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RESEARCH ARTICLE

Farming Under Drought: An Analysis of the Factors Influencing Farmers' Multiple Adoption of Water Conservation Practices to Mitigate Farm-Level Water Scarcity

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Abstract

This paper investigates the factors that drive farmers' simultaneous adoption of six water conservation practices (WCPs) and the intensity of their adoption. 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, and farm size (among other factors) influence the probability and extent of adoption of WCPs. Furthermore, combinations like drip and/or sprinkler irrigations and cover cropping, drip and/or sprinkler irrigations and intercropping (among others) are complements, suggesting the bundling of these WCPs.

Keywords: Climate change; Drought; Farmers' multiple adoption; Limpopo River Basin; Multivariate probit; South Africa; Water conservation practices

JEL classifications: Q1; Q2; Q3; Q5

1. Introduction

In many parts of Africa where much of the agriculture is dependent on rainfall, water scarcity as a result of droughts caused by climate change is a major concern for farmers, policymakers, and international organizations. Finding remedies to water scarcity in agriculture is key in the face of unpredictable weather conditions that have often resulted in production uncertainties, severe food shortages, food and nutritional insecurity, poverty, rural unemployment, and low development. In southern Africa, the effects of climate change are becoming more frequent and more severe, with prolonged droughts and extreme temperatures higher than the global average (UNFCCC, 2020). Given this climate emergency, it is imperative to protect water resources and to consolidate and enhance the gains from agriculture that are threatened by droughts and water shortages (DWSs). Since farmers suffer the brunt of the shocks of intensified DWSs and given that the agricultural sector of South Africa uses the bulk of the country's freshwater (about 60%), its farmers are expected to be at the center of all efforts to save, conserve, and promote water-use efficiency. To this effect, our study attempts to understand how the agricultural sector in South Africa is responding to the water-scarcity problem, with a focus on the Limpopo River Basin (LRB).

South Africa's National Development Plan (NDP) for 2030 requires adequate water of the right quality and quantity to support agriculture, equitable economic growth, and the achievement of the national developmental goals (The National Development Plan, 2030, 2012). Yet, the country is severely water-stressed, prone to multi-year DWSs that are being exacerbated not only by climate change but also by economic industrialization, agricultural development, and population growth, among other factors. These shocks not only pose unprecedented challenges to farmers but also have severe negative impacts on the whole agricultural supply chain, food security, and rural employment at large. For instance, the droughts from 2015 to 2018 resulted in the loss of large tracts of farmland and significant amounts of livestock in some parts of the country, increased the price of staple food items like maize, and induced the imposition of harsh water-restriction measures.

Droughts are often unpredictable; therefore, preparedness measures are paramount in enabling farmers to cope with the pervasive long-term effects and severity of DWSs. Anticipatory measures include the adoption of water conservation practices (WCPs) that help to conserve water and enhance its efficient use at the farm level. According to International Rivers (2000), 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% more efficient. This is in line with the literature on the adoption of WCPs, which shows that the adoption of these practices does more than conserve water (Uygan et al., 2021). These practices have additional benefits, such as increases in water-use efficiency (Cai, Rosegrant, and Ringler, 2003), the preservation and improvement of water quality (Howell, 2001), decrease in tillage requirements and cultivation costs (both in terms of labor and fuel), and increases in agricultural production (Heilig, Fischer, and Van Velthuizen, 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 to reducing poverty and inequality within the farming community (Abdulai and Huffman, 2014; FAO, 2017).

Therefore, the purpose of this study is to identify and analyze the factors that motivate farmers' multiple adoption of WCPs, and the interrelationships of these in mitigating farm-level water scarcity. This would enable us to advise policy and enlighten farmers on water-use efficiency in the region studied—the LRB. We are particularly interested in how farmers in the LRB are adopting multiple WCPs simultaneously (bundling[1]) to adapt to climate change, improve resilience to DWSs and promote water-quality improvement. South Africa and especially the LRB adds an important angle to the study of policy regulations on the promotion and adoption of WCPs under extreme water-scarce conditions with poverty considerations.

The LRB is shared by four countries—Botswana, Zimbabwe, Mozambique, and South Africa (LBPTC, 2010). South Africa has the largest share, with an estimated area of about 184,150 square kilometers, or approximately 45% of the basin (LBPTC, 2010). Agricultural activities constitute a large portion of land use in the LRB, particularly in the South African part of the basin (LBPTC, 2010). It is estimated that over 273,000 smallholder farmers live in the Limpopo Province (Statistics South Africa, 2002). However, the dominance of agriculture in the area is greatly threatened by frequent DWSs. Additionally, the province is a semi-arid to arid region, receiving little precipitation (250–500 millimeters of rainfall per year). Further, extreme temperatures in the area mean high evaporation rates, and much of the rain that falls soon returns to the atmosphere. This causes high surface-water scarcity and diminishing groundwater levels. All these factors, together with the lagging water infrastructural development in the area, create severe water scarcity in the basin, which endangers the province's economic development strategy, which identifies agriculture as one of the three pillars of economic growth.

Using six WCPs,[2] we first determine the factors that motivate farmers to adopt multiple WCPs (bundles of WCPs) instead of one conservation practice. Second, we determine the

[1]Bundling of agricultural technologies takes place when farmers use several technologies and management practices that complement each other instead of adopting one technology or management practice independently (Reints, Dinar, and Crowley, 2020).

[2](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.

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interrelationships among the WCPs of the study, paying particular attention to those that are complementary. Finally, we determine the intensity of the adoption (number of practices adopted) of WCPs by farmers. Our study contributes to the literature on WCP adoption and agricultural water management. First, it enhances the understanding of the factors that influence the bundling of WCPs and their interrelationships. Second, beyond its academic contribution, our study provides policymakers with key insights for the design of relevant and proactive water-management policies to improve water-use efficiency in the agricultural sector. Lastly, the study offers guidance for farmers and policymakers in South Africa and other water-risk hotspots across the globe on how to cope with absolute and relative water scarcity.[3] We applied a multivariate probit (MVP) model to estimate the factors that motivate farmers' adoption of WCPs and their interrelationships, using survey data from 555 farmers in the study area. However, to estimate the intensity of adoption, we used an ordered probit model (OPM). Our results show, among other findings, that female farmers are low adopters of mulching; literate farmers are more likely to adopt more efficient performing irrigation methods (MEPIDs); and farm ownership, market access, and off-farm and farm incomes have positive effects on the adoption of MEPIDs. On the interrelationships of the WCPs a positive correlation is evident for cover cropping and MEPIDs, intercropping and MEPIDs, and mulching and MEPIDs, among others, which suggests significant bundling of these practices.

The rest of the paper is structured as follows. In Section 2, we review related literature and provide a brief description of the study area in Section 3. Section 4 comprises the methodology, followed by section 5, which presents the empirical results and their discussion. The last section explores policy implications and discusses the limitations of the study and directions for future research

2. Review of Related Literature

Farmers tend to adopt technologies and conservation practices that may help them increase their expected profit (De Graaff et al., 2008). The factors that drive or constrain agricultural innovation adoption have been studied extensively (Dinar and Yaron, 1992). 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, and farm characteristics, among other factors (Abdulai, Owusu, and Bakang, 2011; Alam, 2015). Specifically, these studies investigated the factors that influence the adoption of WCPs (Alotaibi and Kassem, 2021; Amsalu and De Graaff, 2007; Jara-Rojas, Bravo-Ureta, and Díaz, 2012; Sileshi et al., 2019 among others) and of climate-smart agriculture technologies (Deressa et al., 2009; Dung, 2020; Maguza-Tembo, Edriss, and Mangisoni, 2017; Teklewold, Kassie, and Shiferaw, 2013a among others) in response to farmers' adaptive strategies to droughts and climate change. Other studies have also investigated barriers to water conservation (Kulkarni, 2011), choices of irrigation technologies to conserve water (Caswell and Zilberman, 1985), and conservation practice programs to protect water quality in agricultural watersheds (Osmond et al., 2012). We present an overview of key-related studies on factors that determine farmers' climate change adaptive strategies in selected countries in Table A1 of Appendix A1.

A recent strand of literature of interest looks at the adoption of bundles of technologies and management practices to adapt to climate change. According to Fleischer, Mendelsohn, and Dinar (2011), and Wang et al. (2010), the adoption of bundles provides farmers with more flexibility, which results in better resilience to climate-change effects, and higher profits. Specifically, Fleischer et al. (2011) used discrete choice analysis to simulate how Israeli farmers, in response to

[3]Absolute water scarcity refers to the insufficiency of supply to satisfy existing total demand after all feasible options to enhance supply and manage demand have been implemented (UNESCWA, 2020), coupled with the inability to find substitutes. Relative water scarcity is an imbalance between supply and demand that varies according to local conditions (FAO, 2022).

changes in climate, bundle the choice of crop species and technology to simultaneously decide which crop to grow and what type of irrigation to use, among others. The study concluded that the shift between bundles provides adaptation capacity and enables farmers to be better prepared to handle climate change impacts and maximize profits.

