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Determinants of water security in smallholder farming systems in South Africa: A review

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ABSTRACT

Water insecurity is one of the factors affecting agricultural production, especially in the smallholder farming sector in South Africa. The review focused on factors that influence water security in smallholder farming systems in South Africa and also proposed possible solutions to improve the water security status for smallholder farmers. A search of published articles was conducted on Scopus and Google Scholar databases using the keywords 'water access', 'water security', 'water scarcity', 'smallholder farmers', 'smallholder agriculture' and 'South Africa'. The study identified various factors that contribute to water insecurity for smallholder farmers, including lack of adequate infrastructure, the poor performance of water infrastructure, lack of farmer involvement in water-related management activities and land tenure insecurity. Smallholder farmers also failed to acquire water-use licences. During drought periods, they were unable to adopt strategies for improving water security. Recommendations include addressing issues related to infrastructure availability, water allocation and distribution, and the capability to operate, manage and maintain the infrastructure. The study also recommends that policy and decision-makers be acknowledged and address the impacts of droughts on water resource availability.

Keywords: Infrastructure, smallholder farmer, South Africa, water access, water governance, water security

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1 Introduction

Climate change and water security are some of the most challenging issues worldwide (Brende, 2020; Tortajada and Biswas, 2022). Water security is crucial not only for the human right to water but also to the human right to food. It is also important for achieving sustainable and economic development and supporting several ecosystem functions (UNDP, 2016; Mishra et al., 2021). However, water security is usually affected by various factors, including climate change, population growth, social-economic-political change, competing uses, over-extraction, poor land use management, and evolving energy needs (Singh, 2017; du Plessis, 2019). The capability to utilise water and make it available to the users in an appropriate quantity and quality at the right place and time is critical compared to mere physical availability. This is mainly because the physical availability of water does not guarantee its security and access to users. Other factors, such as socioeconomic issues and institutional capabilities, are equally important. In agriculture, improving food production with limited water access is one of the most significant challenges facing several farmers around the globe. The UNDP estimates that water security will be the major contributor to agricultural production in the coming years rather than sufficient arable land (UNDP, 2016). This shows that access to land without water does not fully promote agricultural production hence there is no agriculture without water security.

In many African countries, low agricultural production is apparent due to water insecurity challenges. More than half of the total population

in Africa is dependent on agriculture (Besada and Werner, 2014), and approximately 30% of the people suffer from chronic hunger, which is ranked among the highest rates globally (FAO, 2019). Even South Africa, a country that is relatively developed in terms of the economy, is also experiencing water security issues due to several factors, including poor management practices and insufficient investment in water infrastructure (Besada and Werner, 2014). Rising water demand as a result of economic growth compounded with extreme climate events such as droughts is also a contributor to the dwindling water resources in South Africa (Muthige et al., 2020). Massive pressure on limited water resources also poses a challenge to water allocation and management to ensure water security (DWAF, 2013), especially for smallholder farmers. The Department of Water and Sanitation (DWS, 2018) also indicates that water insecurity is one of the critical challenges in the 21st century.

To enhance agricultural production to meet the rising global food demand, the world's rain-fed and irrigating smallholder farmers have a pivotal role. These farmers occupy approximately 500 million farms and contribute a significant amount to agricultural production (Giordano et al., 2019). In key bodies such as the United Nations Commission on Development, the smallholder farmer's role in contributing to world food supply is increasingly gaining centre stage (IFAD, 2011). However, even though smallholder agriculture is critical in contributing to the future of global food production, many smallholder farmers involved in rain-fed agriculture have failed to produce adequate food due to the increasing variability of rainfall as a result of extreme climate events such as drought (Dejen, 2015). To reduce the water insecurity crisis caused by rainfall variability, various organisations such as FAO and some countries in Africa, Asia, and America have promoted irrigation development programmes to boost agricultural production (Yedra et al., 2016). Increasing agricultural land, especially under smallholder irrigation farming, has been encouraged as one of the strategies for enhancing the reliability of food supplies. According to Oni et al. (2011), irrigation plays a critical role in feeding growing populations, and it will continue to do so in the future. Also, during drought periods, irrigation can act as a mitigation measure for enabling farmers to boost their agricultural production (Moyo et al., 2016). However, despite the support provided to promote smallholder irrigation, many smallholder irrigation farming systems around the world have failed to attain their intended objectives (Dittoh et al., 2010). For instance, Moyo et al. (2016) reported that the underperformance of several smallholder irrigation systems in many developing countries was a result of factors involving insufficient institutional arrangements and poor technical capacity, which consequently led to irrigation water insecurity. Improving water governance in developing countries is critical to achieving water security (Araral and Wang, 2014; Makaya et al., 2020).

