \text{K if } \gamma_{K-1} < y^*. \end{cases} \quad (5)$$

where γ's are unknown parameters to be estimated. Because the coefficients of the OPM are less informative[5], we estimate the marginal effects of each outcome (see Greene & Hensher, 2008 for details). Assuming that ε follows a normal distribution with zero mean and unit variance, the probability of each outcome is then expressed as follows:

$$\begin{aligned} &\Pr(y = 0|x) = \Theta(-x'\beta) \\ &\Pr(y = 1|x) = \Theta(\gamma_1 - x'\beta) - \Theta(-x'\beta) \\ &\Pr(y = 2|x) = \Theta(\gamma_2 - x'\beta) - \Theta(\gamma_1 - x'\beta) \\ &\vdots \\ &\Pr(y = K|x) = 1 - \Theta(\gamma_{K-1} - x'\beta) \end{aligned}$$

where $\Theta(\,.\,)$ is the standard normal cumulative distribution function. Both parameters γ and β are estimated by maximum likelihood estimation. The log-likelihood function is specified as follows:

$$log\mathcal{L} = \sum_{i=1}^{N} \sum_{\omega=1}^{I} ln\,(\Theta(\gamma_i - x'\beta) - \Theta(\gamma_1 - x'\beta)) \quad (6)$$

4.3 Dependent Variables and Justification

Six WCPs are used as our dependent variables in the MVP model. First, ***more efficient performance irrigation techniques*** (MEPIDs) involve the use of advanced water conserving/saving methods such as drip and sprinkler irrigations. In ***drip irrigation*** water and

[5] The coefficients in an ordered choice model provide, in isolation, almost no useful information about the phenomenon under study. There is no natural conditional mean function in the model. The outcome variable, y, is merely a label for the unordered, non-quantitative outcomes. As such, there is no conditional mean function, $E[y|x]$ to analyze (Greene & Hensher, 2008). A moment's inspection shows that neither the sign nor the magnitude of the coefficient is informative, so the direct interpretation of the coefficients is fundamentally ambiguous. [A counterpart result for a dummy variable in the model would be obtained by using a difference of probabilities, rather than a derivative]. Suppose D is a dummy variable in the model (such as Married) and γ is the coefficient on D. The effect of a change in D from 0 to 1 with all other variables held at the values of interest (perhaps their means) is measured using $\Delta_j(D) = [F(\mu_j - \beta' x_i + \gamma) - F(\mu_{j-1} - \beta' x_i + \gamma)] - [F(\mu_j - \beta' x_i) - F(\mu_{j-1} - \beta' x_i)]$. The implication of the result is that the effect of a change in one of the variables in the model depends on all the model parameters, the data, and which probability (cell) is of interest. Thus, neither the signs nor the magnitudes of the coefficients are directly interpretable in the ordered choice model (Greene & Hensher, 2008).

nutrients are conveyed from the source of water through emitters and delivered at or near the root zone of plants, drop by drop where the water is needed most (Ayars et al., 2007; Dasberg & Or, 1999; Sharma, 2001). The method enhances water use efficiency by reducing or eliminating water losses caused by excess deep percolation, evaporation and runoff that happens with other irrigation methods. It has field water use efficiency of about 90 percent (Howell, 2003; Camp et al., 2001). The system has the potential not only to conserve water but also improve crop quality and yield (Dasberg & Or, 1999; Yildirim & Korukcu, 2000). It also increases fertilizer use efficiency (fertigation), reduces labour cost, improves disease and pest control and is suitable for undulating sloppy lands (Michael, 2008). With ***sprinkler irrigation,*** water is applied to crops from overhead by high-pressure sprinklers (movable or stationary) that simulate natural rainfall. This method has field water use efficiency of about 70–80 percent (Dasberg & Or, 1999). Second, ***conservation tillage*** **(**minimum tillage and/ or no-tillage) improves resilience to climatic change adaptation through a shift in tillage practices from repetitive annual tillage to minimal or zero tillage practices. The method deliberately leaves at least 30 percent of previous crop residue on the soil surface to protect soils from extreme heat events, reduce surface runoff and improve crop productivity through increased water and nutrient retention (Clements et al., 2011; Lipiec et al., 2006; World Bank, 2009). The method also saves fuel, labour and machinery costs, improves soil organic carbon and increases fertilizer use efficiency (Clements et al., 2011;Recha et al., 2014). Third, ***cover crops*** are close-growing crops that provide soil and seeding protection and soil improvement between periods of normal crop production (Soil Science Society of America, 2008). The method has been shown to positively impact soil water content by, reducing runoff and improving infiltration and soil water storage capacity. It also decreases evaporative losses through a mulching effect, both following cover crops termination and during growth (Basche et al., 2016b; Daigh et al., 2014; Reese et al., 2014).

In the fourth case, we combine **intercropping and agroforestry** following Geno and Geno (2001), who classified agroforestry as a type of intercropping synonymous with polyculture. In ***intercropping*** two or more crop species are grown simultaneously on the same field with definite or alternate row pattern types (Willey, 1990). Intercropping provides better coverage of the soil surface, enhances light interception, reduces the direct impact of raindrops, protects soil from erosion, decreases water evaporation thereby increasing soil water retention (Mobesser et al., 2014; Singh et al., 1997; Vanwalleghem. 2016). With ***agroforestry***, woody perennials are deliberately integrated spatially or temporally with crops and/or animals on the same land management unit (Recha et al., 2014). The trees reduce the direct impact of raindrops and sunlight and protects soil from erosion. The leaves that litter act as a protective layer over the soil decreasing evaporative losses through a mulching effect that reduces runoff and improves infiltration and soil water storage capacity (Clements et al., 2011; Recha et al., 2014). Fifth, ***mulching*** is the process of spreading organic or inorganic materials to cover soil surface to protect it from erosion, reduce evaporation, increase infiltration and therefore conserving soil moisture (Govindappa et al., 2015; Jabran, 2019; Pang et al., 2010). The method can be used in high rainfall regions to decrease soil and water losses, and in low rainfall regions for soil moisture conservation. Lastly, ***drought tolerant crops*** or plants that can endure water stress and survive during periods of droughts (Chaves et al., 2003; Blum, 2005) is another way by which farmers can cope with the effects of droughts and water shortages. Crop species that are native to arid regions are naturally drought-tolerant, while other crop varieties have been selected over time for their low water needs.

4.4 Sampling and Data

A two-stage sampling approach involving purposive and random sampling procedures were used in selecting the study area and the farmers. In the first stage, we purposively selected Folovhodwe and Tshiombo farming communities because these are largely agrarian hubs in the Limpopo province. In the second stage, we applied a simple random sampling technique to select farmers for the survey. Our survey data is collected from farmers with the aid of structured questionnaires in the study area. Enumerators conducted a one-on-one interview with farmers to complete the questionnaires. The data collection exercise spanned one month between March and April of 2021. A total of 559 questionnaires were sent out, and 555 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 sought information on farmers water quality improvement behaviour. Section C sought information on the farmers' drought experience, whether the farm is prone to DWSs, the losses suffered because of DWSs, the farmer's perception of future droughts and the water conservation measures adopted to mitigate the effects of DWSs. Included in this section were also the WCPs the study sought to investigate and perceived costs of the WCPs amongst others. Section D collected information on institutional factors such as access to credit facilities, provision of government subsidies, secured rights to the land, local government authority imposition of water restrictions amongst others. Prior to finalizing our questionnaires for the face-to-face engagements with farmers, we had two focus group discussions (FGDs). One with farmers and extension service officers and the other with stakeholders and industry experts from the Department of Agriculture, Forestry and Fisheries (DAFF) and the DeBeers Group (the world's largest producer and distributor of diamonds, but with special interest in the water quality and quality farming practices in the Limpopo River Area) amongst others. The purpose of the research was discussed and experts opinions sought on how best to make the questionnaires more relevant and appealing to farmers. Additionally, before commencing the face-to-face interviews, our enumerators with varying levels of education completed (first degree, college and Matric (or high school or secondary)) were taken through a vigorous two-day training process.

4.5 Descriptive Statistics

The descriptive statistics both in Table 1 and Table A2 in Appendix A2 show that 45 percent of farmers use MEPIDs (drip and/or sprinkler irrigations). Thirty percent use conservation tillage. Those that practice cover cropping constitute 81 percent, whilst the sample share of intercropping, mulching and drought tolerant crops constitute 85, 43 and 54 percent, respectively. With respect to the *intensity of adoption*, less than 1 percent of the sample are non-adopters of any form of WCP. Whereas those adopting 1, 2, 3, 4, 5 and 6 WCPs constitute 4.7, 17.7, 26, 29, 18 and 3.9 percent respectively. *Females* constitute 55 percent of our sample. This was not surprising as the 2011 Population Census shows that women constitute 54.4 percent of the population of Folovhodwe and 53.7 percent in Tshiombo (Census, 2011). The average *age* for the sample is 51 years. With regards to *education*, 94 percent of the sample have received at least 6 years or more formal education. Eighty four percent of *spouses* are literate whilst 10 percent of the sample are without spouses. The average farming *experience* is 16 years. Farmers who cultivate their own farmlands or family lands constitute 93 percent. The average *farm size* is 3.27 hectares. On crop choice information, 81 percent of farmers grow *vegetables* as the dominant crop. The vegetables grown include tomatoes, green chilies, spinach, cabbage, okra, green beans, lettuce, egg plants and carrots amongst others. Fifty-four percent grow *maize* as the dominant crop whilst 12 percent grow *fruits*, including mangoes, oranges, and banana amongst others. Thirty one percent grow *spices* including garlic, ginger and hot chilies amongst others whilst 24 percent grow dry beans.

Table 1: Summary Statistics and Measurements of Variables

Variables	Type	Description	Mean	Std D.
Dependent Variables				
MEPIDs	D	1 = drip and/ or sprinkler irrigations, and 0 otherwise	0.553	0.497
Conservation tillage	D	1 = conservation tillage, and 0 otherwise	0.297	0.457
Cover cropping	D	1 = cover cropping, and 0 otherwise	0.813	0.391
Intercropping	D	1 = intercropping, and 0 otherwise	0.852	0.355
Mulching	D	1 if mulching is practiced, and 0 otherwise	0.427	0.495
Drought tolerant crops	D	1 = drought tolerant crops, and 0 otherwise	0.541	0.498
Number of WCPs adopted	Ca	Total number of WCPs adopted on a farm. Ranges from 0 to 6 (0 means no adoption)	3.482	1.245
Explanatory Variables				
Gender	D	1 = female and 0 otherwise	0.553	0.497
Age	C	Age of the farmer	50.98	15.11
Age squared	C	Age squared	2826.9	1620.3
Education	D	1 = literate farmer, and 0 otherwise	0.940	0.237
Spousal education	Ca	Educational status of farmer's spouse. 0 = spouse is non literate, 1 = spouse is literate and 2 = farmer has no spouse or is single	3.304	1.360
Experience	C	Years of farming	16.22	9.88
Farm ownership	D	1 = land owned by farmer, and 0 otherwise.	0.929	0.256
Farm size	C	Total farm size cultivated in hectares	3.262	3.927
Vegetables	D	1 = farmer allots largest land share to vegetables, and 0 otherwise	0.811	0.392
Maize	D	1 = farmer allots largest land share to maize, and 0 otherwise	0.544	0.498
Fruits	D	1 = farmer allots largest land share to fruits, and 0 otherwise	0.117	0.321
Spice	D	1 = farmer allots largest land share to spices, and 0 otherwise	0.306	0.461
Beans	D	1 = farmer allots largest land share to beans, and 0 otherwise	0.241	0.428
Diversified farming	D	1 = farmer grows different crops, and 0 otherwise	1.376	0.485
Market access	D	1 = farmer has market access (sells to main customers/supermarkets), and 0 otherwise	0.807	0.395
Distance to market	C	Distance to the nearest market or urban center	55.70	27.42
Location of farm	D	1 = farm is upstream and 0 otherwise	1.376	0.485
Source of water	D	1 = surface water is main source for farming, and 0 otherwise	1.104	0.306
Proximity to water	D	1 = ≤ 1 kilometer from source, and 0 otherwise	1.259	0.438
Farm income	D	1 = total annual farm income is greater than 11000 ZAR, and 0 otherwise	0.800	0.400
Off-farm income	D	1 = farmer has off-farm income, and 0 otherwise	0.313	0.464

Household size	C	Total number of people in the household	6.281	2.549
Member cooperative	D	1 = member of a cooperative or a farmers' associations, and 0 otherwise.	0.622	0.485
Drought experience	D	1 = experienced droughts in the last 5 years, and 0 otherwise.	0.995	0.073
Perception of droughts	D	1 = perceives future droughts to get worse, and 0 otherwise	0.541	0.498
Perceived cost	D	1 = farmer perceives cost of implementing WCPs as expensive, and 0 otherwise.	0.657	0.474
Extension services	D	1 = farmer has access to extension services, and 0 otherwise.	0.969	0.172
Access to credit	D	1 = farmer has access to credit, and 0 otherwise.	0.205	0.404
Secured land rights	D	1 = farmer has secured rights, and 0 otherwise	0.756	0.429

NOTE: **D**, **C** and **Ca** means dummy, continuous and categorical variables.