Wang et al. (2010) simulated how farmers' crop choices might change in response to climate change in China. The crux of this study is how farmers have adapted to the different climates across China using different cropping patterns with different water requirements. Their results show that, depending on the region, certain crop bundles provide farmers with flexibility in dealing with climate change impacts on water scarcity. Further, climate change will cause some crops to increase in some regions and fall in others across China.

Reints et al. (2020) examined 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. One important conclusion from their study is that regional climates and water conditions matter. Therefore, farmers will need to be more flexible in their approach to water management to mitigate climate change effects and improve water-use efficiency.

The review of the literature shows that, first, no study exists of farmers' simultaneous adoption of the unique six WCPs. Therefore, we investigate for the first time (to the authors' knowledge), the factors that motivate the adoption of multiple WCPs by farmers in adapting to intensifying climate-change effects in South Africa. This is important to the debate as to whether farmers should adopt WCPs individually or as bundles. It is our view that, identifying these factors and the possible bundles of WCPs will contribute to effective policies that deliver high payoffs to farmers amid DWSs. Second, despite the importance of water conservation in agriculture, few studies (Baiyegunhi, 2015; Gbetibouo, Hassan, and Ringler, 2010; Mogogana, Olorunfemi, and Oladele, 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 that motivate farmers' simultaneous adoption of multiple WCPs. Farmers are often faced with different crop choices and environmental factors among others. Accordingly, they may want to adopt WCPs jointly as complements, substitutes, or supplements to deal with the overlapping constraints that may occur in single adoptions. Farmers, therefore, consider the way different technologies interact and take their interdependencies into account in their adoption decisions. Ignoring these interdependencies can lead to biased estimates and inconsistent policy recommendations (Marenya and Barrett, 2007). This implicates most of the studies on South Africa and provides a justification for our study, which accounts for interdependencies among WCPs.

3. An Overview of the Study Area

The study is conducted in two farming communities, namely Folovhodwe and Tshiombo, as shown in Figure 1. Folovhodwe is in the Musina local municipality, and Tshiombo is in the Thulamela local municipality[4]. Both local municipalities are in the Vhembe District municipality of the Limpopo Province in South Africa.

The district has a population of about 1,294,722, while the Musina and Thulamela local municipalities have a total population of 686,821 (Census, 2011). According to Statistics South Africa (2022), both local municipalities have a total agricultural household population of 74,073. Much of the agricultural activity in the Limpopo Province occurs in this district, especially in the two farming communities, which are located near important tributaries of the Limpopo River. The Nwanedi River passes through Folovhodwe, which is the site of the Nwanedi Irrigation Scheme.

[4]South Africa has a three-tier local government system – provinces (or regions), which consist of district municipalities (or districts), which consist of local municipalities.

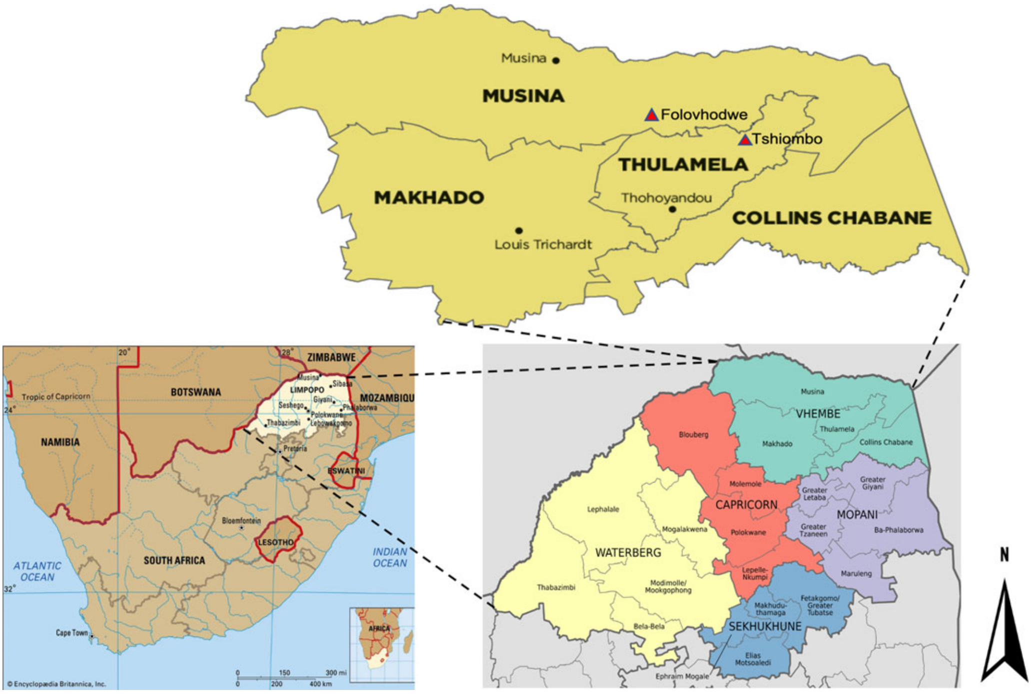

Figure 1. Map of the study area (Google Maps, 2022).

The Tshiombo Irrigation Scheme, one of the largest in Limpopo Province, is in Tshiombo at the western end of the Tshiombo Valley on the south bank of the Mutale River (Lahiff, 1997). Agricultural activities predominantly consist of vegetables, bananas, citrus fruits, maize, melons, peanuts (groundnuts), and poultry and livestock production, among others.

4. Methodology

4.1. Multivariate Probit (MVP) Model

We employed the MVP model because it enabled 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., (2013a), the observed outcome of the adoption of these WCPs follows a random utility formulation. A farmer is more likely to adopt a particular WCP if the benefits of its adoption are higher than those of 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 or 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 ($j = me, ct, cc, mu, in, dt$), 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), then the i^{th} farmer decides to adopt the j^{th} conservation practice if $Y^*_{ifj} = U^*_j - U_0 > 0$. The net benefit ($Y^*_{ifj}$) 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 affect the farmer's adoption decisions. The MVP model is thus specified as follows:

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

where X_{if} denotes the observed characteristics of the farmer, the farm, and other factors that influence the farmer's 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:

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

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 a 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 are given by:

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

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 among the stochastic components of the different types of WCPs. This specification with nonzero off-diagonal elements allows for correlation across the error terms of several latent equations. If these correlations in the covariance matrix are nonzero, this justifies our use of the MVP instead of a univariate probit model 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 farm 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 one WCP, 2 means a farmer adopts two WCPs, and so on). Defining the intensity of adoption as the number of WCPs adopted implies that 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 among 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 that influences the adoption of other WCPs, hence our use of the OPM. The OPM is specified as follows:

$$y^{*} = x'\beta + \varepsilon \tag{4}$$

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

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

where γs 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 and 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:

$$\begin{aligned} \Pr(y = 0|x) &= \Theta(-x'\beta) \\ \Pr(y = 1|x) &= \Theta(\gamma_1 - x'\beta) - \Theta(-x'\beta) \\ \Pr(y = 2|x) &= \Theta(\gamma_2 - x'\beta) - \Theta(\gamma_1 - x'\beta) \\ &\vdots \\ Pr(y = K|x) &= 1 - \Theta(\gamma_{K-1} - x'\beta) \end{aligned} \tag{6}$$

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:

$$logL = \sum_{i=1}^{N} \sum_{\omega=1}^{I} ln(\Theta(\gamma_i - x'\beta) - \Theta(\gamma_1 - x'\beta)) \tag{7}$$

4.3. Variables and Justification

4.3.1. Dependent Variables

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 irrigation. In *drip irrigation*, water is conveyed from the source and delivered drop by drop, at or near the root zone of plants, where it is needed most (Dasberg and Or, 1999). This method enhances water-use efficiency by reducing or eliminating water loss caused by excess deep percolation, evaporation, and runoff. Its field water-use efficiency is about 90% (Howell, 2003). Additionally, it increases fertilizer-use efficiency (fertigation), reduces labor costs, improves disease and pest control, and is suitable for undulating sloped lands (Michael, 2008). With *sprinkler irrigation,* water is applied to crops from overhead by high-pressure

[5]The coefficients in an ordered choice model, in isolation, provide 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, nonquantitative outcomes. As such, there is no conditional mean function, $E[y|x]$, to analyze (Greene and 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 of 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 and Hensher, 2008).

sprinklers (movable or stationary) that simulate natural rainfall. This method has a field water-use efficiency of about 70–80% (Dasberg and 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% of the previous crop residue on the soil surface to protect the soil from extreme heat events, reduce surface runoff, and improve crop productivity through increased water and nutrient retention (Clements et al., 2011). The method also saves fuel, labor 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 are used primarily to slow erosion, improve soil health and infiltration, and smother weeds, among others (SSSA, 2008). It decreases evaporative losses through a mulching effect, both after cover crop termination and during growth (Basche et al., 2014).