South Africa is a water-scarce country that relies on irrigated crop production for food security (Nephawe et al., 2021). About 70% of crop production in South Africa is rain-fed. Unfortunately, it is very challenging to achieve successful rain-fed (dryland) crop production since only 35% of the country receives adequate rainfall (Brende, 2010). The country is a semi-arid country with scarce water resources (Muller et al., 2009). Rainwater is the main input to water resources (Botai et al., 2018). The amount of rainfall the country receives is also highly variable (DWS, 2018). Sinyolo et al. (2014) highlight the importance of smallholder irrigation farmers in enhancing agricultural production due to the unreliability of rainfall. Unfortunately, many smallholder farmers face various water security challenges. Zwane (2019) reports that the inadequate availability of water is one of the major factors contributing to the limitation of agricultural production in South Africa. Water insecurity faced by many historically disadvantaged individuals (HDIs) such as South African smallholder farmers is still a persisting challenge that has not been fully addressed since the end of the apartheid era (Denby, 2014). The South African National Water Act of 1998 is recognized as one of the most comprehensive water laws globally that were aimed to redress inequalities of the past. However, despite its wide recognition, water access is still biased along racial lines (Kemerink et al., 2011; DWS, 2018). This article explores factors that prevent smallholder farmers from attaining water security status for agriculture. Four dimensions of water security were assessed, namely, availability, accessibility, use and stability. Accessibility includes physical access, economic access, culturally acceptable access, and political access. Identifying these factors will enable decision-makers to come up with strategies for addressing water insecurity challenges. This is crucial to enhancing water security and subsequently improving agricultural production for smallholder farmers. The concept of water security is defined, followed by the description of the factors influencing water insecurity for smallholder farmers in South Africa. The proposed solutions to enhance water security for smallholder farmers are presented, based on previous literature.

2 Review methodology

Google Scholar and Scopus electronic databases were searched for relevant literature. Most of the literature used in the study was obtained from Scopus, an electronic database that is considered reliable, especially for peer-reviewed work (Fischer and Onyango, 2012). Google Scholar was used to acquire additional rele-

vant literature that was not in the Scopus database. After database searching, the references were organised into themes and suitable articles were evaluated and analysed. Manual sorting of all articles was carried out to determine their relevance to the study. Only articles published in English were considered for this study. The keywords that were used to search the databases included water security, water access, water scarcity, smallholder agriculture, smallholder farming, and South Africa.

3 Smallholder farming in South Africa

There is no universally accepted definition of a smallholder farmer (Khalil et al. 2017). Various approaches have been used to define and characterise smallholder farmers. Most often, the term "smallholder farmer" is used interchangeably with "subsistence farmer", "family farmer", "resource-poor farmer", "small-scale farmer", "low-input farmer", "low-technology farmer", "small" or "low-income farmer" . In South Africa, smallholder farmers are defined as "those farmers who produce for household consumption and markets. Their farming businesses are the source of income for the family but are not usually the major source of income. Various non-farm activities also exist as a source of income to sustain the family" (SADA, 2015). Additionally, South African smallholder farmers were previously characterised as less educated and usually situated in several locations, from deep rural areas of townships that are less developed in terms of infrastructure such as water-efficient irrigation systems .

Some scholars describe South African smallholder farmers as less developed and poorly resourced and almost all of their land is communally owned (Aliber and Hart, 2009; Thamaga-Chitja and Morojele, 2014). These farmers usually comprise diversified individuals and households that experience challenges regarding the capability to carry out profitable agricultural activities (van Averbeke et al., 2011) and some of these challenges are related to water security. Pienaar and Traub (2015) report that the majority of South African smallholder farmers comprise women, children, and aged people. These farmers are also categorised as historically disadvantaged individuals (HDIs) and emerging farmers. According to Saruchera (2008), emerging farmers are farmers that have leased or bought agricultural land and they are characterized by poor natural, physical and economic resources.

The South African smallholder sector consists of small, labour-intensive farms where producers mostly use traditional production techniques. The agricultural production of South African smallholder farmers is usually in the gardens, demarcated fields, or open rangelands (Aliber and Hart, 2009). The size of the land cultivated varies, but it is generally extremely small, ranging from 0 to 1.5 ha (Pienaar and Traub, 2015). However, a considerable number of South African smallholder farmers are farming on less than 5 ha while a small percentage farm on plots that are larger than 5 ha (Pienaar and Traub, 2015).

There are about two million smallholder farmers in SA, many of whom reside in areas where water resources are inadequate due to poor rainfall (Obi et al., 2012). Studies have shown that smallholder farmers play an important role in creating job opportunities and alleviating poverty, especially in rural areas (van Averbeke et al., 2011; Sinyolo et al., 2014). Despite some livelihood strategies such as social grants and pension remittances for most households in South African rural and marginalised areas, Thamaga-Chitja and Morojele (2014) argue that smallholder farming will continue to play a leading role in providing required subsistence mainly in the form of food. For this study, smallholder farmers are defined as those farmers who are less developed, poorly resourced, practise agricultural production on a small scale for their household consumption and market some products to the local or other markets to earn income for the family.