Furthermore, 93 percent of the sample have *diversified* farms growing a mixture of the crops mentioned above. Eighty one percent of the sample have *access to markets*, supplying to a few main customers, supermarkets and malls. The mean *distance to the nearest market* is 56 kilometers. For *location*, 63 percent of the sample is made up of upstream farmers whilst 90 percent use surface water sources for farming. For *proximity to water*, farmers less than a kilometer away from the water source constitute 74 percent of the sample. Farmers with annual *farm income* greater than 11,000 South African Rands (ZAR) (US$ 733.91 in April 2021) constitute 80 percent of the sample, whilst 69 percent have no *off-farm income*. The average number of people in a *household* is 6. Those with membership in *cooperative associations* constitute 62 percent. On *drought experience,* 99 percent affirm that they have experienced some droughts in the last 7 years, whilst 54 percent of farmers *perceive future droughts* to get worse. Sixty six percent of farmers *perceive cost* of especially drip and sprinkler irrigations and some of the other WCPs to be costly. Seventy nine percent of the sample does not have *access to credit,* whilst 97 percent report *access to extension services* and 76 percent have *secured land rights* to their farmlands.

5. Results and Discussions

5.1 Results of the Multivariate Probit Model (MVP)

The results of our MVP model reported in Table 2 show first, that the likelihood ratio test [chi2(15) = 77.14; Prob > chi2 = 0.0000] rejects the null hypothesis that the covariance of the error terms across the equations are not correlated. This indicates that, the pair–wise correlation coefficients across the error terms of the multiple decision equations are correlated. Second, the Wald test's [Wald chi2(180) = 647.62; Prob > chi2 = 0.000)] rejection of the null hypothesis that all regression coefficients in each equation are jointly equal to zero shows that the MVP model fits the data well. These statistics justify our use of the MVP model in analyzing farmers bundling of WCPs in the LRB.

5.1.1 Inter-relationships amongst WCPs in the LRB

The pair-wise correlation coefficients across the residuals of the MVP model that indicate interdependence amongst the six WCPs, show significant and positive association amongst combinations such as cover cropping and MEPIDs; intercropping and MEPIDs; mulching and MEPIDs; intercropping and conservation tillage; intercropping and cover cropping and growing drought tolerant crops and intercropping. This suggest that these combinations are complements and that farmers adopt them together, confirming significant bundling of these WCPs. This outcome is further confirmed by the summary statistics of the *intensity of adoption* in Table A2 of Appendix A2, where cumulatively 95 percent of farmers are bundling 2, 3, 4, 5 and 6 WCPs on the farms. However, the pair-wise correlation of the following combinations—conservation tillage and MEPIDs; drought tolerant crops and MEPIDs; cover cropping and conservation tillage; mulching and conservation tillage; drought tolerant crops and conservation tillage; mulching and cover cropping; drought tolerant crops and cover cropping; mulching and intercropping, and drought tolerant crops and mulching are insignificant, even though most have the right expected apriori signs.

Table 2: Results of the Multivariate Probit Regression

Model Statistics												
Log likelihood												–1510.31
Wald chi2(180)												647.62
Prob > chi2												0.0000
Number of observations												555
Variables	**MEPIDs**		**Conservation tillage**		**Cover cropping**		**Intercropping**		**Mulching**		**Drought tolerant crops**	
	Coeff.	**|z|**	**Coeff.**	**|z|**	**Coeff.**	**|z|**	**Coeff.**	**|z|**	**Coeff.**	**|z|**	**Coeff.**	**|z|**
Gender	–0.041	0.31	0.027	0.22	0.189	1.21	0.077	0.48	**–0.298****	2.30	0.119	0.93
Age	–0.007	0.25	**0.054****	2.02	**–0.075****	2.10	**0.084*****	2.67	–0.007	0.28	–0.017	0.67
Age squared	0.00004	0.14	**–0.0005***	1.80	**0.0007****	2.19	**–0.0008*****	2.56	–0.00002	0.08	0.0002	0.80
Education	**0.613****	2.01	0.251	0.82	0.139	0.39	–0.651	1.42	0.428	1.44	0.122	0.42
Spousal education												
Literate spouse	**–0.784*****	2.74	**–0.444***	1.67	–0.008	0.02	0.518	1.61	**–0.763*****	2.68	–0.236	0.86
Without spouse	**–0.994*****	2.80	–0.127	0.38	–0.400	0.95	0.584	1.44	**–0.617***	1.73	–0.261	0.75
Experience	0.003	0.32	–0.010	1.14	0.002	0.19	0.002	0.14	0.013	1.40	**–0.023****	2.46
Farm ownership	**0.508****	2.02	**0.649****	2.36	**–0.578***	1.71	0.294	1.02	–0.014	0.05	0.233	0.94
Farm size	0.032	1.62	0.018	1.05	0.013	0.56	0.005	0.21	**0.069*****	3.45	**–0.049*****	2.71
Vegetables	0.275	1.48	0.207	1.12	–0.065	0.30	**0.332***	1.76	**0.428****	2.11	0.207	1.13
Maize	0.052	0.37	–0.113	0.83	0.140	0.82	**–0.482*****	2.61	0.184	1.31	**1.259*****	8.87
Fruits	0.245	1.00	–0.205	1.21	0.332	0.98	**0.797***	1.66	0.003	0.01	**–0.470*****	2.69
Spices	**–0.769*****	4.28	0.056	0.26	–0.336	1.56	**0.546****	2.14	**–0.355****	2.12	–0.244	1.02
Beans	–0.068	0.42	0.003	0.02	**0.598*****	2.62	0.061	0.29	0.134	0.85	–0.092	0.58
Diversified farming	–0.382	1.44	0.199	0.74	**1.675*****	6.17	**1.072*****	4.10	–0.268	0.98	–0.251	0.98
Market access	**0.378****	2.21	–0.078	0.46	0.090	0.44	–0.223	1.02	–0.181	1.04	–0.211	1.22
Distance to market	**0.018*****	4.88	0.002	0.65	0.004	0.90	–0.004	1.01	**0.024*****	6.50	–0.004	1.03
Location of farm	–0.132	0.95	**–0.315****	2.28	–0.247	1.54	–0.069	0.41	0.073	0.52	0.123	0.89
Source of water	**1.079*****	4.49	–0.057	0.27	**–0.522****	2.39	–0.339	1.49	0.036	0.17	0.263	1.21
Proximity to water	0.088	0.52	**0.295***	1.88	0.178	0.94	0.164	0.85	–0.165	1.00	**0.269***	1.71
Farm income	**0.728*****	4.24	–0.173	1.01	0.122	0.54	0.203	0.97	0.137	0.77	0.093	0.52
Off-farm income	**0.422*****	2.91	**–0.380*****	2.59	0.048	0.28	0.0001	0.01	0.163	1.11	–0.118	0.81

Household size	–0.006	0.22	–0.002	0.10	0.036	1.15	0.002	0.06	–0.014	0.55	0.055**	2.21
Member cooperative	0.134	0.86	–0.054	0.36	–0.635***	3.11	–0.276	1.33	–0.430***	2.76	–0.062	0.39
Drought experience	0.677	0.88	–1.015	1.18	1.938**	2.03	1.610	1.58	0.059	0.07	0.508	0.55
Perception of droughts	–0.239	1.64	0.112	0.78	–0.522***	2.94	0.191	1.04	0.229	1.58	–0.114	0.77
Perceived cost	0.227	1.61	–0.303**	2.25	0.409**	2.48	–0.619***	3.18	0.049	0.36	–0.309**	2.22
Extension services	0.705	1.63	0.493	1.15	0.556	1.17	0.408	1.06	0.663	1.53	–0.406	1.04
Access to credit	0.162	1.22	–0.135	1.03	0.128	0.80	–0.367**	2.29	0.069	0.52	–0.268**	2.01
Secured land rights	0.675***	3.58	–0.246	1.31	0.138	0.64	0.500**	2.36	0.259	1.33	0.360*	1.91
Constant	–4.752***	3.61	–1.448	1.08	–0.858	0.56	–3.578**	2.34	–1.559	1.20	–0.587	0.43

Interrelationships

<table>
<tr><th>Correlations</th><th>Coefficient</th><th>|z-value|</th></tr>
<tr><td>rho21 (Conservation tillage and MEPIDs)</td><td>0.095</td><td>1.26</td></tr>
<tr><td>rho31 (Cover cropping and MEPIDs)</td><td>0.208**</td><td>2.35</td></tr>
<tr><td>rho41 (Intercropping and MEPIDs)</td><td>0.254***</td><td>2.74</td></tr>
<tr><td>rho51 (Mulching and MEPIDs)</td><td>0.158**</td><td>2.06</td></tr>
<tr><td>rho61 (Drought tolerant crops and MEPIDs)</td><td>0.038</td><td>0.49</td></tr>
<tr><td>rho32 (Cover cropping and conservation tillage)</td><td>0.035</td><td>0.38</td></tr>
<tr><td>rho42 (Intercropping and conservation tillage)</td><td>0.673***</td><td>8.62</td></tr>
<tr><td>rho52 (Mulching and conservation tillage)</td><td>–0.073</td><td>0.97</td></tr>
<tr><td>rho62 (Drought tolerant crops and conservation tillage)</td><td>0.038</td><td>0.51</td></tr>
<tr><td>rho43 (Intercropping and cover cropping)</td><td>0.311 ***</td><td>3.34</td></tr>
<tr><td>rho53 (Mulching and cover cropping)</td><td>0.055</td><td>0.61</td></tr>
<tr><td>rho63 (Drought tolerant crops and cover cropping)</td><td>0.013</td><td>0.15</td></tr>
<tr><td>rho54 (Mulching and intercropping)</td><td>–0.032</td><td>0.36</td></tr>
<tr><td>rho64 (Drought tolerant crops and intercropping)</td><td>0.165 **</td><td>2.02</td></tr>
<tr><td>rho65 (Drought tolerant crops and mulching)</td><td>–0.012</td><td>0.15</td></tr>
</table>

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho32 = rho42 = rho52 = rho62 = rho43 = rho53 = rho63 = rho54 = rho64 = rho65 = 0

chi2(15) = 77.1373 Prob > chi2 = 0.0000

Note: ***, ** and * denote 1, 5 and 10 percent significance levels respectively

5.1.2 Determinants of multiple WCPs adoption in the LRB

Our results show that gender influences the adoption of mulching negatively. That is, *female* farmers are less likely to adopt mulching compared to their male counterparts. Gender, however, is insignificant for the rest of the WCPs. This result is anticipated as previous studies show that gender inequality due to income, asset ownership and right to productive resources, education, etc., is linked to lower adoption rates of new agricultural technologies by females (Doss & Morris, 2000; Ndiritu et al., 2014). Our results are in accordance with Fisher et al. (2018), who found female headed households to be low adopters mulching. However, Mango et al. (2017) did not find gender to significantly influence the adoption of land, soil and water conservation technologies including mulching in their study.

Age is quadratic and statistically significant for conservation tillage, cover cropping and intercropping. However, *age* is insignificant for the other WCPs. The results demonstrate first that, the adoption of conservation tillage and intercropping increase with *age* at a decreasing rate, until a turning point is reached at age $-\frac{0.054}{2(-0.0005)} = 54$ years for conservation tillage and at age $-\frac{0.084}{2(-0.0008)} = 53$ years for intercropping. This implies that the adoption of conservation tillage and intercropping increases with younger farmers until ages 54 and 53 years respectively, after which their adoption decreases with older farmers, all else constant. This outcome according to Mauceri et al. (2007) and Adesina and Zinnah (1993), implies as farmers grow older, there is an increase in risk aversion and a decreased interest in long term investment in the farm and, therefore, turn to decrease their adoption rates, whilst younger farmers on the other hand, are typically less risk-averse and are more willing to try new technologies. Hence, this result. Second, the adoption of cover cropping decreases with *age* at an increasing rate, until a turning point is reached at $-\frac{-0.075}{2(0.0007)} = 54$ years. This indicates that the adoption of cover cropping decreases with younger farmers until age 54 years when the adoption increases with older farmers, all else constant. This is consistent with the adoption literature's assertion that as farmers age, they are assumed to have gained knowledge and experience over time and are better placed to evaluate information and the benefits of a technology than younger farmers (Kariyasa & Dewi 2011; Mignouna et al, 2011). Therefore, they tend to have a higher probability of adoption, which we see with respect to cover cropping. Our results show the importance of modelling *age* as quadratic in the adoption literature, as it signals that there is probably an age threshold for the adoption of these WCPs, which failing to acknowledge can bias the estimates of a study.

With respect to *education,* literate farmers are more likely to adopt MEPIDs. Whilst *education* has no effect on the other WCPs. This finding is consistent with the adoption literature's assertion that literate farmers are better informed about the existence and performance of technologies and may be better placed to appreciate the advantages of adopting such technologies (Abdulai et al., 2011; Alam, 2015). Our results agree with Zhang et al. (2019). For *spousal education,* farmers with literate spouses and those without spouses compared to farmers whose spouses are non-literate are less likely to adopt MEPIDs, mulching and conservation tillage, all else constant. This outcome is unexpected, as literate spouses are expected to assist their partners in making sound farm decisions and assisting with resources, that may increase adoption. A probable explanation, however, may be that the decisions to adopt WCPs may be an isolated one that is not part of the overall household decision.