Fourth, *intercropping* is the practice where two or more crop species are grown simultaneously on the same field with definite or alternate-row pattern types (Willey, 1990). The method provides better coverage for the soil surface, enhances light interception, reduces the direct impact of raindrops, protects soil from erosion, and decreases water evaporation (Mobasser, Vazirimehr, and Rigi, 2014). We also classify *agroforestry* as a type of intercropping synonymous with polyculture, following Geno and Geno (2001). In agroforestry, woody perennials are 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 protect the soil from erosion. The leaf litter acts as a protective layer over the soil, decreasing evaporative losses and improving 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 the soil surface to protect it from erosion, reduce evaporation, and thereby conserve soil moisture (Govindappa and Seenappa, 2015).

Finally, growing *drought-tolerant crops* that can endure water stress and survive periods of drought (Blum, 2005) is another way farmers can cope with the effects of DWSs.

4.3.2. Explanatory Variables

Economic theory and the empirical literature on the adoption of agricultural technology (Kassie et al., 2015; Teklewold et al., 2013b) provided the basis for selecting the explanatory variables described below for our empirical models. The first set of these variables is the *farmer's characteristics*. It includes the gender of the farmer, age, education, spousal education, farming experience, farm ownership, farm and off-farm incomes, farmer's membership in an association, and household size of the farmer.

Gender of the farmer shows that males are more likely to adopt agricultural technologies than their female counterparts (Obisesan, 2014). In sub-Saharan Africa, due to sociocultural values and norms, males—mostly as the head of the household and primary decision-maker—are known to have more access to and control over vital production resources than women (Mignouna et al., 2011). *Age* is found to either influence the adoption of agricultural technologies positively (Kariyasa and Dewi, 2013; Mignouna et al., 2011) or negatively (Mauceri et al., 2007). Thus, we expected age to exert a positive or negative influence on the adoption of some of our WCPs. *Educated farmers* are more likely to be aware of and better appropriators of new technologies (Ndiritu, Kassie, and Shiferaw, 2014). Therefore, it is perceived to influence the adoption of WCPs positively. However, the education of the farmer may not be enough, as the *education of the farmer's spouse* is also thought to be an important determinant in the adoption of agricultural innovations. Thus, spousal education is also expected to exert a positive influence on the adoption of WCPs. *Farming experience* influences farmers' adoption positively. According to Alam (2015), the greater the experience, the more likely farmers are to adopt alternative adaptation strategies.

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Therefore, we expected this variable to positively influence the adoption of WCPs. *Farm ownership* increases the assurance of future access to the return on investments (Kassie et al., 2009). Therefore, we perceive farm owners to be greater adopters of WCPs than tenants.

Further, on *farm income,* Gebregziabher et al. (2014) assert that farmers with limited incomes are reluctant to adopt unfamiliar technologies due to the risks of possible low crop yields. Given this, we expect farmers with adequate farm income to be more adopters of modern technologies than those with inadequate farm income. Also, *off-farm income* is known to exhibit a positive influence on farmers' adoption behavior. It provides farmers with an additional source of critical liquid capital needed to stimulate adoption and purchase productivity-enhancing inputs (Diiro, 2013). However, this income may also exert a negative influence on agricultural adoptions. According to Namara, Nagar, and Upadhyay (2007), the pursuit of off-farm income may undermine the adoption of modern technology by farmers, especially if it becomes their main source of livelihood. Therefore, off-farm income is perceived to be positively or negatively associated with the adoption of our WCPs. A farmer's *membership in an association* or cooperative engenders social networking, through which farmers can obtain information about new technologies, which tends to enhance adoption rates (Bandiera and Rasul, 2006; Mariano, Villano, and Fleming, 2012). However, social effects can be negative when networks are very large, perhaps due to strategic delays (Bouma, Bulte, and Van Soest, 2008)—waiting and adopting only if one is certain about the new technology's higher returns (Dong and Saha, 1998). We expect this variable to exert a positive or negative influence on the adoption of our WCPs. *Household size* (measured as the number of people in a household) is often used to depict labor endowment (Kassie et al., 2009; Ndiritu et al., 2014). The larger the household size, the higher the availability of labor. This makes the adoption of labor-intensive technologies possible. However, some studies report a negative relationship between this variable and the adoption behavior of farmers (Amsalu and De Graaff, 2007; Belachew, Mekuria, and Nachimuthu, 2020). Therefore, household size is expected to have a positive or negative influence on the adoption of our WCPs.

The second group of explanatory variables is the *farm characteristics*, which comprise farm size, diversified farming, distance to market, location of the farm, source of water, proximity to water, and secured land rights, among other factors. *Farm size* is used to depict the impact of wealth (assets) on the adoption decision process (Abdulai et al., 2011). Farmers with larger farms could have greater wealth (assets) to stimulate the adoption of WCPs positively (Berhanu et al., 2016) compared to those with smaller farms. However, farm size may be negative because not all agricultural technologies are feasible on large or small farms. We expected farm size to have a positive or negative influence on the adoption of our WCPs. *Diversifying production* increases the likelihood of adopting integrated irrigation technologies (He, Cao, and Li, 2007). However, where production is highly specialized, it can lead to a low probability of adoption, as farmers are less likely to have the ability to withstand risks arising from the adoption (Zhang et al., 2019). We perceive this variable to have a positive influence on the adoption of our WCPs. *Distance to the market* is associated with the transaction cost of purchasing inputs and transporting farm produce to the market. It can influence the availability of information on new technologies and enhance adoption (Kassie et al., 2013). Mariano et al. (2012) noted that a greater distance between the farm and the nearest market indicates poor access, which constrains adoption. Thus, we expect the adoption of WCPs to increase with proximity to markets, as reported by Sarker et al. (2021), among others.

In addition, the *location of the farm* (upstream or downstream) is important in determining farmers' adoption of WCPs. Upstream farmers have better access to water resources compared to downstream farmers in terms of water availability, quality, and timing (Chuchird, Sasaki, and Abe, 2017). Given that downstream farms are the most adversely affected by water shortages, we expect them to be greater adopters of WCPs. The *source of water* (surface or groundwater) significantly influences the adoption of water-saving technologies. Farmers who exclusively use groundwater are more likely to adopt MEPIDs (Alam, 2015; Caswell and Zilberman, 1985). Given this fact, we expected this variable to have a positive influence on the adoption of some of our WCPs. *Proximity to water* shows that a greater distance from the water source means a lower likelihood of the adoption of some WCPs (Sithole, Lagat, and Masuku, 2014). Therefore, we expect this variable to have a positive influence on the adoption of some of our WCPs. Farmers with *secured land rights* were likely to take up adaptation strategies, particularly when they pertained to long-term investment—capital and maintenance (Deressa et al., 2009). Therefore, we perceive the security of land rights to have a positive influence on the adoption of some of our WCPs.

The third group is the *crop choice characteristics*. It comprises the production of vegetables, maize, fruits, spices, and beans, among others. Some of these crops require the adoption of integrated technologies. Therefore, we expect these crop choices to exert positive influences on the adoption of some of our WCPs.

The fourth group is the *cost characteristic*, which comprises the *perceived cost of implementing WCPs*. Farmers who perceive the incremental net benefits of modern technology to exceed its cost would adopt it (Bandiera and Rasul, 2006), irrespective of the cost. Therefore, we expect this variable to have a negative influence on the adoption of some of our WCPs.

The fifth group is the *environmental factors*, which comprise *drought experience* and the *perception of future droughts getting worse*. Farmers who either have experienced drought or perceive droughts getting worse are more likely to adopt WCPs. This is in accordance with the literature's assertion that technologies that save water are more likely to be adopted when water resources are scarce because of droughts (Caswell and Zilberman, 1986).