4 The concept of water security

In recent years, the concept of water security has gained much attention, especially in the debates of both policy and academics (Cook and Bakker, 2012; Pradhanang, 2017). The term water security is used to frame numerous water problems, ranging from flooding and drought to pollution, poor sanitation and lack of access (Strickert et al., 2015). Several definitions of water security have been developed by various scholars (Grey and Sadoff, 2007; Muller et al., 2009; Cook and Bakker, 2012; Sinyolo et al., 2014; Klumper et al., 2017). Most of these definitions are based on a specific context and disciplinary perspective regarding water use (Cook and Bakker, 2012). Unfortunately, the major disadvantage of most of these definitions is that they are only applicable when analysing water security at national and global levels (APWF, 2013). In their review of the key definitions of water security, Lautze and Manthrithilake (2012) highlight that the meaning of water security has changed extensively since it started to be used. Cook and Bakker (2012) reported that the literature concerning water security had mainly focused on the concepts of availability of water, the vulnerability of humans to hazards, sustainability and the development of human needs, with a particular focus on food security. Some scholars have highlighted the shortcomings in the existing approaches to water security, including (1) an overemphasis and reliance on physical aspects of water security, (2) water policy that is driven by en-

vironmental determinism, and (3) isolation of water security from other security-related aspects (Strickert et al., 2015).

Various scholars have defined water security as an overarching goal, where every person has access to sufficient, safe water that is affordable in terms of cost to lead a clean, healthy and productive life while ensuring the environment is protected and water-related disasters such as droughts and floods are prevented (Grey and Sadoff, 2007; Cook and Bakker, 2012; Wheater and Gober, 2013). In the agricultural sector, water supply reliability is of utmost importance because a reliable amount enables farmers to plan water use for their farming practices . Singh (2017) defines water security as access at all times to sufficient good quality water to satisfy varied needs. Singh further points out that both quantity and quality, as well as access at all times, are important components of water security. From a legal point of view, water security is generally linked to the allocation rules that aim to secure the rights to a desired amount of water (Tarlock and Wouters, 2010). Water security also involves power-sharing of the governance and management of water (Ncube, 2018) and the capability of water users to claim their rights to water against other water users (Sinyolo et al., 2014).

Water security can vary with space and time. The spatial variability of water security usually ranges from an individual household to a village, municipality, district, province, country, continent, or the whole world, while the time dimension of water security varies from a day, week, month, or season (winter, spring, summer or autumn), to a year, decade, or century. Concerning the time dimension of water security, a region can be water-secure in a specific part of the year and not in other parts of the year. Most often, the time dimension of water security is directly linked to the variation of climate from year to year, which ultimately impacts the availability and supply of water (Singh, 2017). This implies that even places that are usually water-secure have the potential of becoming water-insecure during climate events such as drought. Young et al. (2021) describe water security as a multidimensional concept which comprises four dimensions that include water availability, accessibility (physical access, economic access, culturally acceptable access, and political access), use and stability. Availability entails the physical existence of water whereas accessibility refers to whether water can be acquired through means that are socially accepted. Use is whether there is adequate water which is safe and acceptable for all needs and stability (reliability) refers to the continuity of the other three domains (availability, accessibility and use) without change across time.

Limited studies have addressed water security at the farm household level (Cook and Bakker, 2012) and few of them link water security to the agricultural sector. Klumper et al. (2017) highlight the importance of redefining water security to make it applicable at the farm household level. This is particularly important in communities where water plays a crucial role in local agricultural production. Focusing on the agricultural sector, Klumper et al. (2017) suggested that the definition of water security is associated with the hydrologic condition (water availability) and the governance (water access) option needed by each farm household to strengthen their agricultural needs, either for commercial or subsistence (smallholder) farming. In this study, water security is centred around the four dimensions of water security; availability, accessibility, use and stability or reliability. A state of water insecurity is when at least one of these dimensions is not satisfied.

5 Determinants of water security in smallholder farming systems in South Africa

Water insecurity is a phenomenon that is a result of both human and natural causes (Tekken and Kropp, 2012). Various factors influence water security for smallholder irrigation farmers in South Africa. These factors can be categorised into climate-related, infrastructure-related and linked to water governance. Climate-related factors include disaster risks such as drought and floods resulting from climate change. Infrastructural factors relate to the availability, type, and performance of built water infrastructures such as dams, canals, pipes, and pumps as well as the availability of funding and capacity to manage those infrastructures. Water governance entails aspects such as legislative framework, water allocation, water rights or water permit systems, and participation of water users in water management-related activities as well as linkages between land and water reforms to ensure water access. Additionally, water governance also involves aspects concerning social, economic, political, institutional, and organisational issues. Socio-economic issues include culture, tradition, gender, income sources, and water users' geographical location, whereas institutions and organisations include local governance structures, water committees, water user associations (WUAs), catchment management agencies (CMAs), power relations as well as rules, regulations, and processes that enable water rights to be respected and conflicts to be resolved.