Farming experience influences the adoption of drought tolerant crops negatively but is insignificant for the rest of the WCPs. The results imply that more experienced farmers are less likely to adopt drought tolerant crops. This is intriguing but not surprising. A possible reason may be that farmers want to avoid the seasonal financial obligations associated with having to buy drought tolerant seeds every farming season. Even though drought tolerant crops produce seeds, the seeds lose some of their drought protection capabilities, therefore farmers are required not to save seeds from their harvest but to buy new seeds at the start of every farming season. This together with other factors such as high seed prices, suitable soil conditions, unavailability of improved seeds, inadequate information and perceived attributes of different varieties of drought tolerant crops amongst others are the major barriers limiting the adoption of this practice (Cavatassi et al., 2011; Fisher & Snapp, 2014; Fisher et al., 2015; Westengen & Brysting 2014). Also, according to Kumar et al. (2020), such an aversion may be because the drought tolerant crop techniques have only recently been introduced and experienced farmers compared to the relatively not so experienced farmers are less likely to quickly switch to their adoption.

Furthermore, *farm ownership* shows that farmers who cultivate their own farmlands or family lands compared to those on rented or leased lands are more likely to adopt MEPIDs and conservation tillage but less likely to adopt cover cropping, all else constant. This outcome underscores the important role *farm ownership* plays in the adoption of WCPs in the LRB. The results support the Marshallian inefficiency hypothesis, which asserts that inputs use by the tenant on rented or borrowed land is lower or less efficient than on owned land (Kpadonou et al., 2017). *Farm size,* which is used to depict the impact of wealth on the adoption decision process (Abdulai et al., 2011), increases the probability of adopting mulching but is negatively correlated with the adoption of drought tolerant crops. The results indicate that wealthier farmers are more likely to adopt mulching but less likely to adopt to drought tolerant crops. Our results agree with Mugonola et al., (2013), who found *farm size* to increase the likelihood of adopting soil and water conservation technologies including mulching, but contradict Martey and Kuwornu (2021), who found *farm size* to be negatively associated with the use of mulching. For farmers aversion of drought tolerant crops with respect to *farm size,* significance reasons have been adduced above to this effect.

Consistent with our expectations, farmers with *vegetables* as their dominant crop are more likely to adopt intercropping and mulching, all else constant. Vegetable cultivation requires adequate cooling at the roots of plants. This is mostly achieved through mulching. Additionally, intercropping is a common practice amongst these farmers. We found evidence of pure vegetable intercropping systems such as spinach–garlic, tomatoes–lettuce and egg plants–okra amongst others during our survey. Studies such as (Guvenc & Yildirim, 1999; Yildirim & Guvenc, 2005) highlight intercropping in vegetables as an important sustainable farming practice that increases productivity of vegetables and net income. *Maize* farmers are less likely to adopt intercropping, but more likely to adopt drought tolerant crops. Generally, most farmers whose dominant crop is maize do not intercrop their fields in the study area. Given that *maize* and *cowpea* are the dominant drought tolerant crops grown in South Africa, this finding is expected. *Fruit* farming is positively associated with the adoption of intercropping but negatively associated with the adoption of drought tolerant crops. We found significant evidence of intercropping amongst fruit farmers during the survey exercise. The findings of Mossie et al. (2020) corroborate our results. However, the adoption of drought tolerant crops is not evident amongst fruit farmers in the study area.

Farmers cultivating s*pices* as their dominant crop are less likely to adopt MEPIDs and mulching but are more likely to adopt intercropping. According to these farmers they would prefer the drip irrigation method for their operations, but the cost is currently a major constraint. Again, the sprinklers which behaves like rain beats down the flowers of their crops, especially chilies/peppers preventing yield. Thus, the cost of the drip method and not too suitable sprinklers are the cause of their aversion. The low adoption of mulching is however, surprising as this is a major practice amongst farmers of *spices*. We found during the survey that some farmers especially those with farm sizes greater than a hectare had issues with the method. They complained that it is not only expensive to apply, but very difficult too to execute, as it requires large amount of labour and mulch. This is confirmed by Junge et al. (2009), who found in their study that cover cropping and mulching were performed only on areas that were smaller than one hectare. Furthermore, the probability of adopting cover cropping increases with *beans* farmers but it is insignificant for the other WCPs. Given that one of the cover crops cultivated in the study area is beans, this finding is anticipated.

In accordance with our expectations, farmers with *diversified farms* (growing multiple crops) compared to their colleagues with *specialized farms* (growing one crop) are more likely to adopt cover cropping and intercropping, all else constant. This finding is consistent in practice because farmers who grow different crops (diversified) can intercrop or grow cover crops to meet the different needs of the different crops, including complementing and compensating each other amongst others. Our results agree with Jensen et al. (2020) and He et al. (2007). This result portrays *diversified farming* as an important pathway in promoting the adoption of different WCPs. *Access to* and *distance to markets* influence the adoption of MEPIDs positively. *Distance to market* further influences the adoption of mulching positively. This suggests that farmers with *access to markets* and those whose farms are nearer to markets are more likely to adopt MEPIDs and mulching practices, all else constant. The nearest major market is 56 km (average distance) away from our study area. The literature suggests that greater distance between the farm gate and the nearest market indicates poor access to market information, farm inputs, and local weather information, which all constrain adoption (Mariano et al., 2012). Our results indicate that most farmers in our sample are not constrained by *distance* or *access to market*, hence the higher probability of adopting MEPIDs and mulching. This result is substantiated by Ersado et al. (2004) and Nkonya et al. (2005), who report that *distance* and better *market access* increases the adoption of soil and water conservation practices (SWCs). However, Darkwah et al. (2019) found *distance* to the nearest market to be negatively associated with the adoption of SWCs.

On *location of the farm,* our results show that downstream farmers compared to upstream farmers are less likely to adopt conservation tillage. This is unexpected because according to

Chuchird et al. (2017), upstream communities have better access to water resources compared to downstream communities in terms of water availability, quality, and timing. Therefore, we expect conservation tillage to be an attractive and cheaper option for downstream farmers to conserve water. A study by Mandiringana et al. (2006), which investigated the acceptance of conservation tillage in South Africa, reported that the high labour input requirements of the method generally lowered its adoption rate, even if farmers' potential for soil and water conservation was high. This, notwithstanding, the challenge for farmers whether downstream or upstream is to identify the most effective WCP that can increase crop production while reducing water usage.

In accordance with previous studies that report that farmers using exclusively groundwater are more likely to adopt modern irrigation technologies (Alam, 2015; Caswell & Zilberman, 1985; Namara et al., 2007), farmers whose *source of water* is underground compared to those who use surface water sources are more likely to adopt MEPIDs but less likely to adopt cover cropping. The low adoption of cover cropping by groundwater users is not surprising. This is because it is challenging to send water to the root zone of all these cover crops because of the use of micro-irrigators. The result on *proximity to water source* (ground and surface sources), indicate that farmers who are more than a kilometer away from the source of water compared to their counterparts who are less than a kilometer away are more likely to adopt conservation tillage, all else constant. Farmers who are more than a kilometer away from the water source suffer water poverty more than those less than a kilometer away. A study of smallholder farmers by Maponya and Mpandeli (2012) in the Tshiombo irrigation scheme in the Limpopo Province emphasized that, farmers who have their plots far away from the canal system, suffer serious water access challenges and low crop yields. It is therefore, not surprising that conservation tillage is an attractive option for this category of farmers more than those who are less than a kilometer away from the source of water.

Consistent with the findings of Abegunde et al. (2020) and Ndamani and Watanade (2016), farmers whose annual *farm income* is greater than 11,000 ZAR are more likely to adopt MEPIDs, all else constant. Further, farmers with *off-farm activities* are more likely to adopt MEPIDs but less likely to adopt conservation tillage. The finding of *off-farm income* is consistent with Diiro (2013). Fluctuations in farm incomes can affect farm decisions and the ability to sustain operations including the adoption of innovations (Mishra & Sandretto, 2002). Therefore, an additional source of income from *off-farm* may enable farmers overcome credit constraints normally faced by rural farm households to adopt new innovations. These findings demonstrate the importance of *farm income* and *off-farm income* in providing farmers with greater incentives for investing in WCPs adoptions. *Household size* increases the probability of adopting drought tolerant crops, all else constant. The finding supports the notion that the likelihood of adopting some WCPs (especially, drought tolerant crops) rises as household labour becomes more abundant. For this practice some amounts of labour is required for some management practices including the removal of weeds and alien species competing with drought tolerant crops for water and even mulching of the crops in some cases. It is therefore, not surprising that *household size* increases the probability of adopting drought tolerant crops. Contrary to this findings, Bekele and Drake (2003) found a negative relationship between *household size* and adoption of SWCs. Farmers with *membership in a cooperative* are less likely to adopt cover cropping and mulching, all else constant. This result is intriguing, as the adoption literature suggests that farmers' membership in cooperatives increases their probability of adopting new agricultural technologies (Mignouna et al., 2011). However, as explained earlier cover cropping and mulching are mostly feasible in small farm sizes, and this may be accounting the aversion with respect to those with *membership in cooperatives*.

Farmers who in the last 7 years have *experienced* one or more droughts are more likely to adopt cover cropping. *Drought experience* does not significantly influence the adoption of the other WCPs. This finding is substantiated by Anyokwu and Olabisi (2019) who report that the potential to increase the adoption of SWCs, including cover crops increased with *drought experience.* With regards to *perceive future droughts,* farmers who expect *future droughts* to get worse are less likely to adopt cover cropping, all else constant. This outcome is not surprising, because during the survey farmers alluded to the fact that some of the previous droughts were prolong and severe, causing the death of most crops including cover crops. Therefore, if future droughts would get worse, cover cropping may not be an attractive option for conserving water or adapting to climate change. In line with the literature's assertion that, if farmers perceive the incremental net benefits of an innovation to exceed its cost, then an adoption would occur (Dridi & Khanna, 2005; Foster & Rosenzweig, 2010), farmers who *perceive the cost* of implementing WCPs to be high are more likely to cover cropping but are less likely to adopt conservation tillage, intercropping and drought tolerant crops, all else being constant. The increased adoption of cover cropping with respect to with *perceived cost* is not surprising because amongst the six WCPs of this study, it is the only practice farmers noted as being cheap and required no technical know-how to implement. Similarly, the low adoption of conservation tillage, intercropping and drought tolerant crops with respect to the cost variable is expected. Various arguments have been advanced to this effect above. Studies such as Ouma et al. (2002) and Wekesa et al. (2003) report high cost of technology as a hinderance to adoption.

Access to extension services does not significantly influence the adoption of any of the WCPs in this study. This is unanticipated as most studies report a positive relationship between extension services and agricultural technology adoptions (Mignouna et al., 2011; Uaiene, 2011). This result, however, is not unique, as Gebru et al. (2020) and Kanyenji et al. (2020) found *access to extension services* to have no significant effect in influencing farmers' adoption of SWCs. A possible explanation to our result could be that extension services officers in the study area are inactive in providing effective extension services, particularly in the area of the adoption of WCPs, or that extension services officers use outmoded extension methods. Farmers with *access to credit* are less likely to adopt intercropping and drought tolerant crops, all else constant. This outcome is intriguing since one of the critical barriers to successful adoption and scaling up of sustainable farming practices and technologies is the fact that they often require significant initial investments while benefits could be realized in a few seasons (Giller et al., 2009). Also, improved *access to credit* should help alleviate liquidity constraints and thus enhance access to complimentary technical, mechanical, and capital inputs (Deressa et al., 2009; Mutyasira et al., 2018b). The implication of our results may be that farmers with *access to credit* may be adopting other WCPs that require larger capital outlays, such as MEPIDs to conserve water. In contrast to our findings is Kassie et al. (2015), whilst Mulwa et al. (2017) found *credit* as a major determinant of farmers' decision to adapt to climate change. Ahmed (2015) did not find *access to credit* to be significant in explaining the adoption decisions of farmers in the Central Rift valley of Ethiopia.

Finally, in line with our *apriori* expectations, farmers with *secured rights* to their farmlands are more likely to adopt MEPIDs, intercropping and drought tolerant crops, all else constant. This finding is expected since most studies show the influence of *secured land rights* as positive in agricultural adoption decisions (Gebremedhin & Swinton, 2003; Zeweld et al., 2017). Our results suggest that *secured land rights* encourage farmers' adoption of WCPs on their own farmlands than on rented (or borrowed) farmlands, possibly reflecting tenure insecurity and Marshallian inefficiency (Kassie et al., 2013; Teklewold et al., 2013). Our results are consistent with Kassie et al. (2013) and Teklewold et al. (2013).

5.2 Determinants of the Intensity of Adoption of WCPs in the LRB

In Table 3, we report the results of the OPM and the marginal effects for each outcome. The Chi-square statistic for our OPM is highly significant [chi2(30) = 166.03; Prob > chi2 = 0.0000]. This suggest that the null hypothesis that all slope coefficients are jointly equal to zero is rejected. As in the MVP model, the results of the OPM also show that several factors influence the intensity of adoption of WCPs. As noted earlier, the direct interpretation of the estimated coefficients of the OPM are less informative, thus, we focus attention on the marginal effects for each outcome. Specifically, the marginal effects show that the number of WCPs adopted increases amongst farmers with *literate spouses* and those *without spouses* up to 3 WCPs. The results show that these farmers are 5.9 percent more likely to adopt up to three WCPs, all else being constant. *Farmers who own* their farms are 3.1 percent more likely to adopt more than four WCPs, all else constant. Farmers whose dominant crop is *vegetable* and *maize* production are found to have higher intensity of adoption. The farmers are 2.7 and 3.0 percent respectively more likely to implement all the six WCPs, all else constant. *Spice* farming is associated with being 4.9 percent more likely to adopt only up to three WCPs.