The last set is the *institutional factors*, which include extension services, access to credit, and market access. Most farmers access information on new technologies through contact with extension service officers. While some studies observed that access to extension services positively influenced adoption (Damtew, Husen, and Demeku, 2015), others, such as Belachew et al. (2020) and Berhanu et al. (2016), reported a negative relationship between this variable and the adoption of soil and water conservation (SWC) practices. Given this, we expect this variable to have a positive or negative influence on the adoption of our WCPs. *Access to credit* helps to alleviate liquidity constraints and thus enhances access to complementary technical, mechanical, and capital inputs (Deressa et al., 2009). It thus facilitates the adoption of improved production technologies (Abdulai et al., 2011). As a result, we expect credit access to influence WCP adoption positively. *Market access*, measured by whether a farmer sells to some main customers in the country, like Tiger Brands Limited (a major distributor of food products in 22 African countries and one of the top 40 companies on the Johannesburg Stock Exchange) or the major supermarkets, is an important determinant of modern agricultural adoptions (Feder, Just, and Zilberman, 1985). Lack of market access is a barrier to market participation by resource-poor smallholders and is responsible for significant market failures in developing countries (Sadoulet, Janvry, and Wehrheim, 1996). We expect market access to have a positive influence on the adoption of some of our WCPs.

A summary description of the variables and their expected signs is shown in Table 1.

4.4. Sampling and Data

A two-stage sampling approach involving purposive and random sampling procedures was used in selecting the study area and the farmers. In the first stage, we purposively selected Folovhodwe and Tshiombo farming communities because these are agrarian hubs in the Vhembe District of Limpopo Province. In the second stage, we applied a simple random sampling technique to select farmers for the survey. The data were collected with the aid of structured questionnaires. Enumerators conducted a one-on-one interview with the farmers at their premises. Before commencing the interviews, our 11 enumerators, who had varying levels of completed education—first degree, college, or Matric (high school or secondary school)—were taken through a rigorous two-day training exercise to master the questionnaires and interview techniques.

Table 1. Explanatory variables, description, and expected signs

Variable	Type	Description	Expected sign
Farmer's characteristics			
Gender (Female = 1)	D	1 = female, and 0 otherwise.	+/–
Age	C	Age of the farmer.	+/–
Age squared	C	Age squared.	+/–
Education	D	1 = literate farmer, and 0 otherwise.	+
Spousal education	Ca	Educational status of farmer's spouse: 0 = spouse is non-literate, 1 = spouse is literate, and 2 = has no spouse or is single.	+
Farm experience	C	Years of farming	+
Farm ownership	D	1 = land owned by farmer, and 0 otherwise.	+
Farm income	D	1 = total annual farm income is greater than USD 733*, and 0 otherwise.	+
Off-farm income	D	1 = farmer has off-farm income, and 0 otherwise.	+/–
Member cooperative	D	1 = member of a cooperative, and 0 otherwise.	+/–
Household size	C	Total number of people in the household.	+/–
Farm characteristics			
Farm size	C	Total farm size cultivated in hectares.	+/–
Diversified farming	D	1 = farmer grows different crops, and 0 otherwise.	+
Distance to market	C	Distance to the nearest market or urban center.	+
Location of farm	D	1 = farm is upstream, and 0 otherwise.	+
Source of water	D	1 = surface water is the main source for farming, and 0 otherwise.	+
Proximity to water	D	1 = $\leq$ 1 km from source, and 0 otherwise.	+
Secured land rights	D	1 = farmer has secured rights, and 0 otherwise.	+
Crop choice characteristics			
Vegetables	D	1 = farmer allots largest land share to vegetables, and 0 otherwise.	+
Maize	D	1 = farmer allots largest land share to maize, and 0 otherwise.	+
Fruits	D	1 = farmer allots largest land share to fruits, and 0 otherwise.	+
Spices	D	1 = farmer allots largest land share to spices, and 0 otherwise.	+
Beans	D	1 = farmer allots largest land share to beans, and 0 otherwise	+
Cost characteristics			
Perceived cost	D	1 = perceives cost of implementing WCPs as expensive, and 0 otherwise.	–

(*Continued*)

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Table 1. (*Continued*)

Variable	Type	Description	Expected sign
Environmental factors			
Drought experience	D	1 = experienced droughts in the last 5 years, and 0 otherwise.	+/–
Perception of droughts	D	1 = perceives future droughts to get worse, and 0 otherwise.	+/–
Institutional factors			
Extension services	D	1 = access to extension services, and 0 otherwise.	+/–
Access to credit	D	1 = farmer has access to credit, and 0 otherwise.	+
Market access	D	1 = market access (sells to main customers and supermarkets), and 0 otherwise.	+

Note: D, C and Ca mean "dummy", "continuous," and "categorical" variables.
*USD is the United States dollar. The exchange rate during the survey (in April 2021) was 1 USD = 15 ZAR.

The data collection exercise spanned one month, between March and April 2021. A total of 559 questionnaires were sent out, and 555 valid questionnaires were returned. This high rate of questionnaires returned was a result of the training our enumerators received and the thorough checks we put in place to scrutinize each questionnaire before accepting it each day. In these checks, if any errors or incomplete fills were detected, the enumerators were made to go back to the respective farmer(s) to complete the questionnaire before we received it. The response rate of our survey was then compared to the minimum sample size required for adequate power analysis, following Cochran (1963) and Yamane (1967) (see Appendix A2). Consequently, a sample of 555 farmers was decided on, based on the above considerations coupled with financial and time constraints.

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 a special interest in the water quality and quality farming practices in the Limpopo River Area). We discussed the purpose of the research and sought experts' opinions on how to make the questionnaires more relevant and appealing to farmers.

4.5. Descriptive Statistics

The descriptive statistics in Table A2 of Appendix A3 show that 45% of farmers used MEPIDs, 30% used conservation tillage, and 81% practiced cover cropping, while 85, 43, and 54% used intercropping, mulching, and drought-tolerant crops, respectively. For the *intensity of adoption*, less than 1% of the sample were non-adopters of any form of WCP, whereas those adopting 1, 2, 3, 4, 5, and 6 WCPs constituted 4.7, 17.7, 26, 29, 18, and 3.9%, respectively. With respect to the explanatory variables, females constituted 55% of our sample. This is not surprising, as the 2011 population census shows that women constituted 54.4% of the population of Folovhodwe and 53.7% in Tshiombo (Census, 2011). The average age was 51 years. With regard to education, 94% of the sample had received at least six years or more of formal education; 84% of spouses were

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literate; and 10% of the sample were without spouses. The average farming experience was 16 years. Farmers who cultivated their own farmlands or family lands constituted 93%. The average farm size was 3.27 hectares. On crop choice, 81% of farmers grew vegetables (tomatoes, green chillies, spinach, cabbage, okra, green beans, lettuce, eggplants, and carrots, among others). Some 54% grew maize, while 12% grew fruits (mangoes, oranges, and bananas, among others). Some 31% grew spices (garlic, ginger, and hot chillies, among others), while 24% grew legumes (especially beans).

Furthermore, 93% of the sample had diversified farms, growing a mixture of the crops mentioned above. Of the sample, 81% had access to markets, supplying a few main customers. The mean distance to the nearest market was 56 km. For location, 63% were upstream farmers, and 90% used surface-water sources for farming. For proximity to water, farmers less than a kilometer away from the water source constituted 74% of the sample. Farmers with an annual farm income greater than USD 733 (in April 2021) constituted 80% of the sample, while 69% had no off-farm income. The average household size was six members. Those with membership in cooperative associations constituted 62%. On drought experience, 99% affirmed that they had experienced some droughts in the last seven years, while 54% of farmers perceived future droughts to get worse. The cost of especially drip and sprinkler irrigation, and mulching was perceived as high by 66% of farmers. Of the sample, 79% did not have access to credit, while 97% reported having access to extension services, and 76% had secured land rights to their farmlands.

These descriptive statistics, in most cases, matched well with those of the 2011 population census for the study area and even at the national level, thus indicating that our sample of 555 was representative.

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 [$chi^2(15) = 77.14$; Prob $> chi^2 = 0.0000$] 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 $chi^2(180) = 647.62$; Prob $> chi^2 = 0.000$] 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. Interrelationships Among WCPs

The pair-wise correlation coefficients across the residuals of the MVP model that indicate interdependence among the six WCPs show significant and positive associations among 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 suggests that farmers adopt them together, confirming a significant bundling of these WCPs. This outcome is further confirmed by the summary statistics of the *intensity of adoption* in Table A2 of Appendix A3, where cumulatively 95% of farmers are bundling 2, 3, 4, 5, and 6 WCPs on their farms. However, the other pair-wise correlations are insignificant, even though most have the right expected positive *a priori* signs.