5.1 Climate related factors

South Africa is a semi-arid country with scarce water resources (Muller et al., 2009), where rainwater is regarded as the main input to water resources (Botai et al., 2018). Singh (2017) pointed out that the

fresh water supply in South Africa is already under stress. South Africa is also the 30th driest country in the world, receiving a low average rainfall of about 465 mm per annum compared to the world's average of 860 mm per annum (DWS, 2018). The country is prone to frequent droughts which ultimately affect the national economy as well as water resource availability (Zwane, 2019). In comparison to other climate-related natural disasters, drought is considered a major disaster that can be very costly and severely affect water resources (Payus et al., 2020).

The Intergovernmental Panel on Climate Change (IPCC) has defined drought as a prolonged deficiency or absence of rainfall that can result in a shortage of water for some group or activity (IPCC, 2007). Drought can lead to severe imbalances in water cycles such as the availability of soil moisture, precipitation, and evaporation processes (Payus et al., 2020). This leads to the reduction of water in streams, rivers, and reservoirs and consequently results in water insecurity (Sharaunga and Mudhara, 2016). The reduction of physical availability of water during drought periods can contribute to the instability of water security. The impacts of drought have affected many South African smallholder farmers for several years. To enhance water security, smallholder farmers in South Africa are unlike commercial farmers who have a variety of choices to cope and adapt during drought periods. Many commercial farmers have good irrigation infrastructure, including drip irrigation systems (Mpandeli et al., 2015) that conserve water and improve water security. In their study, Pili and Ncube (2022) stated that insufficient access to resources such as finance, inadequate skills and insufficient timely information as some of the contributing factors that are hindering smallholder farmers from adopting strategies for using agricultural water during drought periods to ensure water security. Drought can also have a negative influence on the quality of water and this reduces the acceptability of water to be utilised for agricultural purposes as well as the stability of water security. During drought periods, the reduction in water quality is caused by decreased concentration of dissolved oxygen and increased nutrient suspension due to decreased water levels in rivers and reservoirs (Gobler, 2020). Lottering et al. (2020) reported the deterioration of water quality for agriculture as one of the main impacts of drought that was experienced by smallholder farmers in KwaZulu-Natal in South Africa.

5.2 Infrastructural related factors

5.2.1 Availability and type of water infrastructure

Water infrastructure such as canal systems is a valuable asset in improving water management to achieve water security (Karimi et al., 2019). Access to water for agriculture is not only reliant on the physical availability of water or water use rights, but is also dependent on the availability of infrastructure for transporting water from the sources to the place where it is required (Chikozho et al., 2020). In SA, the lack of adequate infrastructure is reducing the capability of smallholder farmers to capture the available water from sources and attain water insecurity. Most often, wealthier people such as commercial farmers have a high capability to capture water from the sources in comparison to the poor smallholder farmers (Hope et al., 2008). For instance, in the Inkomati Water Management Area, well-developed water infrastructure such as dams and canals were reserved to be used by the white population only (Peters and Woodhouse, 2019). This has put water security for smallholder farmers at risk. Lack of water infrastructure can also enable farmers to use a very small part of their formal water rights . This shows that sufficient water infrastructure is critical for ensuring water security.

The availability of water infrastructure is also important to improve the resilience of as smallholder farmers during drought. Murugani and Thamaga-Chitja (2017) reported that the seasonal water shortage experienced by smallholder farmers in Limpopo was a result of the capacity of the dam that had not been upgraded to match the needs of farmers. Infrastructure availability can also help smallholder farmers to store water during rainy seasons which can then be used during dry seasons when the physical availability of water is not sufficient thereby improving the stability of water security. Even though the National Water Act (NWA) (Act no 36 of 1998) aimed to improve water security, it mainly focuses on water allocation without necessarily considering the distributional aspects such as the availability of water infrastructure to increase the physical access to productive water by smallholder farmers (Kemerink et al., 2011). The type of infrastructure that is used to supply water to the plots of farmers can also contribute to the level of water security of farmers. For instance, Sinyolo et al. (2014) found that farmers that were using gravity were less water-secure than those that were using either a diesel pump or an electric pump. Chikozho et al. (2020) and Fanadzo et al. (2021) also pointed out that smallholder farmers in SA usually do not afford to pay electricity tariffs for the water pumps. In this case, a lack of affordability is an economic factor which contributes to the incapability of farmers to physically access water. Lack of affordability is a result of poverty which is associated with many smallholder farmers in South Africa (Thamaga-Chitja and Morojele, 2014).

