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Agricultural resilience under increasing water security threats: insights for smallholder farming in Limpopo Province, South Africa

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Abstract

Smallholder farmers in South Africa are facing increased pressure to manage water use due to growing scarcity and environmental water demand. This prompts the need to build resilient irrigation systems particularly for smallholder farmers. Building resilience is more pertinent in Limpopo province, where crop and animal production is hampered by water scarcity. Currently, there is an array of generic adaptation strategies for attaining resilient irrigation schemes in South Africa and beyond. However, the effectiveness and feasibility of these resilience measures at farm level, particularly among smallholders in marginalised areas, are not well researched in Limpopo Province. The current paper draws lessons from adaptation mechanisms in Southern Africa, indicates areas that require further studies and recommends ways for enhancing smallholder resilience against water scarcity. The article contributes to efforts for enhancing water security and fulfil the targets set in sustainable development goal 2 of zero hunger, South Africa Vision 2030, and the government's food security mandate, particularly through suggesting ways for enhancing smallholder farmer resilience and water security.

Key words: agriculture, resilience, smallholder farmers, water scarcity

Highlights

- The paper identifies gaps in the application of current water management techniques among smallholder farmers
- Focuses on socio-economic inequalities, a dimension which is normally omitted in water security and resilience studies for smallholder farmers
- Provides recommendations based on recent case studies in the focus area rather than focusing on literature from elsewhere.

INTRODUCTION

In arid and semi-arid regions, water scarcity and uncertainty have prompted a re-think about the way agriculture utilizes and manages water resources. In South Africa, increasing water access inequalities are likely to affect smallholder farmers and deepen poverty (Rijsberman 2006; Namara *et al.* 2010). When faced with the prospect of long-term water shortages in agriculture, smallholder farmers mostly mitigate water scarcity through reactive mechanisms like adjusting crop production and utilization of livelihood assets (Chuku & Okoye 2009), crop insurance, crop shares, asset smoothing and diversification among other mechanisms (Osbahr *et al.* 2008; Eriksen & Silva 2009). However, adaptation techniques in agriculture within Southern Africa have been criticized for being survivalist

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and unsustainable (Maleksaeidi & Karami 2013), which negatively impacts their resilience and the achievement of zero hunger as enshrined in the Sustainable Development Goals (SDGs). Reduced farmer resilience further implicates the achievement of the National Development Plan Vision 2030 ambitions. This paper seeks to identify the generic adaptation techniques widely utilized by smallholder farmers and assess their applicability, especially considering the socio-economic inequalities and limited resources in Limpopo Province. Drawing lessons from the weaknesses of adaptation practices, recommendations for enhancing smallholder farmer resilience are made. The paper draws insights from 40 articles mainly obtained through EBSCOhost, Google Scholar and Science Direct search engines. The Atlasti 8 software was utilized to synthesize literature. Relevant articles were identified through the word list and map software function with words such as water scarcity and smallholder resilience being the key words.

Limpopo Province is situated in the Northern part of South Africa, bordering Zimbabwe and Mozambique. Rainfall is variable in the province, ranging from less than 400 to 800 mm annually (The Department of Agriculture Forestry and Fishery: DAFF 2015). Thus, there is competition for water between established users, which are the 2,915 commercial farmers, mines, municipalities and emerging farmers who historically had limited or no access to surface water before. There are about 180 schemes, with an area of 20,788 ha in the province (The Department of Agriculture Forestry and Fishery: DAFF 2015). The Vhembe District, which is one of the Districts in the province, is a major fruit and vegetable producer in the country. The District produces no less than 4.4 percent of South Africa's total agricultural output (DAFF 2011). The climatic conditions in the area are subtropical, with mild, moist winters and wet, warm summers. Unfortunately, the average annual potential evaporation in the district is higher than the combined rainfall in almost all other districts in the Province. Musina District, where case studies presented in this paper were conducted, is one of the areas with the highest evaporation rate of approximately above 2,700 mm (DAFF 2011). These conditions perpetuate water scarcity and thus necessitate the need for vigilant water management to promote water use sustainability in farming. Figure 1 is a map showing the location of Limpopo Province in South Africa.

POVERTY AND SOCIO-ECONOMIC INEQUALITIES IN LIMPOPO

The nexus between agriculture and poverty is long existing. For this article, understanding poverty and inequalities helps to explain the dynamics for building smallholder farmer resilience against water scarcity. Poverty remains one of the most pressing economic and social issues in South Africa. Historical and deep inequalities in assets, incomes and opportunities account for the current poverty challenges (Human Science Research Council: HSRC 2015).

Among other dimensions, land sizes, for instance, (less than 10 hectares) is associated with significantly high poverty levels while as land size increase above 10 hectares, poverty levels fall below 15%. There is also significantly high (57%) poverty among those who access land on a communal basis (HSRC 2015). Most poor people are disproportionately located in rural areas and are mainly active in agricultural value chains (Mears & Blaauw 2010). Previous studies similarly show an increase in poverty in smaller and more rural villages (Mears *et al.* 2008). Table 1 shows the incidence of poverty and the share of household poverty contributed by each province to the national profile. In 2015, Eastern Cape and Limpopo had the highest incidence of poverty and share of poverty respectively. (Statistics South Africa 2015). Furthermore, the poverty gap and severity of poverty measures were similarly larger for female-headed households as compared to households headed by males. Given the high costs required for agricultural water management, poverty and inequalities can determine the resilience capacity of smallholder farmers during water shortages.