5.1.2. Determinants of the Adoption of Multiple WCPs

Our results show that gender influences the adoption of mulching negatively. That is, *female* farmers are less likely to adopt mulching than their male counterparts. Gender is, however,

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Table 2. Results of the multivariate probit regression

	MEPIDs		Conservation Tillage		Cover Cropping		Intercropping		Mulching		Drought-tolerant Crops	
Variables	Coeff.	|z|	Coeff.	|z|	Coeff.	|z|	Coeff.	|z|	Coeff.	|z|	Coeff.	|z|
Farmer's characteristics												
Gender (Female = 1)	−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
Farm 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 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
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
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
Farm characteristics												
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
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
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
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
Crop choice characteristics												
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
Cost characteristics												
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
Environmental factors												
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
Institutional factors												
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
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
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

(*Continued*)

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Table 2. (*Continued*)

Variables	MEPIDs Coeff.	MEPIDs |z|	Conservation Tillage Coeff.	Conservation Tillage |z|	Cover Cropping Coeff.	Cover Cropping |z|	Intercropping Coeff.	Intercropping |z|	Mulching Coeff.	Mulching |z|	Drought-tolerant Crops Coeff.	Drought-tolerant Crops |z|
Interrelationships among WCPs												
Correlations					**Coefficient**						**|z-value|**	
rho21 (Conservation tillage and MEPIDs)					0.095						1.26	
rho31 (Cover cropping and MEPIDs)					**0.208****						2.35	
rho41 (Intercropping and MEPIDs)					**0.254*****						2.74	
rho51 (Mulching and MEPIDs)					**0.158****						2.06	
rho61 (Drought-tolerant crops and MEPIDs)					0.038						0.49	
rho32 (Cover cropping and conservation tillage)					0.035						0.38	
rho42 (Intercropping and conservation tillage)					**0.673*****						8.62	
rho52 (Mulching and conservation tillage)					−0.073						0.97	
rho62 (Drought-tolerant crops and conservation tillage)					0.038						0.51	
rho43 (Intercropping and cover cropping)					**0.311*****						3.34	
rho53 (Mulching and cover cropping)					0.055						0.61	
rho63 (Drought-tolerant crops and cover cropping)					0.013						0.15	
rho54 (Mulching and intercropping)					−0.032						0.36	
rho64 (Drought-tolerant crops and intercropping)					**0.165****						2.02	
rho65 (Drought-tolerant crops and mulching)					−0.012						0.15	
Log likelihood											−1510.31	
Wald $chi^2(180)$											647.62	
Prob > chi^2											0.0000	
Number of observations											555	

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho32 = rho42 = rho52 = rho62 = rho43 = rho53 = rho63 = rho54 = rho64 = rho65 = 0 $chi^2(15)$ = 77.1373 Prob > chi^2 = 0.0000.
Note: ***, **, and * denote 1, 5, and 10% significance levels, respectively.

insignificant for the other WCPs. This result is anticipated as gender inequality due to income, asset ownership (land title and tenure tend to be vested in men, either by legal conditions or by sociocultural norms), and the right to productive resources are linked to lower adoption rates by females (Ndiritu et al., 2014). Our results are in accordance with Fisher et al. (2018), who found female-headed households to be low adopters of mulching. However, Mango et al. (2017) did not find gender to significantly influence the adoption of land and SWC technologies, including mulching, in their study.

Age is quadratic and statistically significant for conservation tillage, cover cropping, and intercropping. However, it is insignificant for the other WCPs. Our result indicates, first, that the adoption of conservation tillage and intercropping increases 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 among younger farmers until ages 54 and 53, respectively, after which (having become older farmers), their adoption decreases, all else being constant. This outcome, according to Mauceri et al. (2007), implies that as farmers grow older, there is an increase in risk aversion and a decreased interest in long-term investment in the farm, which, therefore, decreases their adoption rates. Younger farmers, on the other hand, are typically less risk averse and more

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willing to try new technologies. 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 crops decreases with younger farmers until age 54 years when its adoption increases with older farmers, all else constant. This is consistent with the literature's assertion that as farmers age, they gain knowledge and experience, making them better able to evaluate information and the benefits of technology than younger farmers (Kariyasa and Dewi, 2013; Mignouna et al., 2011). Our results show the importance of modeling age as nonlinear, as it signals that there is an age threshold for the adoption of these WCPs, which failing to acknowledge can bias the estimates of a study.

Literate farmers are more likely to adopt MEPIDs. However, this variable has no effect on the adoption of the other WCPs. Our finding is consistent with the literature, which shows that literate farmers are better informed and more likely to adopt modern technologies (Abdulai et al., 2011; Zhang et al., 2019). On spousal education, farmers with literate spouses and those without spouses are less likely to adopt MEPIDs, mulching, and conservation tillage, all else being constant. This outcome is unexpected, as literate spouses are expected to help their partners make sound farm decisions and assist with resources to increase adoption. However, we found during our survey that the decision to adopt WCPs is an isolated one and not part of the overall household decision-making process.

More experienced farmers are less likely to adopt drought-tolerant crops, all else being constant. However, the variable is insignificant for the other WCPs. This outcome is intriguing but not surprising. According to Kumar et al. (2020), the low adoption of drought-tolerant crops is because the technique has only recently been introduced and experienced farmers—compared to relatively less experienced farmers—are less likely to quickly switch to their adoption. In addition, during the survey, one reason adduced for the low adoption of drought-tolerant crops was that farmers wanted 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, inadequate information, and the perceived attributes of different varieties of drought-tolerant crops, are the major barriers to the adoption of this practice (Fisher and Snapp, 2014).

In line with the literature's assertion that ownership of farms increases the assurance of future access to the return on investments (Kassie et al., 2009), farmers who cultivate their own farmlands are more likely to adopt MEPIDs and conservation tillage but are less likely to adopt cover cropping, all else being constant. This outcome underscores the important role that farm ownership plays in the adoption of WCPs in the LRB.

Consistent with the findings of Abegunde, Sibanda, and Obi (2019), farmers with an annual farm income greater than USD 733 are more likely to adopt MEPIDs, all else being constant. However, fluctuations in farm income can affect farm decisions and the ability to sustain operations, including the adoption of innovations (Mishra and Sandretto, 2002). An additional source of income from off-farm work may enable farmers to overcome credit constraints or fluctuations in farm income. It is, therefore, not surprising that farmers with off-farm activities are more likely to adopt MEPIDs but are less likely to adopt conservation tillage, all else being constant. These findings demonstrate the importance of farm and off-farm incomes in providing farmers with greater incentives to invest in WCPs.

Farmers with membership in a cooperative are less likely to adopt cover cropping and mulching, all else constant. This result is not unexpected, as we explained earlier, social effects can be negative when networks are very large (Dong and Saha, 1998), and that cover cropping and mulching are mostly feasible on small farms. Therefore, the low adoption of these practices suggests that farmers have large farms, making these practices unsuitable.

Household size increases the probability of adopting drought-tolerant crops but does not influence the adoption of the other WCPs, all else being constant. The finding supports the notion that the likelihood of adopting some WCPs (especially drought-tolerant crops) rises as household labor becomes more abundant. For this practice, some amounts of labor are required for some management practices, including mulching and the removal of weeds and alien species that compete with drought-tolerant crops for water. It is, therefore, not surprising that household size increases the probability of adopting drought-tolerant crops.

Farm size increases the probability of adopting mulching but is negatively associated with the adoption of drought-tolerant crops. Farm size is insignificant for the other WCPs. Our results agree with Mugonola et al. (2013), who found farm size to increase the likelihood of adopting SWC technologies, including mulching, but contradict Martey and Kuwornu (2021), who found farm size to be negatively associated with the use of mulching. On the other hand, farmers' reluctance to adopt drought-tolerant crops is a result of some of the reasons adduced above for the challenges that farmers face with respect to the adoption of this practice.

In accordance with our expectations, farmers with diversified farms (growing multiple crops) are more likely to adopt cover cropping and intercropping compared to those with specialized farms (growing one crop). However, this variable is insignificant for the other WCPs. Our results agree with Jensen, Johnston, and Olsen (2020) and He et al. (2007). This finding is consistent in practice, as farmers who grow different crops (diversified) can intercrop and/or grow cover crops to meet the different needs of the different crops, including complementing and compensating each other.

Distance to market influences the adoption of MEPIDs and mulching positively but does not influence the adoption of the other WCPs. Our results indicate that most farmers are not constrained by distance to market, hence the greater adoption of MEPIDs and mulching. Our finding is in line with Ersado, Amacher, and Alwang (2004), who report that distance to the market increases the adoption of SWCs. Our results point out the importance of markets in promoting the adoption of WCPs.

With respect to the location of the farm, downstream farmers are less likely to adopt conservation tillage. This is unexpected, as we earlier alluded to the fact that downstream farmers suffer water problems more than upstream farmers (Chuchird et al., 2017), therefore, we expected this practice to be an attractive option for downstream farmers to conserve water. However, a study by Mandiringana, Mabi, and Simalenga (2006) on the acceptance of conservation tillage in South Africa reported that the method's high labor requirements generally made it less attractive. Also, the special equipment required for the successful implementation of the method is generally not available to all farmers. These factors account for the low adoption of this method.