Farmers with *diversified farms* are 5.1 percent more likely to implement all the six WCPs, all else constant. This outcome is consistent with the MVP model's and shows importance of *diversified farming* in the bundling of WCPs by farmers. Additionally, the intensity of adoption of WCPs increases with *distance to market* by 0.09 percent for full implementation of all 6 WCPs, all else kept constant. Farmers with annual *farm income* greater than 11,000 ZAR are 2.1 percent more likely to implement all the six WCPs, all else being constant. This also confirms the MVP model's and shows relative importance of cash in the bundling of WCPs by farmers. Further, the number of WCPs adopted increases amongst farmers who are *members of a cooperative*. They are 2.4 percent more likely to implement up to three WCPs. The number of WCPs adopted is significantly high amongst farmers with *access to extension services*. Farmers with *access to extension services* are 3.9 percent more likely to implement all the six WCPs, all else kept constant. This finding shows that a factor can have varying influence on both the probability and the intensity of adoption. In the MVP model, *access to extension services* is insignificant for all WCPs, but with the intensity of adoption it is importantly increasing the number of WCPs adopted. Consistent with the MVP model's result on *secured land rights* and the Marshallian inefficiency hypothesis. Farmers with *secured land rights* are 3.1 percent more likely to adopt all six WCPs, all else being constant.

Table 3: Results of the Ordered Probit Model and the Marginal Effects of each Outcome

Intensity of WCP adoption			**Marginal Effects of each Outcome**													
	Ordered Probit		**Pr(Y=0|X)**		**Pr(Y=1|X)**		**Pr(Y=2|X)**		**Pr(Y=3|X)**		**Pr(Y=4|X)**		**Pr(Y=5|X)**		**Pr(Y=6|X)**	
	Coef.	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**
Gender of farmer	–0.013	0.13	0.0002	0.13	0.001	0.13	0.002	0.14	0.001	0.13	–0.001	0.14	–0.002	0.13	–0.001	0.13
Age	0.011	0.57	–0.0002	0.55	–0.001	0.56	–0.002	0.56	–0.001	0.56	0.001	0.56	0.002	0.56	0.001	0.56
Age squared	–0.0001	0.55	1.5e-06	0.53	7.2e-06	0.54	0.00001	0.55	8.3e-06	0.55	–8.6e-06	0.55	–0.00002	0.55	–7.2e-06	0.55
Education	0.312	1.44	–0.005	1.21	–0.023	1.40	–0.052	1.44	–0.027	1.42	0.027	1.44	0.056	1.44	0.023	1.40
Spousal education																
Literate spouse	–0.526***	2.58	0.005*	1.88	0.029***	3.07	0.078***	2.90	0.059**	2.17	–0.023***	3.69	–0.097***	2.59	–0.054**	1.90
Without spouse	–0.516**	2.01	0.005	1.39	0.028**	1.90	0.077**	2.06	0.059**	1.93	–0.022	1.42	–0.095**	2.04	–0.053*	1.74
Experience	–0.003	0.46	0.00005	0.45	0.0002	0.46	0.0005	0.46	0.0003	0.46	–0.0003	0.46	–0.0006	0.46	–0.0002	0.46
Farm ownership	0.349*	1.87	–0.005	1.43	–0.026*	1.79	–0.058*	1.86	–0.029*	1.84	0.031*	1.83	0.063*	1.87	0.026*	1.80
Farm size	0.022	1.60	–0.0003	1.29	–0.002	1.55	–0.004	1.59	–0.002	1.58	0.002	1.56	0.004	1.60	0.003	1.55
Vegetables	0.364***	2.64	–0.006*	1.68	–0.027**	2.47	–0.060***	2.64	–0.031**	2.50	0.032***	2.59	0.065***	2.61	0.027**	2.42
Maize	0.409***	3.91	–0.006*	1.89	–0.030***	3.32	–0.068***	3.84	–0.035***	3.65	0.036***	3.59	0.073***	3.81	0.030***	3.38
Fruits	0.092	0.55	–0.001	0.54	–0.007	0.55	–0.015	0.55	–0.008	0.55	0.008	0.55	0.017	0.55	0.007	0.55
Spice	–0.568***	4.38	0.009**	1.95	0.042***	3.59	0.094***	4.28	0.049***	4.02	–0.049***	3.88	–0.102***	4.34	–0.042***	3.58
Beans	0.078	0.66	–0.001	0.63	–0.006	0.66	–0.013	0.66	–0.007	0.66	0.007	0.66	0.014	0.66	0.006	0.66
Diversified farming	0.700***	3.65	–0.011*	1.84	–0.052***	3.30	–0.116***	3.61	–0.059***	3.23	0.061***	3.44	0.125***	3.54	0.051***	3.13
Market access	–0.036	0.28	0.001	0.28	0.003	0.28	0.006	0.28	0.003	0.28	–0.003	0.28	–0.006	0.28	–0.003	0.28
Distance to market	0.013***	4.87	–0.0002**	1.99	–0.0009***	3.83	–0.002***	4.73	–0.001***	4.41	0.001***	4.22	0.002***	4.79	0.001***	3.87
Location of farm	–0.134	1.31	0.002	1.13	0.009	1.28	0.022	1.30	0.011	1.30	–0.012	1.29	–0.024	1.31	–0.009	1.28
Source of water	0.142	0.91	–0.002	0.85	–0.010	0.91	–0.023	0.91	–0.012	0.91	0.012	0.91	0.025	0.91	0.010	0.90
Proximity to water	0.175	1.47	–0.003	1.20	–0.013	1.44	–0.029	1.47	–0.015	1.45	0.015	1.45	0.031	1.46	0.013	1.44
Farm income	0.289**	2.22	–0.004	1.56	–0.021**	2.07	–0.048**	2.22	–0.025**	2.18	0.025**	2.17	0.052**	2.21	0.021**	2.08
Off-farm income	0.035	0.33	–0.0005	0.33	–0.003	0.33	–0.006	0.33	–0.003	0.33	0.003	0.33	0.006	0.33	0.003	0.33
Household size	0.016	0.85	–0.0002	0.79	–0.001	0.84	–0.003	0.85	–0.001	0.85	0.001	0.85	0.003	0.85	0.001	0.84
Member cooper.	–0.285**	2.48	0.004*	1.65	0.021**	2.29	0.047**	2.46	0.024**	2.40	–0.025**	2.38	–0.051**	2.47	–0.021**	2.30
Drought experience	0.733	1.16	–0.011	1.03	–0.054	1.14	–0.121	1.16	–0.063	1.16	0.064	1.15	0.131	1.16	0.054	1.14
Perception drought	–0.062	0.58	0.001	0.56	0.005	0.58	0.010	0.58	0.005	0.58	–0.005	0.58	–0.011	0.58	–0.005	0.58
Perceived cost	–0.112	1.09	0.002	0.98	0.008	1.07	0.019	1.08	0.009	1.08	–0.009	1.08	–0.020	1.09	–0.008	1.07
Extension services	0.526*	1.93	–0.008	1.45	–0.039*	1.84	–0.087**	1.93	–0.045**	1.90	0.046*	1.91	0.094**	1.92	0.039*	1.84
Access to credit	–0.099	1.01	0.002	0.92	0.007	1.00	0.016	1.01	0.008	1.01	–0.009	1.01	–0.017	1.01	–0.007	0.99
Secured land rights	0.415***	2.91	–0.006*	1.76	–0.031***	2.66	–0.069***	2.89	–0.035***	2.78	0.036***	2.84	0.074***	2.89	0.031***	2.60

/cut1_cons	0.957	0.97						
/cut2_cons	**1.973****	2.04						
/cut3_cons	**3.004*****	3.10						
/cut4_cons	**3.865*****	3.98						
/cut5_cons	**4.798*****	4.92						
/cut6_cons	**5.940*****	6.04						
Log likelihood	–818.42							
Pseudo R^2	0.1000							
chi2(30)	166.03							
Prob > chi2	0.0000							
Number of obs.	555	555	555	555	555	555	555	555

Note: ***, ** and * denote 1, 5 and 10 percent significance levels respectively

6. Conclusion and policy implications

The study investigated the factors that drive farmers' multiple adoption (bundling) of Six WCPs and the intensity of their adoption in the LRB in South Africa. Two estimations strategies—the multivariate probit model and the ordered probit model were used to estimate the relationships from our survey data. The results from the MVP model that estimated farmers' probability of multiple adoption and the interrelationships amongst the six WCPs show strong evidence of the bundling of WCPs in the LRB. Additionally, key socio-economic, farm, farmer, institutional and environmental factors like gender, age, education, spousal education, farm ownership, off-farm and farm incomes, and distance to market amongst others, trigger the probability and extent of adoption of multiple of the six WCPs differently. While some determinants influence the adoption of the various WCPs positively, others do so negatively. Additionally, not all the parameter estimates are statistically significant. With respect to the OPM, the marginal effects show that the various determinants of the intensity of adoption of WCPs have varying marginal probabilities. Our results offer some important implications for policy. WCPs are interdependent, therefore, the design of any effective strategy(ies) aiming at increasing their uptake rate must take this interdependence into consideration. Majority of female farmers suffer from resource constraints, which makes them low adopters of more efficient WCPs. Therefore, to bridge this gender gap in the adoption of more efficient performing WCPs, we recommend policy interventions that make the adoption of these WCPs attractive to female farmers. Additionally, we advocate for initiatives that support education, training and continuous awareness creation on the likely effects of climate change on farmers. Similarly, we recommend the education and training of extension services officers on modern best agricultural practices that incorporate the adoption of WCPs into farming to mitigate water scarcity at the farm level in response to DWSs. We further advocate for improved access to credit facilities that are tailor made to help farmers who are financially vulnerable to acquire these technologies on soft terms. Finally, we advocate for special initiatives that aim specifically at the uptake of conservation tillage and the planting of drought tolerant crops in severe drought-stricken areas. These, if done successfully can go a long way to increase the uptake rate of these WCPs, which in tend would increase agricultural productivity, improve incomes and enable even higher adoptions.

This study is not without limitations. First, it is limited by its scope, which focused only on the determinants and number of WCPs adopted but not the effects or challenges of the adoption of

WCPs. The second limitation has to do with our desire to cover a greater stretch of the Limpopo Water Management Area (WMA) or even the entire part of the Limpopo River in South Africa, but budget constraints hindered us. This study can further be advanced with similar research in the other parts of the Limpopo WMA or even in other parts of South Africa. This could be done including other variables (like temperature and rainfall changes, weather forecast figures, and soil types, amongst others) or same variables as this study. Replicating the study this way could give a higher power of generalizability to the current study. In the end, WCPs can make enormous contributions by not only helping farmers produce more with less water but can lessen the potential impact of climate change on agriculture by helping farmers cope significantly with droughts.

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References

Abdulai, A., & Huffman, W. (2014). The adoption and impact of soil and water conservation technology: An endogenous switching regression application. *Land economics*, *90*(1), 26-43. https://doi.org/10.3368/le.90.1.26

Abdulai, A., Owusu, V., & Bakang, J.E.A. (2011). Adoption of safer irrigation technologies and cropping patterns: evidence from Southern Ghana. *Ecological Economics. 70* (7), 1415–1423. https://doi.org/10.1016/j.ecolecon.2011.03.004

Abegunde, V. O., Sibanda, M., & Obi, A. (2019). Determinants of the adoption of climate-smart agricultural practices by small-scale farming households in King Cetshwayo District Municipality, South Africa. *Sustainability*, *12*(1), 195.

Adesina, A. A., & Zinnah, M. M. (1993). Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. *Agricultural economics*, *9*(4), 297-311.

Adusumilli, N., & Wang, H. (2018). Analysis of soil management and water conservation practices adoption among crop and pasture farmers in humid-south of the United States. International Soil and Water Conservation Research, *6*(2), 79 – 86 https://doi.org/10.1016/j.iswcr.2017.12.005

Ahmed, M. H. (2015). Adoption of multiple agricultural technologies in maize production of the Central Rift Valley of Ethiopia. *Studies in Agricultural Economics*, *117*(3), 162-168.

Alam, K. (2015). Farmers' adaptation to water scarcity in drought-prone environments: A case study of Rajshahi District, Bangladesh. *Agricultural water management*, *148*, 196-206.

Alauddin, M., Sarker, M. A. R., Islam, Z., & Tisdell, C. (2020). Adoption of alternate wetting and drying (AWD) irrigation as a water-saving technology in Bangladesh: Economic and environmental considerations. *Land Use Policy*, *91*, 104430.