5.2.2 Water infrastructure funding

The deterioration of the performance of water infrastructure can also be worsened by the failure of

water users to contribute to water use fees . Smallholder farmers in South Africa are characterised as poor with low-income levels (Thamaga-Chitja and Morojele, 2014) and this limit their capability to pay water use fees. This indicates that low-income levels of smallholder farmers in South Africa are hampering water affordability or economic access and consequently reducing the stability of accessing water. Water payments from water users are usually used for the operation and maintenance activities to improve infrastructure performance and consequently physical accessibility of water. Refusal of farmers to pay for water use fees can contribute to the inadequate funds for the operation and maintenance of irrigation infrastructure (Dirwai et al., 2018). In their study, Dirwai et al. (2018) found that the unwillingness of water users to pay for water use has contributed to the deterioration of irrigation infrastructure performance for smallholder farmers in South Africa. However, various scholars have blamed weak institutional and organisational arrangements as the major causes of the dysfunction of the irrigation infrastructure for smallholders in South Africa (van Averbeke et al., 2011; Fanadzo, 2012; Sinyolo et al., 2014; Sharaunga and Mudhara, 2018). Sinyolo et al. (2014) further pointed out that the governance of irrigation systems for smallholder farmers in SA has not received sufficient attention. Investment in water infrastructure is required to be closely related to water governance, including institutions (formal and informal), policies, regulations, management practices, laws, and participation models to ensure the efficient management of water resources (Molden et al., 2014).

Funding is also an economic factor influencing water security status for smallholder farmers in South Africa. Insufficient government support as a result of funding constraints is contributing to the lack of adequate irrigation infrastructure for most smallholder farmers in South Africa (Chikozho et al., 2020). It is very challenging to guarantee water access if there are insufficient funds to invest in sustainable water infrastructure. Water allocations in South Africa usually went unused by many smallholder black farmers as a result of restrictions in the investment of water infrastructure (Woodhouse, 2012).

5.2.3 Performance of water infrastructure

Acquiring water infrastructure does not necessarily translate to water security. The performance of water infrastructure plays an essential role in improving the stability of water supply and achieving water security. Degrading water infrastructure can lead to water losses and consequently water insecurity. Good infrastructure performance is also critical to boosting water security for smallholder farmers even during extreme climate change-related events such as drought. To ensure water security, infrastructure is required to deliver water reliably, equitably, and efficiently to all users. The water security of the users is threatened if the irrigation infrastructure is characterised by low conveyance efficiency and high leakages. In South Africa, most irrigation infrastructure for smallholder farmers was reported to be performing below expectation and this has contributed to water insecurity (Fanadzo, 2012). A review of the performance of irrigation systems conducted by van Averbeke et al. (2011) found that the poor performance of irrigation infrastructure for smallholder farmers was due to inadequate maintenance. Insufficient maintenance of water infrastructure can reduce water flow capacity and consequently increase water insecurity (Chikozho et al., 2020). Other studies have pointed to the decline of the performance of irrigation infrastructure to be a result of insufficient government support to carry out the operation and maintenance activities of the existing irrigation infrastructure (Muchara et al., 2014; Dirwai et al., 2018; Chikozho et al., 2020). Irrigation infrastructure that is well-managed and maintained can control the spatial and temporal supply of water to enhance water security (Oni et al., 2011).

5.2.4 Human capacity to manage infrastructure

Even though the investment in adequate irrigation infrastructure is critical for ensuring water security, it does not yield any benefits without considering human resource capacity, such as skilled, trained, and committed human capital to manage irrigation infrastructure to improve their performance (Mnkeni et al., 2010). Participation of farmers in the collective management of irrigation schemes such as carrying out maintenance activities is also very critical and it can be influenced by training farmers in irrigation water management (Muchara et al., 2014). Muchara et al. (2014) further pointed out that economic factors such as income from farming also influence the participation of smallholder farmers in collective action. Farmers who are not receiving enough income from farming are usually not willing to participate in collective action and this negatively affects their water security status. In their study, Dirwai et al. (2018) found that water management training was very important in ensuring the adequacy of water in smallholder irrigation schemes. Mvelase (2016) indicated that most South African smallholder farmers lack training skills and this includes training concerning water management.

5.3 Water governance

5.3.1 Legislative framework

South Africa's (SA) historical legacy is very important to better understand the evolution of its water governance as well as the current water security status for

historically disadvantaged individuals such as smallholder farmers. Before South Africa was colonised, the water rights system was governed by the African customary law. During the apartheid era, there were inequalities between white commercial farmers and black smallholder farmers in terms of access to natural resources such as water and land. The allocation of and access to water, especially for agriculture, was hugely skewed and conducted along with gender, class, and racial lines as a result of policies that favoured the white minority population. This led to high inequality in terms of water access for smallholder farmers (van Koppen, 2009; Forster et al., 2017). The apartheid government was mainly interested in formulating laws and rules that were in favour of their own political, economic and civil interests without considering the interests of the indigenous black South African people (van Koppen, 2009).