As reported by the following studies (Alam, 2015; Caswell and Zilberman, 1985), farmers who exclusively use groundwater are more likely to adopt MEPIDs but are less likely to adopt cover crops. The low adoption of cover crops by groundwater users is surprising. However, we notice that the types of cover crops grown in the study area (sweet potatoes, beans, pumpkin, and watermelons, among others) were not popular among groundwater users (10% of the sample). These groundwater users were mainly into fruits (largely bananas and grapes) and a few vegetable productions.

On proximity to a water source, farmers who are more than a kilometer away are more likely to adopt conservation tillage, all else being constant. Water poverty is more prevalent on farms more than a kilometer from the source compared to farms less than a kilometer away. A study of smallholder farmers by Maponya and Mpandeli (2012) in the Tshiombo Irrigation Scheme in Limpopo Province emphasized that farmers whose plots are far from the canal system suffer serious water access challenges and low crop yields. It is, therefore, not surprising that conservation tillage is a more attractive option for this category of farmers.

Farmers with secured rights to their farmlands are more likely to adopt MEPIDs, intercropping, and drought-tolerant crops, all else being constant. Our results suggest that a sense of exclusive rights to their property motivates farmers to improve the land and adopt water management practices in both irrigated and rain-fed systems (Alam, 2015). Additionally, it encourages farmers to take up adaptation strategies that pertain to long-term investment—capital and maintenance (Deressa et al., 2009). This finding underscores the importance of secured land rights in motivating farmers' adoption of WCPs on their own farmlands than more so on rented (or borrowed) farmlands, possibly reflecting tenure insecurity and Marshallian inefficiency (Kassie et al., 2013; Teklewold et al., 2013a).

Consistent with our expectations, farmers who produce vegetables are more likely to adopt intercropping and mulching, all else constant. Vegetable cultivation requires adequate cooling at the roots of the plants. This is mostly achieved through mulching. Additionally, intercropping is a common practice among these farmers. We found evidence of pure vegetable intercropping systems such as spinach–garlic, tomatoes–lettuce, and eggplants–okra, among others, during our survey. Studies such as Yildirim and Guvenc (2005) highlight intercropping in vegetables as an important sustainable farming practice that increases the productivity of vegetables and net income.

Maize farmers are less likely to adopt intercropping but more likely to adopt drought-tolerant crops. Generally, most maize farmers in the study area do not intercrop their fields. Also, 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 among 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 among fruit farmers in the study area.

Spice farmers are less likely to adopt MEPIDs and mulching but are more likely to adopt intercropping. According to these farmers, they would prefer MEPIDs for their operations, but first, the cost of the drip irrigation method is currently a major constraint. Second, sprinklers—which behave like rain—beat down the flowers of their crops, especially tomatoes, chillies/peppers, and thus reduce or prevent yield. So, the cost of the drip method and the seemingly unsuitable sprinklers are the causes of this aversion. The low adoption of mulching is, however, surprising, as this is a major practice among spice farmers in the study area. During the survey, some farmers, especially those with farms over a hectare, expressed concerns about the method. They complained that it is not only expensive to apply but also very difficult to execute, as it requires a large amount of labor and mulch to be successful. Junge et al. (2009) confirmed that cover cropping and mulching were performed only on areas that were smaller than one hectare.

The probability of adopting cover crops increases with beans farmers. Given that one of the cover crops cultivated in the study area is beans, this finding is anticipated.

In accordance with the literature, if farmers perceive the incremental net benefits of an innovation to exceed its cost, then adoption would occur (Foster and Rosenzweig, 1995). Farmers who perceive the cost of implementing WCPs to be high are less likely to adopt conservation tillage, intercropping, and drought-tolerant crops but more likely to adopt cover cropping, all else being constant. 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. In addition, Wekesa et al. (2003) report the high cost of technology as a hindrance to adoption.

Farmers who in the last seven years, have experienced one or more droughts are more likely to adopt cover cropping but not 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 perceived 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 previous droughts were severe and prolonged, killing off most crops, including cover crops. Therefore, if future droughts would get worse, the adoption of cover crops might not be an attractive option for conserving water or adapting to climate change, as demonstrated by (Cai and Rosegrant, 2004; Caswell and Zilberman, 1986).

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). This result, however, is not unique: Gebru et al. (2020) found access to extension services to have no effect on farmers' adoption of SWCs. Our results indicate that, first, extension officers in the study area are inactive in providing effective services, particularly in relation to the adoption of WCPs. That is, they are more focused on crops and livestock production than on WCPs, as claimed by Amsalu and De Graaff (2007). Second, extension officers may be using outmoded extension service methods.

Farmers with access to credit are less likely to adopt intercropping and drought-tolerant crops, all else being constant. This outcome is not unexpected, as our interactions with farmers show that those with access to credit are more likely to adopt other WCPs, such as MEPIDs. Even though our results do not reflect this, this is the reality we found on the ground during our survey. 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, access to markets is positively associated with the adoption of MEPIDs but is insignificant for the other WCPs. This finding suggests that farmers with access to markets are more likely to adopt MEPIDs, all else being constant. Farmers in our sample are not constrained by access to market. They mostly have contractual agreements with Tiger Brands Limited and/or some of the major supermarkets to which they supply their harvested farm products. Additionally, some farmers sell their produce at mini markets that exist by the wayside near the highways nearer to their farms. It is, therefore, expected that farmers would exhibit a higher probability of adopting MEPIDs with respect to this variable. Ersado et al. (2004) observed that better market access increased the adoption of SWC practices.

5.2. Determinants of the Intensity of Adoption of WCPs

In Table 3, we report the results of the OPM and the marginal effects of each outcome. The chi-squared statistic for the OPM is highly significant [$chi^2(30) = 166.03$; Prob $>$ $chi^2 = 0.0000$]. This suggests that the null hypothesis that all slope coefficients are jointly equal to zero is rejected. The results of the OPM show that several factors influence the intensity of adoption of WCPs. As noted earlier, the direct interpretation of the estimated coefficients of the OPM is less informative, therefore, we focus on the marginal effects for each outcome.

The marginal effects show that the number of WCPs adopted increases among farmers with literate spouses and those without spouses by up to three WCPs. They are 5.9% more likely to adopt up to three WCPs, all else being constant. Farmers who own their farms are 3.1% more likely to adopt more than four WCPs. While those with an annual farm income greater than USD 733 are 2.1% more likely to implement all six WCPs. In addition, farmers who are members of a cooperative are 2.4% more likely to implement up to three WCPs. Those with diversified farms are 5.1% more likely to implement all six WCPs, all else being constant. This outcome confirms the importance of diversified farming in the bundling of WCPs in the MVP model.

Furthermore, the intensity of adopting WCPs increases with distance to market by 0.09% for full implementation of all six WCPs, all else being constant. Consistent with the MVP model's result on secured land rights and the Marshallian inefficiency hypothesis. Farmers with secured land rights are 3.1% more likely to adopt all six WCPs, all else being constant. Farmers predominantly involved in vegetable and maize production are 2.7 and 3.0%, respectively, more likely to implement all six WCPs, all else being constant. Spice farmers are 4.9% more likely to adopt up to three WCPs. Farmers with access to extension services are 3.9% more likely

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Table 3. Results of the ordered probit model and the marginal effects of each outcome

	Ordered Probit Model and 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)	
Intensity of WCP Adoption	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**
Farmer's characteristics																
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
Farm 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 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
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
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
Farm characteristics																
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
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
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
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

(*Continued*)

Table 3. (*Continued*)

	Ordered Probit Model and 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)	
Intensity of WCP Adoption	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**	**Coef.**	**| z |**
Crop choice characteristics																
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
Spices	**−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
Cost characteristics																
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
Environmental characteristics																
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
Institutional characteristics																
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
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
/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															
$chi^2(30)$	166.03															
Prob > chi^2	0.0000															
Number of obs.	555		555		555		555		555		555		555		555	

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

to implement all six WCPs. This finding shows that a factor can have a 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 increases the number of WCPs adopted. This set of outcomes additionally confirms the bundling of WCPs by farmers.

6. Conclusion and Policy Implications

This study investigated the factors that drive farmers' simultaneous adoption of six WCPs (bundling) and the intensity of their adoption in the LRB of South Africa. Multivariate probit and ordered probit models were used to estimate the relationships from our survey data. Our results show, first, that key farm, farmer, institutional, and environmental factors, like gender, age, education, off-farm and farm incomes, and access to markets, among others, trigger the probability and extent of adoption of the WCPs differently. While some determinants influence the adoption of the various WCPs positively, others do so negatively, and yet others are statistically insignificant. Second, the interrelationships among the six WCPs show strong evidence of the bundling of WCPs in the LRB. Finally, in the intensity of adoption model, the results show that a minimum of two practices to a maximum of six were being adopted. These findings are relevant not only for farmers, decision-makers, and other stakeholders in the Limpopo Province of South Africa for the promotion and adoption of WCPs but also for their counterparts in other water-risk hotspots where climate-change effects have become rampant on water resources and in the agricultural sector.