Alotaibi, B. A., & Kassem, H. S. (2021). Adoption of Sustainable Water Management Practices among Farmers in Saudi Arabia. *Sustainability*, *13*(20), 11260. https://doi.org/10.3390/su132011260

Amsalu, A., & de Graaff, J. (2007). Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. *Ecological Economics, 61*(2), 294–302. https://doi.org/10.1016/j.ecolecon.2006.01.014

Anyokwu, E. E., & Olabisi, S. B. (2019). Land tenure security, soil water conservation adoption and farm household welfare in south-western Nigeria. Center for Development research (ZEF), University of Bonn, Germany. https://ic-sd.org/wp-content/uploads/2019/11/ewere_anyokwu.pdf

Aryal, J. P., Jat, M. L., Sapkota, T. B., Khatri-Chhetri, A., Kassie, M., Rahut, D. B., & Maharjan, S. (2018). Adoption of multiple climate-smart agricultural practices in the Gangetic plains of Bihar, India. *International Journal of Climate Change Strategies and Management*, *10*(3), 407–427. https://doi.org/10.1108/IJCCSM-02-2017-0025

Ayars, J. E., Bucks, D. A., Lamm, F. R., & Nakayama, F. S. (2007). Introduction. In F. R. Lamm, J. E Ayars, & F. S. Nakayama (Eds.), Microirrigation for crop production. *Design, operation, and management*, 1 – 26. Amsterdam: Elsevier.

Baiyegunhi, L. J. S. (2015). Determinants of rainwater harvesting technology (RWHT) adoption for home gardening in Msinga, KwaZulu-Natal, South Africa. *Water SA*, *41*(1), 33-39.

Basche, A. D., Miguez, F. E., Kaspar, T. C., & Castellano, M. J. (2014). Do cover crops increase or decrease nitrous oxide emissions? A meta-analysis. *Journal of Soil and Water Conservation*, *69*(6), 471–482. https://doi.org/10.2489/jswc.69.6.471

Bekele, W., & Drake, L. (2003). Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: A case study of the Hunde-Lafto area. Ecological Economics, 46(3), 437-451. https://doi.org/10.1016/S0921-8009(03)00166-6.

Belachew, A., Mekuria, W., & Nachimuthu, K. (2020). Factors influencing adoption of soil and water conservation practices in the northwest Ethiopian highlands. *International Soil and Water Conservation Research*, *8*(1), 80–89. https://doi.org/10.1016/j.iswcr.2020.01.005

Belderbos, R., Carree, M., Diederen, B., Lokshin, B., & Veugelers, R. (2004). Heterogeneity in R&D cooperation strategies. *International journal of industrial organization*, *22*(8-9), 1237-1263.

Bjornlund, H., Nicol, L., & Klein, K.K. (2009). The adoption of improved irrigation technology and management practices: a study of two irrigation districts in Alberta,Canada. *Agricultural Water Management, 96* (1), 121–131.

Blum, A. (2005). Drought resistance, water-use efficiency, and yield potential—Are they compatible, dissonant, or mutually exclusive? *Australian Journal of Agricultural Research*, *56*(11), 1159. https://doi.org/10.1071/AR05069

Cai, X. M., Rosegrant, M. W. & Ringler, C. (2003) Physical and economic efficiency of water use in the river basin: implications for efficient water management. *Water Resources Research, 39*(1), 1013.

Camp, C. R., Sadler, E. J., Busscher, W. J., Sojlka, R. E., & Karrlin, D. L. (2001). Experiencing with sprinkler irrigation for agronomic crops in the southeastern USA

Caswell, M. F., Zilberman, D. (1985). The choices of irrigation technologies in California. *American Journal of Agricultural Economics*, *67*(2), 224–234.
Cavatassi, R., Lipper, L., & Narloch, U. (2011). Modern variety adoption and risk management in drought prone areas: insights from the sorghum farmers of eastern Ethiopia. *Agricultural Economics*, *42*(3), 279-292.
Census (2011). Main Place 966029, https://census2011.adrianfrith.com/place/966029
Chaves, M. M., Maroco, J. P., & Pereira, J. S. (2003). Understanding plant responses to drought—from genes to the whole plant. *Functional plant biology*, *30*(3), 239-264.
Chen, H., Wang, J., & Huang, J. (2014). Policy support, social capital, and farmers' adaptation to drought in China. *Global Environment Change, 24*, 193–202.
Chuchird, R., Sasaki, N., & Abe, I. (2017). Influencing factors of the adoption of agricultural irrigation technologies and the economic returns: A case study in Chaiyaphum Province, Thailand. *Sustainability*, *9*(9), 1524
Clements, R., J. Haggar, A. Quezada, and J. Torres (2011). Technologies for climate change adaptation–agriculture sector. X. Zhu (Ed.). UNEP Rise Centre on Energy, Climate and Sustainable Development, Roskilde.
Daigh, A. L., Helmers, M. J., Kladivko, E., Zhou, X., Goeken, R., Cavdini, J., ... & Sawyer, J. (2014). Soil water during the drought of 2012 as affected by rye cover crops in fields in Iowa and Indiana. *Journal of Soil and Water Conservation*, *69*(6), 564-573.
Darkwah, K. A., Kwawu, J. D., Agyire-Tettey, F., & Sarpong, D. B. (2019). Assessment of the determinants that influence the adoption of sustainable soil and water conservation practices in Techiman Municipality of Ghana. *International soil and water conservation research*, *7*(3), 248-257.
Dasberg, S., & Or, D. (1999). Practical applications of drip irrigation. In *Drip irrigation* (pp. 125-138). Springer, Berlin, Heidelberg.
De Graaff, J., Amsalu, A., Bodnar, F., Kessler, A., Posthumus, H., & Tenge, A. (2008). Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries. *Applied Geography*, *28*(4), 271-280.
Delgado, J. A., Groffman, P. M., Nearing, M. A., Goddard, T., Reicosky, D., Lal, R., ... & Salon, P. (2011). Conservation practices to mitigate and adapt to climate change. *Journal of soil and water conservation*, *66*(4), 118A-129A. https://doi.org/10.2489/jswc.66.4.118A
Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environment Change, 19*(2), 248–255.
Diallo, M., Aman, N., & Adzawla, W. (2019). Factors influencing the adoption of climate smart agriculture by farmers in Ségou region in Mali. In *Proceedings of the Conference on Climate Change and Food Security in West, Africa Dakar, Senegal* (pp 17-18).
Diiro, G. (2013). Impact of Off-farm Income on Technology Adoption Intensity and Productivity: Evidence from Rural Maize Farmers in Uganda. International Food Policy Research Institute, Working Paper 11
Dinar, A., & Yaron, D. (1992). Adoption and abandonment of irrigation technologies. *Agricultural economics*, *6*(4), 315-332.
Dinar, A., & Wolf, A. (1994). International markets for water and the potential for regional cooperation: economic and political perspectives in the western Middle East. *Economic development and cultural change*, *43*(1), 43-66.
Doss, C. R., & Morris, M. L. (2000). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. *Agricultural Economics*, 25(1), 27–39. https://doi.org/10.1111/j.1574-0862.2001.tb00233.x

Dridi, C., & Khanna, M. (2005). Irrigation technology adoption and gains from water trading under asymmetric information. *American Journal of Agricultural Economics*, *87*(2), 289-301
Dung, L. T. (2020). Factors Influencing Farmers' Adoption of Climate-Smart Agriculture in Rice Production in Vietnam's Mekong Delta. *Asian Journal of Agriculture and Development* 17(1) https://doi.org/10.37801/ajad2020.17.1.7.
Ellis, F. (1993). Peasant Economics. Cambridge University Press, Cambridge.
Ersado, L., Amacher, G., & Alwang, J. (2004). Productivity and land enhancing technologies in northern Ethiopia: Health, public investments, and sequential adoption. *American Journal of Agricultural Economics*, *86*(2), 321-331.
Fisher, M., & Snapp, S. (2014). Smallholder farmers' perceptions of drought risk and adoption of modern maize in southern Malawi. *Experimental Agriculture*, *50*(4), 533-548
Fisher, M., Abate, T., Lunduka, R. W., Asnake, W., Alemayehu, Y., & Madulu, R. B. (2015). Drought tolerant maize for farmer adaptation to drought in sub-Saharan Africa: Determinants of adoption in eastern and southern Africa. *Climatic Change*, *133*(2), 283-299
Fisher, M., Holden, S. T., Thierfelder, C., & Katengeza, S. P. (2018). Awareness and adoption of conservation agriculture in Malawi: what difference can farmer-to-farmer extension make?. *International Journal of Agricultural Sustainability*, *16*(3), 310-325.
Fleischer, A., Mendelsohn, R., & Dinar, A. (2011). Bundling agricultural technologies to adapt to climate change. *Technological Forecasting and Social Change*, *78*(6), 982-990.
Foltz, J. D. (2003). The economics of water-conserving technology adoption in Tunisia: An empirical estimation of farmer technology choice. *Economic development and cultural change*, *51*(2), 359-373.
Food and Agriculture Organization of the United Nations (2017b). Water for sustainable food and agriculture. A report produced for the G20 Presidency of Germany. FAO, Rome, Italy. http://www.fao.org/3/a-i7959e.pdf
Food and Agriculture Organization of the United Nations. (2022). Water scarcity. FAO, Rome, Italy, FAO. https://www.fao.org/land-water/water/water-scarcity/en/
Foster, A. D., & Rosenzweig, M. R. (1995). Learning by doing and learning from others: Human capital and technical change in agriculture. *Journal of political Economy*, *103*(6), 1176-1209.
Gbetibouo, G. A., Hassan, R. M., & Ringler, C. (2010). Modelling farmers' adaptation strategies for climate change and variability: The case of the Limpopo Basin, South Africa. *Agrekon*, *49*(2), 217–234. https://doi.org/10.1080/03031853.2010.491294
Gebremedhin, B., & Swinton, S. (2003). Investment in soil conservation in northern Ethiopia: the role of land tenure security and public programs. *Agricultural Economics, 29*(1), 69–84
Gebru, K. M., Woldearegay, K., van Steenbergen, F., Beyene, A., Vera, L. F., Tesfay Gebreegziabher, K., & Alemayhu, T. (2020). Adoption of road water harvesting practices and their impacts: Evidence from a Semi-Arid Region of Ethiopia. *Sustainability*, *12*(21), 8914.
Geno, L. M., & Geno, B. J. (2001). *Polyculture production: principles, benefits and risks of multiple cropping land management systems for Australia: a report for the rural industries research and development corporation*. Rural Industries Research and Development Corporation.
Giller, K. E., Witter, E., Corbeels, M., & Tittonell, P. (2009). Conservation agriculture and smallholder farming in Africa: the heretics' view. *Field crops research*, *114*(1), 23-34.
Govindappa, M., Pallavi, & Seenappa, C. (2015). Importance of mulching as a soil and water conservation practice in fruit and vegetable production–Review. *International Journal of Agriculture Innovations and Research, 3*, 2319 – 1473
Greene, W. H., & Hensher, D. A. (2008). *Modeling ordered choices: A primer and recent developments. SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1213093
Guvenc, I., & Yildirim, E. (1999). Multiple cropping systems in vegetable production. In *Proceedings of the Organic Agriculture Symposium,* 21–23 June, Izmir, Turkey, (pp. 288-296).

Hassan, R. M., & Nhemachena, C. (2008). Determinants of African farmers’ strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, *2*(311-2016-5521), 83-104.
He, X. F., Cao, H., & Li, F. M. (2007). Econometric analysis of the determinants of adoption of rainwater harvesting and supplementary irrigation technology (RHSIT) in the semiarid Loess Plateau of China. *Agricultural water management*, *89*(3), 243-250.
Heilig, G. K., Fischer, G., & Van Velthuizen, H. (2000). Can China feed itself? An analysis of China's food prospects with special reference to water resources. *The International Journal of Sustainable Development & World Ecology*, *7*(3), 153-172.
Howell, T. A. (2001). Enhancing water use efficiency in irrigated agriculture, *Agronomy Journal, 93*(2), 281–289.
Howell, T. A. (2003). Irrigation efficiency. In: Encyclopedia of Water Science. http://www.researchgate.net/publication/43256707
International Rivers (2000). The Potential for Water Conservation in Southern Africa. https://archive.internationalrivers.org/resources/the-potential-for-water-conservation-in-southern-africa-4116
Jabran, K. (2019). *Role of mulching in pest management and agricultural sustainability*. Switzerland, AG: Springer International Publishing.
Jara-Rojas, R., Bravo-Ureta, B. E., & Díaz, J. (2012). Adoption of water conservation practices: A socioeconomic analysis of small-scale farmers in Central Chile. *Agricultural Systems*, *110*, 54–62. https://doi.org/10.1016/j.agsy.2012.03.008
Jensen, E. S., Chongtham, I. R., Dhamala, N. R., Rodriguez, C., Carton, N., & Carlsson, G. (2020). Diversifying European agricultural systems by intercropping grain legumes and cereals. *Ciencia e investigación agraria: revista latinoamericana de ciencias de la agricultura*, *47*(3), 174-186.
Jha, S., Kaechele, H., & Sieber, S. (2019). Factors influencing the adoption of water conservation technologies by smallholder farmer households in Tanzania. *Water*, *11*(12), 2640. https://doi.org/10.3390/w11122640
Junge, B., Deji, O., Abaidoo, R., Chikoye, D., & Stahr, K. (2009). Farmers' adoption of soil conservation technologies: A case study from Osun state, Nigeria. *Journal of agricultural education and Extension*, *15*(3), 257-274: https://doi.org/10.1080/13892240903069769
Kanyenji, G. M., Oluoch-Kosura, W., Onyango, C. M., & Karanja Ng'ang'a, S. (2020). Prospects and constraints in smallholder farmers' adoption of multiple soil carbon enhancing practices in Western Kenya. *Heliyon*, *6*(3), e03226 https://doi.org/10.1016/j.heliyon.2020.e03226
Kariyasa, K., & Dewi, Y. A. (2013). Analysis of factors affecting adoption of integrated crop management farmer field school (ICM-FFS) in swampy areas. *International Journal of Food and Agricultural Economics*, *1*(2), 29-38.
Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological forecasting and social change*, *80*(3), 525-540
Kassie, M., Teklewold, H., Jaleta, M., Marenya, P., & Erenstein, O. (2015). Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. *Land use policy*, *42*, 400-411.
Kerse, B. L. (2018). Factors affecting adoption of soil and water conservation practices in the case of Damota watershed, Wolaita zone, Southern, Ethiopia. *International Journal of Agricultural Science Research*, *7*(1), 1-9.
Koech, R., & Langat, P. (2018). Improving irrigation water use efficiency: A review of advances, challenges and opportunities in the Australian context. *Water*, *10*(12), 1771.