Institutional structure and water resource management approaches were mostly centralised. The water rights were mostly in the hands of the white minority commercial farmers and it was through the riparian rights system. Under the riparian system, water rights were given per the ownership of land under the discriminatory land Act of 1913. Unfortunately, most of the land was in the hands of the white minority and about 13% of the land was reserved only for 70% of the majority poverty black population who were situated in segregated geographical areas (Lahiff, 2007). The arrival of democracy in 1994 led to the development of a new Constitution (Act 108 of 1996) and a huge law-reform process including thorough changes to the law governing the management of water resources (Kapfudzaruwa and Sowman, 2009). The new Constitution was aimed to redress imbalances of the past, including the allocation and management of water resources whilst considering the constitutional rights of all citizens. This Constitution has led to the formulation of the Water Services Act (WSA) (Act no 108 of 1997) and the NWA. The National Water Act was enacted to govern the South African national water resources and it has adopted the principles of equity, efficiency, and sustainability of the Integrated Water Resources Management (IWRM) as guiding principles for the development, use, protection, conservation, control and management of water resources (Funke and Jacobs 2011). The NWA has also encouraged the involvement of stakeholders in the decision-making process through the development of new water management institutions (WMI) such as catchment management agencies (CMAs) and WUAs. These institutions were established to ensure that all the interests of water users in water governance are represented (Kahinda et al., 2016). The WUA was supposed to be the lowest water management institution. WUAs were supposed to be created from the transformation of irrigation boards which were established under the 1956 Water Act. Unfortunately, until now, most irrigation boards have not been transformed, meaning that the water remains in the hands of the majority of previous owners (Peters and Woodhouse, 2019).

5.3.2 Water allocation

According to Kemerink et al. (2011), the legacy and segregation of the past still dominate the political and economic arena in SA, particularly how water is allocated. This greatly influences water security for smallholder farmers. Despite the wide global recognition of the NWA as one of the most comprehensive water laws that aimed to redress inequalities from the past (Movik, 2009), little progress has been made on equitable water allocation. The South Africa National Water Act (1998) aimed to redress the inequity of the past in terms of water allocation to enable all racial groups to have access to water for productive purposes (Goldin, 2010). Unfortunately, most South African disadvantaged individuals, especially the smallholder farmers, are still struggling to increase their access to productive water sources (Kemerink et al., 2011). The South African government has failed to fully drive and implement the reforms of water allocation through constructive reallocation, which is considered the primary pathway for water reform (Rawlins, 2019). Several challenges have contributed to the unsuccessful implementation of the water policy, including insufficient funding within institutions that are supposed to support smallholder farmers, the complexities of the legal framework for allocating water, and poor cooperation between various government departments (Rawlins, 2019). Additionally, the development, regulation, implementation, administration, monitoring, and enforcement of all policies related to water allocation are still centralised with the Department of Water and Sanitation (DWS) (Rawlins, 2019). Redistribution of formal water use rights through a compulsory licensing process was one of the instruments that were supposed to be used to address water allocation inequalities (Movik, 2014). However, it was not clear how the re-allocation of water rights should be conducted in practice .

5.3.3 Water rights or water permit systems

Restrictive water rights or water permit systems have hindered equitable water access, especially for many marginalised smallholder farmers in SA (van Koppen and Schreiner, 2019). The formalisation of water rights through the water permit system, paved the way for wealthier, better-connected users and powerful individuals with opportunities to manipulate registration to serve their interests (Bruns, 2007). As a result, smallholder farmers, due to their race, gender, and structural inequalities have been hindered from claiming their water use rights and this has increased

their unequal access to water for productive uses (Kemerink et al., 2011). In their study, Sharaunga and Mudhara (2016) highlighted that women's access to resources such as water has been limited by cultural traditions. This shows that gender inequalities contribute to the obstruction of women from accessing water because of their lower class in society as a result of cultural biases. According to Movik (2012), the water reform was developed with a strong emphasis on maintaining the water rights of those who are economically and commercially viable. This was done through the appreciation of Existing Lawful Uses, instead of redressing inequalities of the past regarding water access. White commercial farmers who acquired water licences a long time ago during the apartheid era are still favoured in accessing water in comparison to black smallholder farmers (Chikozho et al., 2020). About 95% of the water is still possessed by white commercial farmers (DWS, 2018) and conflicts about agricultural water access are still experienced by smallholder farmers (Ncube, 2018). Government officials who are supposed to assist farmers with the process of licensing are not adequately responsive (Chikozho et al., 2020). The current licensing processes are very costly, bureaucratic, and inaccessible to many South African smallholder farmers (DWAF, 2013) and it is a very lengthy and time-consuming process for smallholder farmers to finally acquire a water use licence (Chikozho et al., 2020). Most smallholder farmers are unaware of the requirements needed to apply for a permit, which is compounded by the inadequate administrative capacity of the State to inform and educate smallholder farmers about permit applications. This, as well as the State's inability to enforce and monitor the conditions that are tied to the permit, are all contributing factors to many smallholder farmers not having permits (van Koppen and Schreiner, 2019).