Our study, like many previous studies, especially those on SWCs and CSAs, both fits established patterns of farmers' adoption behavior of these practices and is unique for agricultural practitioners and policymakers. The study suggests that in conditions of extreme climate change effects and droughts, farmers in South Africa exhibit similar characteristics of farmers' adaptation behavior and adopt strategies to mitigate the effects of intensified climate change and farm-level water scarcity. The study, however, is unique in that, first, unlike many previous studies on WCPs, it underscores the important need for farmers to consider combining several WCPs (bundling) in mitigating their farm-level water scarcity, or in response to climate change intensification, consider the adoption of the best bundle mix and the supporting technologies that are appropriate for tackling the different levels of DWSs encountered. Second, our six unique WCPs provide farmers and policymakers with a mixed toolset that is effective at helping farmers counter climate change effects and DWSs in water-stressed areas.

Our framework is not only critical for long-term planning under likely changes in climate but also provides farmers with more flexibility, better resilience, and a wide range of toolsets to adapt to increased climate volatility. This way, farmers have more control over climate change effects and their related impacts over time. Our choice of the six WCPs further makes our study unique and enriches the discussions and policy regulations on their promotion and adoption. Our results offer some important implications for policy. First, WCPs are interdependent; therefore, the design of any effective strategy(ies) aimed at increasing their uptake rate must take this interdependence into consideration. Second, we found that being female reduces the probability of adopting mulching. Policies aimed at fostering and making the adoption of MEPIDs more appealing to females are necessary. One approach is to expand the availability of credit to women for this purpose, not just mulching. Third, education increases the adoption of MEPIDs, implying that improving farmers' knowledge will positively impact adoption decisions. Therefore, initiatives that support farmers' education, training, and continuous awareness of the likely effects of climate change on water resources and agricultural productivity are recommended. In addition, we recommend the education and training of extension service officers on modern best agricultural practices that incorporate the adoption of WCPs into farming in response to DWSs. Fourth, the government should strive to create a conducive atmosphere for farmers to secure tenure rights to their farmlands, as tenure rights significantly influence the adoption of MEPIDs. In addition, the significant and positive impacts of access to and distance to markets indicate that policies aimed at improving access to and distance to markets will help promote the adoption of WCPs, especially MEPIDs.

Finally, these suggestions would go a long way toward increasing the adoption rate of WCPs, thereby increasing water conservation efforts and efficiency of use. This is important to alleviate the water shortage in water-stressed South Africa, especially in the arid Limpopo Province. By doing so, farmers would not only be conserving water under drought circumstances but would also be ensuring the sustainability of water resources for increased agricultural production, food security, improved incomes, poverty alleviation, rural employment, and above all, sustained and continuous contributions to economic and social development. 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. Second, due to time and financial constraints, we could cover only two farming communities in the Limpopo Water Management Area (WMA). Not including the entire Limpopo WMA or even the entire portion of the Limpopo River in South Africa means our findings are entirely of those two farming communities. We believe that a study that covers these areas could have a higher power of generalizability and further advance this study. Such a study could be done by including other variables (like temperature and rainfall changes, weather forecast figures, and soil types, among others) or the same variables as this study. In addition, future studies could examine the impact of the adoption of WCPs on farm output and profits.

Data availability statement. The data that support the findings of this study are available from the corresponding author [A.T.A] upon request.

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Appendices

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 irrigation WUE, document the challenges encountered as well as explore opportunities for further development.	Engineering and technological innovations, advancements in plant and pasture science, environmental, and socioeconomic factors	A review of advances, challenges, and opportunities	1. The review showed that improvements in irrigation infrastructure through modernization 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 trends in irrigation water-use efficiency (WUE) include engineering and technological innovations, advancements in plant and pasture science, environmental factors, and socioeconomic considerations. 4. Challenges that might be encountered include a lack of public support, especially when the methods used are not cost effective, and the reluctance of farmers 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 conservation and water-efficiency practices.	DV: soil conservation practices, water-quality protection, and water conservation (efficiency practices). IV: relationship between farming practices and water quality, type of farm operation, land ownership, 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.	A bivariate probit model	1. Farmers' beliefs about the relationship between farming practices and water quality can play a role in protecting the quality of surrounding waters. 2. Participation in federal programs has 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. 4. The type of farm operation, participation in federal programs, 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.

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Table A1. (*Continued*)

Authors	Study area/sample size (N)	Objective(s)	Variables of study	Empirical model(s)	Summary of findings
Zhang et al. (2019)	Beijing, China $N = 490$	To identify the major factors and provide an understanding of farmers' sustainable irrigation practices used to cope with water stress in water-scarce 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-user association, drought-prone area, neighboring farmers, policy subsidies).	Binary logit choice model	1. The results revealed that education, farm size, on-farm demonstration, cooperatives, training, groundwater, access to information, water-use associations, drought-prone areas, neighboring farmers, and policy subsidies significantly improved the adaptation to water scarcity. 2. Specifically, the findings 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 significant negative impact on farmers' adoption of WSIT. 3. Farm size had a positive and significant impact on the adoption of WSIT. On-farm demonstrations showed a positive influence 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.
Pagliacci et al. (2020)	Veneto region, 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 shed 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 (utilized 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 utilized agricultural area at the municipality level).	Poisson and logit regression models	1. These results showed, among others, that for no-tillage, the number of adopters by municipality is positively affected by the farming factors. In particular, the municipality's 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 clay soils rather than sandy soils. 4. No-tillage on clay 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.

(*Continued*)

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Table A1. (*Continued*)

Authors	Study area/sample size (N)	Objective(s)	Variables of study	Empirical model(s)	Summary of findings
Valizadeh, Bijani, and Abbasi (2018)	West Azerbaijan Province, Iran. $N = 378$	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 toward consequences, attitude toward participation in water conservation, social pressure toward water conservation, quality of agricultural extension services and satisfaction of water resources management.	Parametric tests were used to analyze their data.	1. Social pressure was one of the most important activators of farmers' active participation in water conservation. It, however, did not have a significant effect on the moral norm of water conservation. 2. The quality of agricultural extension services was positively and significantly associated with farmers' active participation. 3. Satisfaction with water resources management was the strongest predictor of farmers' active participation in water conservation, highlighting the issue of the 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 practices 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 (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).	Multivariate probit and ordered probit models	1. The adoption of the various CSA practices is interrelated. Specifically, among other findings of the 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 were 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 the major household characteristics that favor 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.

(*Continued*)

Table A1. (*Continued*)

Authors	Study area/sample size (N)	Objective(s)	Variables of study	Empirical model(s)	Summary of findings
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 saves irrigation water use, reduces irrigation cost, and increases or stabilizes 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 and cultivated lands, and had 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 the low elevation of the land. 5. The 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 (USD 9,808) per share of irrigation water, low payment (USD 5,954) 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 generated greater efficiency in the use of water for irrigation. 2. Age and education show inconclusive results. 3. Family size is positive and significant. This supports the notion that the likelihood of adopting water conservation practices rises as family labor becomes more abundant. 4. Farm size (land) is significant and positive, which is similar to the results reported by Bekele and Drake (2003). 5. Both land and livestock are positive and consistent with the notion that wealthier farmers are more able to undertake risk and thus are more likely to be adopters. However, home consumption is negative. 6. Access to credit, which exhibits mixed results in the literature, was not significant in their study.

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Table A1. (*Continued*)

Authors	Study area/sample size (N)	Objective(s)	Variables of study	Empirical model(s)	Summary of findings
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, labor, economically active, group membership, livestock, main crop, literacy, adoption of land, soil, and water (LSW).	Binary logistic and ordinary least squares regression models,	1. The results showed that gender, household size, education, extension, casual labor, skilled labor, 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 positively influenced the adoption of small-scale irrigation farming. Access to irrigation equipment and a reliable water source were vital for farmers to try small-scale irrigation farming. 4. Awareness of WCPs, such as rainwater harvesting, had a positive and significant influence on the adoption of small-scale irrigation farming. The distance traveled 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 suggest, among other findings, that warmer winters and springs promoted switching to the 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.