Kohler, M. (2016). Confronting South Africa's water challenge: A decomposition analysis of water intensity. *South African Journal of Economic and Management Sciences,*19(5), 831 http://dx.doi.org/10.4102/sajems.v19i5.1590
Kohonen, T. (2013). Essentials of the self-organizing map. *Neural networks*, *37*, 52-65.
Koundouri, P., Nauges, C., & Tzouvelekas, V. (2006). Technology adoption under production uncertainty: Theory and application to irrigation technology. *American Journal of Agricultural Economics, 88*(3), 657–670. https://doi.org/10.1111/j.1467-8276.2006.00886.x
Kpadonou, R. A. B., Owiyob, T., Barbie, B., Dentona, F., Rutabingwa, F., & Kiema, A. (2017). Advancing climate-smart-agriculture in developing drylands: Joint analysis of the adoption of multiple on-farm soil and water conservation technologies in West African Sahel. *Land Use Policy*, *61*, 196-207. https://doi.org/10.1016/j.landusepol.2016.10.050
Kulkarni, S. (2011). Innovative technologies for water saving in irrigated agriculture. *International journal of water resources and arid environments*, *1*(3), 226-231.
Kumar, S., Singh, D. R., Singh, A., Singh, N. P., & Jha, G. K. (2020). Does adoption of soil and water conservation practice enhance productivity and reduce risk exposure? empirical evidence from semi-arid tropics (SAT), India. *Sustainability*, *12*(17), 6965.
Kurgat, B. K., Lamanna, C., Kimaro, A., Namoi, N., Manda, L., & Rosenstock, T. S. (2020). Adoption of climate-smart agriculture technologies in Tanzania. *Frontiers in Sustainable Food Systems*, *4*, 55. https://doi.org/10.3389/fsufs.2020.00055
Lahiff, Edward, (1997), Land, water and local governance in South Africa: A case study of the Mutale River Valley, No 30571, Global Environmental Change Programme Phase III Project: Working Paper No 7. University of Manchester, Institute for Development Policy and Management (IDPM), https://EconPapers.repec.org/RePEc:ags:idpmrr:30571
Limpopo Basin Permanent Technical Committee [LBPTC] (2010). Joint Limpopo River Basin Study Scoping Phase. Final Report http://www.limpopo.riverawarenesskit.org/
Lipiec, J., Kuś, J., Słowińska-Jurkiewicz, A., & Nosalewicz, A. (2006). Soil porosity and water infiltration as influenced by tillage methods. *Soil and Tillage Research,* 89(2), 210-20.
Maguza-Tembo, F., Edriss, A.-K., & Mangisoni, J. (2017). Determinants of Climate Smart Agriculture Technology Adoption in the Drought Prone Districts of Malawi using a Multivariate Probit Analysis. *Asian Journal of Agricultural Extension, Economics & Sociology*, *16*(3), 1–12. https://doi.org/10.9734/AJAEES/2017/32489
Mandiringana, O. T., Mabi, M., & Simalenga, T. E. (2006). Evaluation of Soil-Water Conservation Tillage Systems for Communal Farmers in the Eastern Cape, South Africa. *Agricultural Mechanization in Asia, Africa & Latin America*, *37*(4), 27.
Mango, N., Makate, C., Tamene, L., Mponela, P., & Ndengu, G. (2017). Awareness and adoption of land, soil and water conservation practices in the Chinyanja Triangle, Southern Africa. *International Soil and Water Conservation Research*, *5*(2), 122-129.
Mango, N., Makate, C., Tamene, L., Mponela, P., & Ndengu, G. (2018). Adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle, Southern Africa. *Land*, *7*(2), 49
Maponya, P., & Mpandeli, S. (2012). Climate change and agricultural production in South Africa: Impacts and adaptation options. *Journal of Agricultural science*, *4*(10), 48.
Marenya, P. P., & Barrett, C. B. (2007). Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. *Food policy*, *32*(4), 515-536.
Mariano, M. J., Villano, R., & Fleming, E. (2012). Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines. *Agricultural Systems, 110,* 41–53.

Martey, E., & Kuwornu, J. K. (2021). Perceptions of climate variability and soil fertility management choices among smallholder farmers in northern Ghana. *Ecological Economics*, *180*, 106870.
Mauceri, M., Alwang, J., Norton, G., & Barrera, V. (2007). Effectiveness of integrated pest management dissemination techniques: a case study of potato farmers in Carchi, Ecuador. *Journal of Agricultural and Applied Economics*, *39*(3), 765-780.
McGuire, J., Morton, L. W., & Cast, A. D. (2013). Reconstructing the good farmer identity: Shifts in farmer identities and farm management practices to improve water quality. *Agriculture and Human Values*, *30*(1), 57–69. https://doi.org/10.1007/s10460-012-9381-y
Mossie, M., Gerezgiher, A., Ayalew, Z., & Nigussie, Z. (2020). Determinants of small-scale farmers' participation in Ethiopian fruit sector's value chain. *Cogent Food & Agriculture*, *6*(1), 1842132. https://doi.org/10.1080/23311932.2020.1842132
Michael, A. M. 2008. *Irrigation Theory and Practice 2nd Ed. Theory and Practice.* Vikas Publishing House PVT. Ltd, Delhi, India.
Mignouna, B., Manyong, M., Rusike, J., Mutabazi, S., & Senkondo, M. (2011). Determinants of adopting imazapyr-resistant maize technology and its impact on household income in western Kenya, *AgBioforum, 14*(3), 158-163.
Mishra, A. K., & Sandretto, C. L. (2002). Stability of farm income and the role of nonfarm income in US agriculture. *Applied Economic Perspectives and Policy*, *24*(1), 208-221.
Mobasser, H. R., Vazirimehr, M. R., & Rigi, K. (2014). Effect of intercropping on resources use, weed management and forage quality. *International Journal of Plant, Animal and Environmental Sciences*, *4*(2), 706-713.
Mogogana, B. P., Olorunfemi, O. D., & Oladele, O. I. (2018). Knowledge and adoption of water use efficiency techniques among women irrigators: evidence from South Africa. *Journal of Agriculture and Environment for International Development*, *112*(2), 271-296.
Mugonola, B., Deckers, J., Poesen, J., Isabirye, M., & Mathijs, E. (2013). Adoption of soil and water conservation technologies in the Rwizi catchment of south-western Uganda. *International journal of agricultural sustainability*, *11*(3), 264-281.
Mulwa, C., Marenya, P., Rahut, D. B., & Kassie, M. (2017). Response to climate risks among smallholder farmers in Malawi: A Multivariate probit assessment of the role of information, household demographics, and farm characteristics. *Climate Risk Management, 16*, 208–221. http://dx.doi.org/10.1016/j.crm.2017.01.002
Mutyasira, V., Hoag, D., & Pendell, D. (2018). The adoption of sustainable agricultural practices by smallholder farmers in Ethiopian highlands: An integrative approach. *Cogent Food & Agriculture*, *4*(1), 1552439. https://doi.org/10.1080/23311932.2018.1552439
Namara, R. E., Nagar, R. K., & Upadhyay, B. (2007). Economics, adoption determinants, and impacts of micro-irrigation technologies: empirical results from India. *Irrigation science*, *25*(3), 283-297.
National Development Plan 2030. Our Future–make it work (2012). National Planning Commission. NDP, Republic of South African https://www.gov.za/documents/national-development-plan-2030-our-future-make-it-work
Ndamani, F., & Watanabe, T. (2016). Determinants of farmers' adaptation to climate change: A micro level analysis in Ghana. *Scientia Agricola*, *73*, 201-208.
Ndiritu, S. W., Kassie, M., & Shiferaw, B. (2014). Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. *Food Policy*, *49*, 117-127. https://doi.org/10.1016/j.foodpol.2014.06.010
Nikouei, A., Zibaei, M., & Ward, F.A. (2012). Incentives to adopt irrigation water saving measures for wetlands preservation: an integrated basin scale analysis. *Journal Hydrology, 464–465*, 216–232.

Nkonya, E., Pender, J., Kaizzi, K. C., Kato, E., Mugarura, S., Ssali, H., & Muwonge, J. (2008). Linkages between land management, land degradation, and poverty in Sub-Saharan Africa: The case of Uganda. International Food Policy Research Institute Report 159.

Ntshangase, N., Muroyiwa, B., & Sibanda, M. (2018). Farmers' Perceptions and Factors Influencing the Adoption of No-Till Conservation Agriculture by Small-Scale Farmers in Zashuke, KwaZulu-Natal Province. *Sustainability*, *10*(2), 555. https://doi.org/10.3390/su10020555

Nyirahabimana, H., Turinawe, A., Lederer, J., Karungi, J., & Herrnegger, M. (2021). what influences farmer's adoption lag for soil and water conservation practices? Evidence from Sio-Malaba Malakisi River Basin of Kenya and Uganda Borders. *Agronomy*, *11*(10), 1985. https://doi.org/10.3390/agronomy11101985

Osmond, D., Meals, D., Hoag, D., Arabi, M., Luloff, A., Jennings, G., McFarland, M., Spooner, J., Sharpley, A., & Line, D. (2012). Improving conservation practices programming to protect water quality in agricultural watersheds: Lessons learned from the National Institute of Food and Agriculture–Conservation Effects Assessment Project. *Journal of Soil and Water Conservation*, *67*(5), 122A-127A.

Ouma, J., Murithi,F., Mwangi, W., Verkuijl, H., Gethi M, De Groote, H. (2002) Adoption of Maize Seed and Fertilizer Technologies in Embu District, Kenya. CIMMYT (International Maize and Wheat Improvement Center), Mexico. D.F

Pagliacci, F., Defrancesco, E., Mozzato, D., Bortolini, L., Pezzuolo, A., Pirotti, F., Pisani, E., & Gatto, P. (2020). Drivers of farmers' adoption and continuation of climate-smart agricultural practices. A study from northeastern Italy. *Science of The Total Environment*, *710*, 136345. https://doi.org/10.1016/j.scitotenv.2019.136345

Pang, H. C., Li, Y. Y., Yang, J. S., & Liang, Y. S. (2010). Effect of brackish water irrigation and straw mulching on soil salinity and crop yields under monsoonal climatic conditions. *Agricultural Water Management*, *97*(12), 1971-1977.

Recha, J. W., Kapukha, M., Wekesa, A., Shames, S., & Heiner, K. (2014). Sustainable agriculture land management practices for climate change mitigation: a training guide for smallholder farmers. Washington DC Eco Agriculture Partners.

Reese, C. L., Clay, D. E., Clay, S. A., Bich, A. D., Kennedy, A. C., Hansen, S. A., & Moriles, J. (2014). Winter cover crops impact on corn production in semiarid regions. *Agronomy Journal*, *106*(4), 1479-1488.

Reints, J., Dinar, A., & Crowley, D. (2020). Dealing with Water Scarcity and Salinity: Adoption of Water Efficient Technologies and Management Practices by California Avocado Growers. *Sustainability*, *12*(9), 3555. https://doi.org/10.3390/su12093555

Sharma, B. R. (2001). Availability, status and development and opportunities for augmentation of groundwater resources in India. *Proceeding ICAR-IWMI Policy Dialogue on Ground Water Management*, at CSSRI, Karnal, 1-18.

Silberg, T. R., Richardson, R. B., Hockett, M., & Snapp, S. S. (2017). Maize-legume intercropping in central Malawi: determinants of practice. *International Journal of Agricultural Sustainability*, *15*(6), 662-680.

Sileshi, M., Kadigi, R., Mutabazi, K., & Sieber, S. (2019). Determinants for adoption of physical soil and water conservation measures by smallholder farmers in Ethiopia. *International Soil and Water Conservation Research*, *7*(4), 354–361. https://doi.org/10.1016/j.iswcr.2019.08.002

Singh, A. K., Kumar, A. K., Katiyar, V. S., Singh, K. D., Singh, U. S. (1997). Soil and water conservation measures in semi-arid regions of South-Eastern Rajasthan. *Indian Journal of Soil Conservation, 25*(3):186-189

Soil Science Glossary Terms Committee, & Soil Science Society of America. (2008). *Glossary of soil science terms 2008*. ASA-CSSA-SSSA.