5.3.4 Participation in water resources management

In South Africa, people's involvement in the governance of water resources is still dominated by the apartheid legacy and segregation of the past (Kemerink et al., 2011). Inclusion and participation of water users in water-related decision-making can influence the fairness of access to and improve water security (Niyazmetov et al., 2019). Participation can also enable users to have a voice in water management-related decisions (Kaufmann et al., 2010). The exclusion of smallholder farmers in the frameworks of water governance processes and water management is apparent in the South African smallholder farming sector and this contributes to the water insecurity crisis for smallholder farmers. Smallholder farmers are usually inhibited from challenging their unequal access to water for productive uses and asserting their rights due to structural, racial, and gender inequalities (Kemerink et al., 2011; Denby et al., 2016). Sinyolo et al. (2018) indicated gender as a significant factor which influences water access among smallholder farmers in South Africa and most often women tend to access water less frequently than men. During decision-making, some farmers are more privileged and have more power in comparison to smallholder farmers due to their influences on water boards and catchment management agencies (Chikozho et al., 2020). Smallholder farmers have been encouraged by the South African National Water Act to be part of WUAs with the hope of increasing their participation in water resource management to enhance their access to water. The participation of smallholder farmers in formal organisations such as WUAs can help them to become involved in water management training through the programmes of capacity building that might be run by the government and other initiatives. However, according to Msibi and Dlamini (2011), research shows that smallholder farmers have not benefited from their inclusion in WUAs. In WUAs, commercial farmers were usually greater in number than smallholder farmers, leading to them having more water rights because they had more voice in terms of decision-making processes concerning water access. Commercial farmers were supposed to share knowledge and assist with skills transfer with smallholder farmers in WUAs. Unfortunately, the capacity building did not happen and it negatively affected the water security status of smallholder farmers.

5.4 Disconnection between land and water reforms

The transition to democracy in South Africa left the ownership of land and water rights in the hands of a great number of powerful and wealthy individuals of the white minority population (Lahiff, 2007; DWS, 2018). Integration among institutions has been affected by the historical overlaps of the roles and responsibilities of the institutions governing the former homelands and the central government of South Africa. Land and water have been governed and managed by different governmental institutions, policies, and funding schemes with overlapping mandates and goals (Denby et al., 2016). The Department of Water and Sanitation is the custodian of water, but it does not have control over agricultural institutions or land, which has led to weaknesses of accountability and challenges in integration. Trust and accountability are very important in increasing confidence in the institutions that are responsible for allocating and distributing water (Herrfahrdt-Pahle, 2012). In many developing countries, including South Africa, water distribution is based mainly on the ownership of land, which makes the development of irrigation biased against those without land (Pariyar et al., 2017).

Table 1. Proposed solutions for water insecurity challenges for smallholder farmers

Challenges	Proposed solutions	References
Lack of adequate infrastructure	Apply for funding to construct adequate water storage and delivery infrastructure such as dams, canals, and water pumps	Mutero et al. (2016); Mkuhlani et al. (2019); Nepal et al. (2019)
	Using renewable energy in the operation of water pumps is required to cater for the high costs of electricity and diesel	Kumar et al. (2020); Bhuiyan et al. (2021)
Poor infrastructure performance	Programs for training farmers regarding the operation and maintenance of infrastructure are needed	Muchara et al. (2014); Sharaunga and Mudhara (2016); Dirwai et al. (2018)
	Encouraging farmers to participate in the operation and maintenance of infrastructure	Chattopadhyay et al. (2022)
Land tenure insecurity	Farmers should be given land in order to have access to water since water access is linked to land access	Pariyar et al. (2017); Hartwig et al. (2021)
Lack of cooperation among institutions	Coordination among institutions responsible for land and water management is needed	Chikozho et al. (2020); Nephawe et al. (2021)
Lack of participation in water management	Farmers should be part of WUAs to improve their participation in water-related decision making	Ma'Mun et al. (2021); Asthana (2022)
	Fairness in decisions relating to water access is needed regardless of gender, race and geographical location	Memon et al. (2019); Imburgia et al. (2021)
Lack of drought management strategies	Programs for training farmers in coping and adaptation strategies during drought periods are required	Ali et al. (2021); Pili and Ncube (2022)
Inadequate water use licence	Training programs for farmers regarding the requirements for the water use license application process are needed	Sadiki and Ncube (2020)
	Adequate technical staff for handling water use license applications is required	Schreiner and van Koppen (2020)