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Table A1. (*Continued*)

Authors	Study area/sample size (N)	Objective(s)	Variables of study	Empirical model(s)	Summary of findings
					5. More experienced farmers were more likely to adapt than less experienced ones. The age of the farmer did not seem to be of significance in influencing adaptation, as almost all marginal effect coefficients were statistically insignificant.
Belachew, Mekuria, and Nachimuthu (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 adopting soil bund, stone bund, check dam, and strip cropping was 74%, 56%, 29%, and 56%, respectively. 2. Specifically, 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 improved farmers' decisions to adopt SWC practices. Household size influenced the adoption of soil bund, and strip cropping, both 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 dams, 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 toward risk, region, household size, household water usage), socioeconomic characteristics (membership in social networks, access to micro-credits, access to public funds, household savings, off-farm employment, household income 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).	Bivariate logistic regression.	1. The results showed that the individual, household, socioeconomic, and farmer perception-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. The 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 statistical significance for the variables relating to the adopter's age, health, ability to read and write, attitude toward risk, region, household size, household water usage, access to microcredits, savings, off-farm employment, 5. household income fluctuations, farmers' perception and recognition of the changing climate and environment, and adoption of WCTs.

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Table A1. (*Continued*)

Authors	Study area/sample size (N)	Objective(s)	Variables of study	Empirical model(s)	Summary of findings
Ntshangase, Muroyiwa, and Sibanda (2018)	Ingwe Municipality in Kwa-Zashuke, Ward 8, KwaZulu-Natal Province, 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 less-educated farmers. Among the more educated farmers, the older farmers had a higher tendency toward 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. The 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)	NorthWest Province, South Africa. $N = 108$	To determine the knowledge and adoption of water-use efficiency techniques among women irrigators in the North West Province of South Africa	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 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 labor, farming experience, number of years in irrigation scheme, water rate, existence of water tariffs, electricity for water pumping, cropping systems.	Frequency counts, percentages, means, standard deviation, and probit regression model.	1. The findings showed that adoption of reduced tillage had a direct relationship with the frequency of extension visits but an inverse relationship with land tenure, membership in farmers' groups, and the existence of water tariffs. 2. Extension visits were found to have a significant positive effect on the adoption of cover crop techniques. 3. The adoption of crop rotation has a direct relationship with age. Membership in a farmers' group, the existence of water rates, and the existence of water tariffs reduced the likelihood of the adoption of crop rotation. 4. The age and number of plots owned by women farmers were positive. Farm size, membership of farmers' groups, and the existence of water rates and tariffs were 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/	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 female farmers. 2. Age had a significant negative effect on the adoption of RWHT.

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Table A1. (*Continued*)

Authors	Study area/sample size (N)	Objective(s)	Variables of study	Empirical model(s)	Summary of findings
			attitude toward RWHT, distance to water tanks and importance of livestock.		3. Household income had a significant positive effect on the adoption of RWHT. A higher level of household income implies a greater incentive for investment in agricultural technologies and the ability to bear the risk associated with their adoption. 4. Social capital had a significant positive effect on adoption of RWHT. Contact with extension had a significant positive effect on the adoption of RWHT. 5. Security of land rights had a significant positive effect on the 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 toward RWHT were more likely to adopt it.
Gbetibouo et al. (2010)	Limpopo River Basin, 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 River).	Multinomial logit model.	1. The results revealed that larger households were more willing to choose "the other" category as an adaptation option, which included adaptations such as the use of soil conservation techniques and chemical treatments that are labor-intensive, especially in small-scale farming. 2. Experienced farmers had an increased likelihood of using portfolio diversification, changing planting dates, and changing land under cultivation. 3. Farm size is significant and positively correlated with the probability of choosing irrigation as an 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 supplements for their livestock. Access to credit increased the likelihood that farmers would take up portfolio diversification to buy feed supplements for their livestock. 5. Households 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) intensifying irrigation, and (3) changing planting dates. A decrease in rainfall is likely to push farmers to delay planting.

Note: DV = the dependent variable(s); IV = the independent variables.

Appendix A2. Sample Size Estimations

In A1, Cochran (1963) assumed there is a large population, but the variability in the proportion that will adopt a practice is unknown, just as in our case. Therefore, assuming a $p = 0.5$ (maximum variability), a 95% confidence level and $\pm 5\%$ precision, the resulting sample size is given as

$$n_0 = \frac{Z^2 pq}{e^2} = \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2} = 385 \textit{ farmers} \quad \text{(A1)}$$

where n_0 is the sample size, Z^2 is the abscissa of the normal curve that cuts off an area α at the tails ($1 - \alpha$ equals the desired confidence level, e.g. 95%), e is the desired level of precision, p is the estimated proportion of an attribute that is present in the population, and q is $1 - p$. The value for Z is found in the statistical which contains the area under the normal curve.

In the case of Yamane (1967), the sample size is calculated as follows:

$$n = \frac{N}{1 + N(e)^2} = \frac{74073}{1 + 74073(0.05)^2} = 398 \textit{ farmers} \quad \text{(A2)}$$

where n is the sample size, N is the population size, and e is the level of precision.

Therefore, our sample of 555 farmers is a representative sample for good power analysis.

Appendix A3

Table A2. Descriptive statistics

Variables	% Sample (N = 555)	Min	Max	Mean	Std D.
Dependent variable					
MEPIDs		0	1	0.553	0.497
No	44.68				
Yes	55.32				
Conservation tillage (CT)		0	1	0.297	0.457
No	70.27				
Yes	29.73				
Cover cropping (CC)		0	1	0.813	0.391
No	18.74				
Yes	81.26				
Intercropping (IN)		0	1	0.852	0.355
No	14.77				
Yes	85.23				
Mulching (MU)		0	1	0.427	0.495
No	57.30				
Yes	42.70				
Drought-tolerant crops (DTCs)		0	1	0.541	0.498
No	45.95				
Yes	54.05				
Total number of WCPs adopted		0	6	3.482	1.245

(*Continued*)

Table A2. (*Continued*)

Variables	% Sample (N = 555)	Min	Max	Mean	Std D.
Does not adopt WCP	0.54				
Adopts 1 WCP	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 variable					
Gender		0	1	0.553	0.497
Male	44.68				
Female	55.32				
Age		20	95	50.98	15.11
Age squared		400	9025	2826.9	1620.3
Education		0	1	0.940	0.237
Non literate	5.95				
Literate	94.05				
Spousal education		0	3	3.304	1.360
Non literate spouse	6.49				
Literate spouse	83.60				
Without spouse	9.91				
Experience		1	55	16.22	9.88
Explanatory variable					
Farm ownership		0	1	0.929	0.256
Leased/rented/government land	7.03				
Owned by the farmer or family	92.97				
Farm size		0.15	27	3.262	3.927
Vegetables		0	1	0.811	0.392
No	18.92				
Yes	81.08				
Maize		0	1	0.544	0.498
No	45.59				
Yes	54.41				
Fruits		0	1	0.117	0.321
No	88.29				
Yes	11.71				

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Table A2. (*Continued*)

Variables	% Sample (N = 555)	Min	Max	Mean	Std D.
Spices		0	1	0.306	0.461
No	69.37				
Yes	30.63				
Beans		0	1	0.241	0.428
No	75.86				
Yes	24.14				
Diversification of farm		0	1	1.376	0.485
Specialized farming	7.39				
Diversified farming	92.61				
Market access		0	1	0.807	0.395
Had no access to markets	19.28				
Had access to markets	80.72				
Distance to market		10	97	55.70	27.42
Location of farm		1	2	1.376	0.485
Upstream	62.34				
Downstream	37.66				
Source of water		1	2	1.104	0.306
Surface	89.55				
Underground	10.45				
Proximity to water		1	2	1.259	0.438
Less than a kilometer	74.05				
More than a kilometer	25.95				
Farm income		0	1	0.800	0.400
Annual farm income less than USD 733	20.00				
Annual farm income more than USD 733	80.00				
Off-farm income		0	1	0.313	0.464
No off-farm income	68.65				
Had off-farm income	31.35				
Household size		1	16	6.281	2.549
Explanatory variable					
Member of a cooperative		0	1	0.622	0.485
No membership in a cooperative	37.84				
Membership in a cooperative	62.16				
Drought experience		0	1	0.995	0.073
No	0.54				
Yes	99.46				

(*Continued*)

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Table A2. (*Continued*)

Variables	% Sample (N = 555)	Min	Max	Mean	Std D.
Perception future droughts		0	1	0.541	0.498
Don't know	45.95				
Would get worse	54.05				
Perceived cost of WCPs		0	1	0.657	0.474
Not costly	34.23				
Very costly	65.77				
Access to extension services		0	1	0.969	0.172
No	3.06				
Yes	96.94				
Access to credit		0	1	0.205	0.404
No	79.46				
Yes	20.54				
Secured land rights		0	1	0.756	0.429
No	24.32				
Yes	75.68				

Source: Authors' estimations based on our survey data (April 2021).
Note: USD is the United States dollar.

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