Teklewold, H., Kassie, M., & Shiferaw, B. (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. *Journal of agricultural economics*, *64*(3), 597-623. https://doi.org/10.1111/1477-9552.12011
Tran, N. L. D., Rañola, R. F., Ole Sander, B., Reiner, W., Nguyen, D. T., & Nong, N. K. N. (2019). Determinants of adoption of climate-smart agriculture technologies in rice production in Vietnam. *International Journal of Climate Change Strategies and Management*, *12*(2), 238–256. https://doi.org/10.1108/IJCCSM-01-2019-0003
Uaiene, R. N. (2011). Determinants of agricultural technology adoption in Mozambique. In *10th African Crop Science Conference Proceedings, Maputo, Mozambique, 10-13 October 2011*. African Crop Science Society.
United Nations Economic and Social Commission for Western Asia (2020). Absolute water scarcity. ESCWA. https://archive.unescwa.org/absolute-water-scarcity
Uygan, D., Cetin, O., Alveroglu, V., & Sofuoglu, A. (2021). Improvement of water saving and economic productivity based on quotation with sugar content of sugar beet using linear move sprinkler irrigation. *Agricultural Water Management*, *255*, 106989.
Valizadeh, N., Bijani, M., & Abbasi, E. (2018). Farmers active participation in water conservation: insights from a survey among farmers in southern regions of West Azerbaijan Province, Iran. *Journal of Agricultural Science and Technology*, *20*(5), 895-910.
Vanwalleghem, T. (2016). Soil erosion and conservation. International Encyclopedia of Geography: People, the Earth, Environment and Technology: People, the Earth, Environment and Technology, 12:1-10
Wang, J., Mendelsohn, R., Dinar, A., & Huang, J. (2010). How Chinese farmers change crop choice to adapt to climate change. *Climate Change Economics*, *1*(3), 167-185.
Wang, J., Klein, K. K., Bjornlund, H., Zhang, L., & Zhang, W. (2015). Adoption of improved irrigation scheduling methods in Alberta: an empirical analysis. *Canadian Water Resources Journal, 40,* 47–61.
Ward, F. A., Michelsen, A. M., & DeMouche, L. (2007). Barriers to water conservation in the Rio Grande Basin 1. *Journal of the American Water Resources Association*, *43*(1), 237-253
Wekesa, E., Mwangi, W., Verkuijl, H., Danda, K., & De Groote, H. (2003). *Adoption of maize production technologies in the coastal lowlands of Kenya*. CIMMYT, Mexico, D.F
Westengen, O. T., & Brysting, A. K. (2014). Crop adaptation to climate change in the semi-arid zone in Tanzania: the role of genetic resources and seed systems. *Agriculture & Food Security*, *3*(1), 1-12.
Willey, R. W. (1990). Resource use in intercropping systems. *Agricultural water management*, *17*(1-3), 215-231.
World Bank (2009). Agricultural Development under a Changing Climate: Opportunities and Challenges for Adaptation. www.worldbank.org/rural.
Yildirim, E., & Guvenc, I. (2005). Intercropping based on cauliflower: more productive, profitable and highly sustainable. *European Journal of Agronomy*, *22*(1), 11-18.
Yildirim, O., & Korukcu, A. (2000). Comparison of Drip, Sprinkler and Surface Irrigation Systems in Orchards. *Faculty of Agriculture,* University of Ankara, Ankara Turkey. 47p.
Zakaria, A., Alhassan, S. I., Kuwornu, J. K. M., Azumah, S. B., & Derkyi, M. A. A. (2020). Factors Influencing the Adoption of Climate-Smart Agricultural Technologies Among Rice Farmers in Northern Ghana. *Earth Systems and Environment*, *4*(1), 257–271.
Zeweld, W., Van Huylenbroeck, G., Tesfay, G., & Speelman, S. (2017). Smallholder farmers' behavioural intentions towards sustainable agricultural practices. *Journal of Environmental Management, 187,* 71–81.
Zhang, B., Fu, Z., Wang, J., & Zhang, L. (2019). Farmers' adoption of water-saving irrigation technology alleviates water scarcity in metropolis suburbs: A case study of Beijing, China. *Agricultural Water Management*, *212*, 349–357. https://doi.org/10.1016/j.agwat.2018.09.021

Appendix

Appendix A1

Table A1: An overview of key related studies around the world.

Authors	Study area/ Sample Size (N)	Objective(s)	Variables of study	Empirical model(s)	Summary of Findings
Koech and Langat (2018)	Australia N = Not applicable	To review the advancements that have been made to improve the irrigation WUE, document the challenges encountered as well as exploring opportunities for further development.	Engineering and technological innovations, advancements in plant and pasture science, environmental factors, and socio-economic	A review of advances, challenges and opportunities	1. The review showed that improvements in irrigation infrastructure through modernisation and automation have led to water savings. 2. To achieve net water savings, water-efficient technologies and practices need to be used in combination with other measures such as incentives for conservation and appropriate regulations that limit water allocation and use 3. Factors that affect the trends in the irrigation water use efficiency (WUE), include engineering and technological innovations, advancements in plant and pasture science, environmental factors, and socio-economic considerations. 4. Challenges that might be encountered include lack of public support, especially when the methods used are not cost-effective, and reluctance of irrigations to adopt new technologies.
Adusumilli and Wang (2018)	U.S.A N = 500	To contribute to the literature on natural resource conservation by analyzing the factors that influence simultaneous adoption of soil	DV: soil conservation practices, water quality protection & water conservation (efficiency practices) IV: relationship between farming practices and water quality, type of farm	A bivariate probit model	1. Farmers' belief about the relationship between farming practices and water quality can play a role in protecting the water quality in surrounding waters. 2. Participation in federal programmes have a positive and significant effect on the likelihood of adopting conservation practices. 3. Percent of land owned and number of years in farming have a negative influence on adoption.

		conservation and water efficiency practices.	operation, land ownship, number of acres farmed in the cropping year, participation in federal programs, source of technical assistance, years of farming, annual gross farm revenue, education, and age		4. Type of farm operation, participation in federal programmes and education level have a positive effect on adoption. 5. The higher the education, the greater the understanding of the links between conservation and crop profitability hence adoption. Age, however, was insignificant
Zhang et al. (2019)	Beijing in China N = 490	To identify the major factors and provide an understanding of farmers' sustainable irrigation practices use to cope with water-stress in water scarcity environments of Beijing, China	DV: water-saving irrigation technology (WSIT) IV: household characteristics (age, education, farming experience), family characteristics (household size, production specialization), farm characteristics (farm size, on-farm demonstration, cooperative), production conditions (agricultural technology training, distance to nearest market, groundwater), perceptions of technology (access to information, cost of adopting WSIT), environmental factors (member of water of user association, drought-prone	Binary logit choice model	1. The results revealed that education, farm size, on-farm demonstration, cooperative, training, groundwater, access to information, water use associations, drought-prone area, neighboring farmers, and policy subsidies significantly improved the adaption to water scarcity. 2. Specifically, the findings amongst others showed that, older farmers had a lower probability of WSIT adoption. Education had a positive effect on the adoption of WSIT. Production specialization had a negative significant impact on farmer's adoption of WSIT. 3. Farm size had a positive and significant impact on the adoption of WSIT. On-farm demonstration variable showed a significantly positive sign in the adoption equation, indicating that farmers who participated in on-farm demonstrations were more likely to adopt WSIT. 4. Being a member of cooperatives improved the likelihood of adoption of WSIT to cope with water scarcity. Attendance at training sessions had a significant positive influence on farmers' WSIT adoption probability.

			area, neighbouring farmers, policy subsidies)		
Pagliacci et al. (2020)	Veneto Region in Italy N = 66	To examine the role of the farming factors, technology accessibility, environmental features, policy design and social expertise at the territorial level on early adoption and to sheds light on farmers' attitudes and motivations and on social pressure on their decision to continue or discontinue the practices	Farming factors (share of farms larger than 30 ha and share of arable crop area), Technology accessibility factors (Irrigable, Irrigation poor, Irrigation medium, Irrigation no constraints and Distance), Environmental factors (Rainfall and Soil type), Policy factors (Nitrate Vulnerable Zones, Rural), Size control (Utilised agricultural area at the municipality level), Spatial diffusion patterns (Share of other agri-environmental schemes beneficiaries, Spatial lag of Share of other agri-environmental schemes beneficiaries and Spatial lag of Utilised agricultural area at the municipality level)	Poisson and logit regression models	1. These results amongst others showed that for No-tillage, the number of adopters by municipality is positively affected by the farming factors. In particular, the municipality specialization in arable crops triggers No-tillage adoption. 2. Among the technology accessibility factors, the share of irrigable area had a negative effect, confirming that farmers who do not have access to irrigation are more inclined to adopt No-tillage. 3. Among the environmental factors, rainfall is not significant. The type of soil matters. A larger number of adopters are associated with clayey rather than sandy soils. 4. No-tillage on clayey soils delivered higher cost savings when compared to traditional tillage practices. With regard to policy factors, those municipalities located in Nitrate Vulnerable Zones show a larger number of adopters.
Valizadeh et al. (2018)	West Azerbaijan Province in Iran	To identify and analyze factors affecting farmers active participation in water conservation (FAPWC).	Farmers' active participation in water conservation, moral norms of water conservation, place attachment, social responsibility towards consequences, attitude towards participation in	Parametric tests were used to analyze their data	1. Social pressure was one of the most important activator of farmers' active participation in water conservation, it however did not have significant effect on moral norm of water conservation. 2. The quality of agricultural extension services was positively and significantly associated with farmers' active participation. 3. Satisfaction of water resources management was the strongest predictor of farmers' active participation in water

	N = 378		water conservation, social pressure towards water conservation, quality of agricultural extension services and satisfaction of water resources management.		conservation. Highlighting the issue of quality and manner of interactions and services provided by governmental structures and bodies.
Aryal et al. (2018)	Bihar and Haryana in the Indo-Gangetic Plains of India N = 1,267	To analyze the factors that determine the probability and level of adoption of multiple climate-smart agriculture (CSA) practices	DV: total number of CSA adopted, seeds of stress-tolerant varieties (STV), minimum tillage (MT), laser land leveling (LLL), site specific nutrient management (SSNM) and crop diversification (DC) IV: household (HH) characteristics (gender, general caste, age, literate, literate spouse, family size, migrant), farm land characteristics (tenure of plot, area of plot, fertile soil, deep soil, gentle slope, distance to plot), economic and social capital (land operated, livestock owned in TLU, asset index, credit access, association in group), access to markets, agricultural extension service and training	Multivariate probit and ordered probit models	1. The adoption of the various CSA practices is interrelated, Specifically, amongst other findings of their MVP model, male-headed households were more likely to adopt LLL but less likely to adopt CD and STV. 2. Older household heads were more likely to adopt CD while they are less likely to adopt MT and SSNM. In addition, older household heads were less familiar with relatively newer technologies. 3. For the intensity of CSA adoption, General caste and literacy are major household characteristics favouring the number of CSA practices adopted. 4. Crop diversification and minimum tillage are found to be significant and negatively associated, implying that farmers consider these practices as either incompatible or substitutes. 5. Other CSA combinations such as MT and STV, MT and SSNM, and STV and SSNM are significantly and positively associated, implying that farmers primarily consider these as complements.

			(distance to market, distance to extension service, agricultural training), source of information (farmer to farmer, extension service, ICT seed traders/private company), climate risks experienced by household over the last 5 years (high temperatures, decreasing rainfall, short winters)		
Alauddin et al. (2020)	Bangladesh N = 108	To determine the factors that influence the adoption of alternate wetting and drying (AWD) irrigation as a water-saving technology in Bangladesh and whether AWD adoption save irrigation water use, reduce irrigation cost, and increase or stabilise crop yield.	DV: AWD adoption IV: Age, education, access to agricultural extension services, access to weather information in advance, access to credit, amount of land irrigated, high elevation, low elevation, soil type, land ownership, irrigation frequency, cost of irrigation	Logit, propensity score matching and multiple regression models	1. The study found that AWD adoption varied inversely with the age and level of education of the household head. Younger farmers were more likely to adopt the AWD irrigation technique than older ones. Household heads with less than 6 years of schooling displayed a greater inclination toward AWD adoption relative to those with more than 6 years of schooling. 2. A significant negative effect of access to prior weather information on AWD adoption was evident. 3. AWD adopters were significantly younger, possessed a significantly higher amount of irrigated land and cultivated land, and higher amounts of high-elevated land and/or land with clay-type soil. 4. Irrigation frequency varied inversely with AWD adoption, and directly with access to prior weather information, and low elevation of land. 5. Cost of irrigation varied inversely with AWD adoption, directly with access to credit, and inversely with clay-loam type soil.