Regardless of the importance of land and water connection, the South African land reform process has followed a different path from water reform (Funke and Jacobs, 2011; Woodhouse, 2012). The disconnection between the reform programmes of land and water has placed South African smallholder farmers in the dilemma of obtaining water without land or land without water (Kemerink et al., 2011). Pahl-Wostl (2015) notes that the impact of the apartheid ideology and the political system on the water sector shows that white farmers had a large water footprint compared to black smallholder farmers. This was because water access was linked to the ownership of land that was mainly assigned to white farmers. Since water and land allocation were carried out as two separate processes it has led to no guarantee of water access for smallholder farmers (Chikozho et al., 2020). Furthermore, the political system in the water sector in South Africa contributes to poor water management and consequently to water insecurity for the poor and powerless smallholder farmers (Denby, 2014).

6 Proposed solutions for improving water security for smallholder farmers in South Africa

The determinants of water security for smallholder farmers in South Africa are multifaceted. Integration of governance and technical solutions is required to solve the persisting water insecurity challenges faced by smallholder farmers. According to Grey and Sadoff (2007), investments in water infrastructure and institutions are required to attain water security. Singh (2017) highlights that even though the management of water to ensure water security is more

non-technical than technical, integration of technology and engineering with socio-economic-political issues is required. Possible solutions for enhancing the water security status of smallholder farmers are summarised in Table 1.

Accessing funding for irrigation water infrastructure development, using renewable energy in operating irrigation water pumps, participation in water management-related activities and training, land ownership security, coordination between land and water institutions and having sufficient technical staff for handling water use licensing are some of the possible solutions for enhancing the water security status of smallholder farmers in South Africa. If implemented, these solutions could boost agricultural production for smallholder farmers by promoting the production of a variety of crops. This could assist in generating income for smallholder farmers and consequently improving their livelihoods.

Funding for irrigation infrastructure such as dams, canals, pipes, and pumps plays an important role in ensuring the viability of smallholder farmers by ensuring water security (Mutero et al., 2016). Funding can also assist farmers to maintain and upgrade their irrigation infrastructure, which would enhance crop water supply (Mkuhlani et al., 2019). Renewable energy is an alternate affordable source of energy that can be used by smallholder farmers to operate water pumps. For instance, solar-powered irrigation systems can reduce the dependency of smallholder farmers on the national grid. Irrigation pumps which use solar energy are advantageous, especially for smallholder farmers who are usually situated deep in rural areas where infrastructure for electricity is still limited (Nepal et al., 2019).

Training farmers in water management-related activities plays a vital role in ensuring water security. During drought periods, training enables farmers to make well-informed decisions concerning coping and adaptation strategies to enable them to access agricultural water (Pili and Ncube, 2022). Training for routine operation and maintenance of irrigation water infrastructure also helps to improve water security by improving infrastructure performance (Dirwai et al., 2018). To make the process of water use licence application easier, farmers need to attend training. Water use license training can be promoted by ensuring the availability of adequate technical staff to conduct the training process (Schreiner and van Koppen, 2020). Land ownership and access to land are linked to water justice (Hartwig et al., 2021).

Participation of farmers in operation and maintenance activities can strengthen cooperation among them and enhance the sustainability and effectiveness of irrigation infrastructure and subsequently, water security (Chattopadhyay et al., 2022). Land ownership and security of farmers are also very important in improving water access. To achieve this, effective coordination between land and water management institutions needs to be strengthened.

7 Conclusion

This paper reviewed the factors affecting water security for smallholder farmers in South Africa and also highlighted possible solutions. Lack of participation in the management of water-related activities was found to limit smallholder farmers in accessing water. Furthermore, inadequate water infrastructure to capture and store water also contributes to water insecurity. The study highlighted that the water infrastructure for smallholder farmers could not deliver water reliably and efficiently due to poor performance. Lack of support from the government as well as lack of funding was found to contribute to the unavailability of adequate infrastructure. The poor performance of water infrastructure for smallholder farmers was found to be linked to inadequate maintenance. The disconnection between land and water reforms hindered smallholder farmers from accessing water. Additionally, it was very challenging for smallholder farmers to acquire licences for accessing water without owning land. This was due to factors such as lack of administrative capacity and lack of knowledge of the necessary requirements to apply for a water use licence. During drought periods, smallholder farmers lacked coping and adaptation strategies to maintain water security, which was related to a lack of training in drought management strategies. Future research should investigate the effectiveness of the proposed solutions for water security for smallholder farmers. Furthermore, future research should also focus on other dimensions of water security such as sustainability. The study recommends funding for investment in water infrastructure as well as ensuring adequate extension services for training farmers in the operation and maintenance of irrigation infrastructure. Finally, the study also recommends policy and decision-making processes that acknowledge the impacts of disasters such as drought when addressing issues relating to water security.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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