Jara-Rojas et al. (2012)	Central Chile N = 319	To determine the factors that contribute to the adoption of a number of water conservation practices by small-scale farmers in Central Chile	DV: Water conservation, No-adoption, Techniques, Technologies IV: age, education, family size, farm size, livestock, home consumption, access to credit, incentives water community, social activities, high payment ($9808) per share of irrigation water, low payment ($5954) per share of irrigation water and no payment (does not pay) for irrigation water	Poisson count data model, logit and multinomial logit models	1. The results showed that social capital, farm size and land use played a key role in the adoption of management practices and in generating greater efficiency in water used for irrigation. Age and education show inconclusive results. 2. Family size is positive and significant. This supports the notion that the likelihood of adopting water conservation practices rises as family labour becomes more abundant. 3. Farm size (land) is significant and positive, which is similar to the results reported by Bekele and Drake (2003). 4. Both land and livestock are positive and consistent with the notion that wealthier farmers are more able to undertake risk and thus are more prone to be adopters. However, home consumption is negative. 5. Access to Credit, which exhibits mixed results in the literature, was not significant in their study.
Mango et al. (2018)	Chinyanja Triangle (Zambia, Malawi and Mozambique) N = 312	To determine the factors that influence the adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on income among smallholder farmers.	DV: irrigation farming, agricultural income IV: gender, age, household size, education, extension, occupation, off-farm employment, credit access, irrigation equipment, reliable water source, awareness of conservation practices, distance to market and land size cultivated, irrigation farming, labour, economically active, group membership, livestock, main crop, literacy,	Binary logistic and ordinary least squares regression models,	1. The results showed that gender, household size, education, extension, casual labour, skilled labour, credit access and land size cultivated did not significantly influence the adoption of small-scale irrigation farming. 2. Age had a negative impact on the adoption of small-scale irrigation farming, which suggested that the odds of adoption were higher among younger farmers than among older farmers. The odds of adoption were found to decrease if the household head's main occupation was either formal employment or involvement in a small-scale business. 3. Off-farm employment was found to significantly influence the adoption of small-scale irrigation farming. Access to irrigation equipment influenced the adoption of small-scale irrigation farming positively. Both access to irrigation equipment and a reliable water source were vital for any farmer to try small-scale irrigation farming.

			adoption of land, soil and water (LSW)		4. Awareness of WCPs such as rainwater harvesting had a positive and significant influence on the adoption of small-scale irrigation farming. The distance travelled to access the nearest market had a significant negative influence on the adoption of irrigation farming.
Hassan and Nhemachena (2008)	11 African countries—Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe N = 8,208	To analyze the determinants of farm-level climate adaptation measures in Africa	DV: multiple crops under irrigation, multiple crops under dryland, mono crop-livestock under dryland, mono crop-livestock under irrigation, multiple crop-livestock under irrigation and multiple crop-livestock under dryland. IV: winter temperature, spring temperature, summer temperature, fall temperature, winter precipitation, spring precipitation, summer precipitation, fall precipitation, farmer noticed changes in climate, sex, household size, age, farming experience, access to extension services, access to credit, access to electricity, distance to markets, own heavy machines and farm size (hectares)	Multinomial logit model	1. The results amongst other findings suggest that warmer winter-spring promoted switching to use of irrigation, multiple cropping and mixing crop and livestock activities especially under irrigation. 2. Irrigation was the strongest adaptation measure against warming for all systems, mixing livestock with crop cultivation seems to work only with multiple cropping under dryland conditions. 3. Better access to extension and credit services had a strong positive influence on the probability of adopting all adaptation measures and abandoning the relatively risky monocropping systems. 4. Access to electricity was strongly associated with the use of irrigation. This could also be because the bulk of irrigation water in Africa is supplied from dams that are also used for power generation. 5. More experienced farmers were more likely to adapt than less experienced. Age of the farmer did not seem to be of significance in influencing adaptation, as almost all marginal effect coefficients were statistically insignificant.

Belachew et al. (2020)	Northwest Ethiopian highlands N = 150	To identify the factors influencing adoption of soil and water conservation practices.	DV: soil bund, stone bund, check dam and strip cropping IV: sex, age, educational level, household size, livestock holding (in TLU), land size, access to credit, distance from home to farmland, slope of the farmland, access to extension service and participation in training on SWC practices	Descriptive statistics and a multivariate probit model	1. The results revealed that the likelihood of decisions to adopt soil bund, stone bund, check dam and strip cropping were 74, 56, 29 and 56 percent respectively. 2. Specifically, amongst other findings, sex influenced the adoption of strip cropping significantly while age influenced the adoption of soil bund negatively. 3. Educational level increased farmers' ability to get and use information and improves farmers' decision to adopt SWC practices. Household size influenced the adoption of soil bund and strip cropping positively and negatively. 4. Livestock holding affected the adoption of soil bund positively. Land size influenced the adoption of stone bund and strip cropping positively. Access to credit influenced the adoption of soil bund, stone bund, check-dam and strip cropping.
Jha et al. (2019)	Tanzania N = 701	To better understand and identify the factors that significantly influence the adoption of water conservation techniques (WCTs) in Tanzania	DV: water conservation measures IV: individual and household characteristics (age, health, gender, ability to read and write, attitude towards risk, region, household size, household water usage), socio-economic characteristics (membership in social networks, access to micro-credits, access to public funds, household savings, off-farm employment, household income	Bivariate logistic regression	1. The results showed that the individual, household, socio-economic, and farmer perceptions related variables affected the adoption of WCTs differently. 2. Specifically, women-led households had a lower likelihood of adoption of WCTs and those farmers who had access to social networks and public funds had a higher likelihood of adopting WCTs. 3. Farmer's perception of rainfall instability had a significant negative influence on the adoption of WCTs. Whereas a positive perception of household wealth and food security by the farmer had a significant positive influence on the adoption of WCTs, as expected. 4. The study found no statistically significance for the variables relating to the adopter's age, health, ability to read and write, attitude towards risk, region, household size, household water usage, access to microcredits, savings, off-farm employment, household income fluctuations, farmers perception and

			fluctuation), farmer perceptions (perception of change in rainfall, perception of climate change, perception of change in environment, perception of household wealth and perception of household food security)		recognition of the changing climate and environment and adoption of WCTs.
Ntshangase et al. (2018)	Ingwe Municipality in Kwa-Zashuke, Ward 8, in KwaZulu-Natal province of South Africa N = 185	To understand the factors affecting the adoption of no-till conservation agriculture (CA) among small-scale farmers, including farmers' perceptions of the technology.	DV: adoption of no-till CA IV: age, gender, education, economically active members, experience in farming, training, extension frequency, access to credit, promotion of no-till, land size and income	Descriptive and inferential statistics and A binary logistic regression model	1. The results showed that the age of the farmer positively influenced no-till CA adoption. 2. More educated farmers tended to be younger than the less educated farmers. Among the more educated farmers, the older farmers had a higher tendency of adoption. 3. Farm size cultivated negatively influenced the adoption of no-till CA. Larger pieces of land were associated with farmers being less likely to adopt the no-till CA, in comparison to the group of farmers with a smaller land size. 4. Frequency of extension visits was categorized into four groups.. Farmers who had more frequent visits were more likely to adopt farming practices that they were exposed to through extension services.
Mogogana, et al. (2018)	North West Province of South Africa	To determine the knowledge and adoption of water use efficiency techniques among women irrigators in the North	DV: water use efficiency techniques (reduced tillage cover crops crop rotation manure and fertilizer) IV: age, marital status, number of dependents, number of members in household, highest level of	Frequency counts, percentages, means, standard deviation and Probit regression model	1. The findings showed that adoption of reduced tillage had a direct relationship with frequency of extension visits but had an inverse relationship with land tenure, membership of farmers' group and existence of water tariffs. 2. Extension visits was found to have a significant positive effect on the adoption of cover crop technique. 3. The adoption of crop rotation had a direct relationship with age. Membership of farmers' group, existence of water rates,

	N = 108	West Province of South Africa	education, land tenure status, farm size number of plots, location of plots in one area, members of farmers' group, contact with extension agent, frequency of extension visits extension agency, sources of labour, farming experience, number of years in irrigation scheme, water rate, existence of water tariffs electricity for water pumping, cropping systems		and existence of water tariffs reduced the likelihood of the adoption of crop rotation. 4. Age and number of plots owned by the women farmers was positive. Farm size, membership of farmers' group, existence of water rates and existence of water tariffs was negative implying an inverse relationship with the adoption of manure and fertilizer
Baiyegunhi (2015)	Msinga, KwaZulu-Natal Province, South Africa N = 180	To evaluate the determinants of farmers' decisions to adopt rainwater harvesting technology (RWHT) among rural home gardeners	DV: rainwater harvesting technology IV: gender of household head, age of household head, household head education, household size, household monthly income, off farm activity, social capital, contact with extension agent, security of land rights, access to farm inputs, perception/attitude toward RWHT, distance to water tanks and importance of livestock	Binary logistic regression	1. The results showed a significant positive relationship between gender and adoption of RWHT, implying that male farmers were more likely to adopt RWHT compared to a female farmer. 2. Age had a significant negative effect on adoption of RWHT. 3. Household income had a significant positive effect on adoption of RWHT. A higher level of household income implies a greater incentive for investment in agricultural technologies and ability to bear the risk associated with its adoption. 4. Social capital had a significant positive effect on adoption of RWHT. Contact with extension had a significant positive effect on adoption of RWHT. 5. Security of land rights had a significant positive effect on adoption of RWHT, suggesting farmers who had secured rights to their lands were more likely to adopt RWHT. 6. Farmer's perception/attitude toward RWHT had a significant positive effect on adoption of RWHT, implying farmers who

					had positive perceptions/attitude towards RWHT were more likely to adopt it.
Gbetibouo et al. (2010)	Limpopo Basin in South Africa	To investigate factors affecting the choice of adaptation strategies (practices and technologies) to climate change at the farm level to generate important policy information on how to enhance the adaptive capacities of rural households in stressed environments like the LRB	DV: Portfolio diversification, irrigation, changing planting dates, changing land area under cultivation, livestock feed supplement and other adaptation methods IV: household (HH) characteristics (age, education, gender, household size, farming experience, wealth), farm characteristics (farm size, soil fertility), institutional factors (extension service, climate information, credit access, off-farm employment, tenure), other factors (temperature, rainfall, latitudes, longitude and Limpopo)	Multinomial logit model	1. The results revealed that larger households were more willing to choose the "the other" category as an adaptation option, which included the adaptation such as use of soil conservation techniques and chemical treatments that are labour-intensive, especially in small-scale farming. 2. Experienced farmers had an increased likelihood of using portfolio diversification, changing planting dates changing land under cultivation. 3. Farm size is significant and positively correlated with the probability of choosing irrigation as adaptation measure. Large-scale farmers were more likely to adopt irrigation as they have more capital and resources to invest in irrigation technologies. 4. Off-farm income increased farmers' likelihood of buying feed supplement for their livestock. Access credit increased the likelihood that farmers would take up portfolio diversification buy feed supplement for their livestock. 5. Households living in regions with high temperatures have an increased likelihood of adopting (1) portfolio diversification, including changing their types of crops (from maize to sorghum, a more heat tolerant crop), (2) intensify irrigation and (3) changing planting dates. A decrease in rainfall is likely to push farmers to delay planting.

Note: DV is dependent variable(s) and IV is independent variables

Appendix A2

Table A2: Further Summary Statistics of the Variables

Variables	**% Sample (N = 555)**	**Min**	**Max**
Dependent Variables			
MEPIDs		0	1
No	44.68		
Yes	55.32		
Conservation tillage (CT)		0	1
No	70.27		
Yes	29.73		
Cover cropping (CC)		0	1
No	18.74		
Yes	81.26		
Intercropping (IN)		0	1
No	14.77		
Yes	85.23		
Mulching (MU)		0	1
No	57.30		
Yes	42.70		
Drought Tolerant crops (DTCs)		0	1
No	45.95		
Yes	54.05		
Total number of WCPs adopted		0	6
Does not adopt WCP	0.54		
Adopts 1 WCPs	4.68		
Adopts 2 WCPs	17.66		
Adopts 3 WCPs	26.13		
Adopts 4 WCPs	29.01		
Adopts 5 WCPs	18.02		
Adopts 6 WCPs	3.96		
Explanatory Variables			
Gender		0	1
Male	44.68		
Female	55.32		
Age		20	95
Age squared		400	9025
Education		0	1
Non literate	5.95		
literate	94.05		
Spousal education		0	3
Non literate spouse	6.49		
Literate spouse	83.60		
Without spouse	9.91		
Experience		1	55
Farm ownership		0	1
Leased/rented/government land	7.03		
Owned by the farmer or family	92.97		
Farm size		0.15	27
Vegetables		0	1

No	18.92		
Yes	81.08		
Maize		0	1
No	45.59		
Yes	54.41		
Fruits		0	1
No	88.29		
Yes	11.71		
Spice		0	1
No	69.37		
Yes	30.63		
Beans		0	1
No	75.86		
Yes	24.14		
Diversification of farm		0	1
Specialized farming	7.39		
Diversified farming	92.61		
Market access		0	1
Had no access to markets	19.28		
Had access to markets	80.72		
Distance to market		10	97
Location of farm		1	2
Upstream	62.34		
Downstream	37.66		
Source of water		1	2
Surface	89.55		
Underground	10.45		
Proximity to water		1	2
Less than a kilometer	74.05		
More than a kilometer	25.95		
Farm income		0	1
Annual farm income less than 11,000 ZAR	20.00		
Annual farm income greater than 11,000 ZAR	80.00		
Off-farm income		0	1
No off-farm income	68.65		
Had off-farm income	31.35		
Household size		1	16
Member of a cooperative		0	1
No membership in a cooperative	37.84		
Membership in a cooperative	62.16		
Drought experience		0	1
No	0.54		
Yes	99.46		
Perception future droughts		0	1
Don't know	45.95		
Would get worse	54.05		
Perceived cost of WCPs		0	1
Not costly	34.23		
Very costly	65.77		
Access to extension services		0	1

No	3.06		
Yes	96.94		
Access to credit		0	1
No	79.46		
Yes	20.54		
Secured land rights		0	1
No	24.32		
Yes	75.68		