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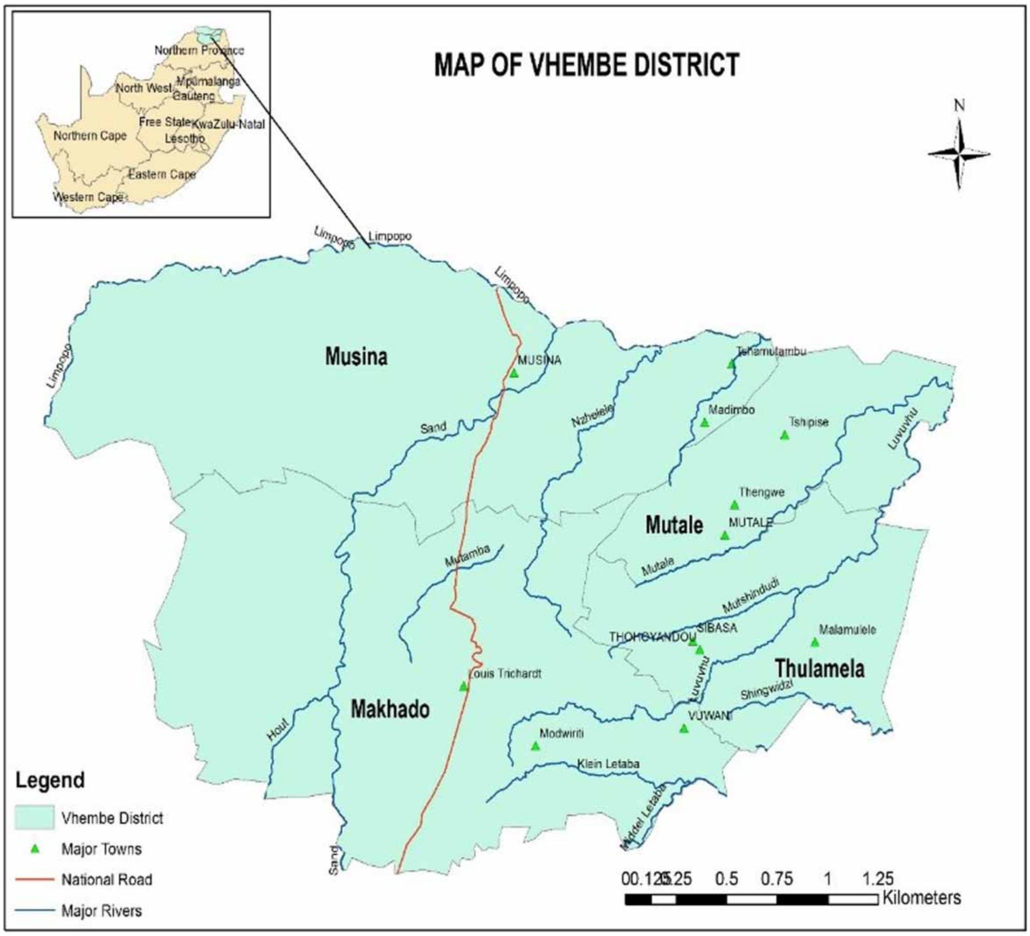

Figure 1 | Map showing Limpopo Province in South Africa.

Table 1 | Poverty headcount and poverty share of adults by province and sex (UBPL), 2015

Province	Incidence (%)	Share (%)
Western Cape	25.3	7.2
Eastern Cape	54.2	14.2
Northern Cape	45.6	2.4
Free State	43.1	6.1
KwaZulu-Natal	48.4	20.6
North West	49.0	9.1
Gauteng	26.0	19.0
Mpumalanga	45.9	8.4
Limpopo	55.5	13.1
South Africa	49.2	100.0

POVERTY AND WATER MANAGEMENT LINK

In South Africa, smallholder farming is concentrated in the former homelands. Since they were created in 1913, the homelands have been characterized by high rural population densities, small individual portions of arable land and shared access to rangeland (Van Averbeke 2013). In areas

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like Limpopo, gravitational irrigation systems characterized by water diversion were common (Van Averbeke 2013). This was a result of limited attention given to smallholder farmers in these homelands. Thus, most irrigation schemes relied on river diversion and furrow irrigation, which were affordable and manageable. Until the 21st century, water management worries were not yet clearly pronounced and thus furrow irrigation, along with other gravitational systems utilized by most poor farmers, were not a policy concern.

From the late 21st century, smallholder irrigation schemes were characterized by modernization in South Africa. This was influenced by the belief that the modern paradigm could lift smallholders from poverty (Faures *et al.* 2007). Thus, through government support efforts for agricultural transformation, by 2011 approximately 52.2% of the land was covered by smallholder irrigation schemes utilizing overhead irrigation. However, the remaining 48.8% still relied on either gravity or gravity-fed overhead systems. This highlights the slow pace at which previously disadvantaged and poor farmers were transforming to modern water saving irrigation systems across South Africa, Limpopo included. Linked to HSRC (2015) findings regarding the relationship between land size and poverty, most of the farmers owning between 5 and 12 hectares can be categorized as poor. These socio-economic disparities inform smallholder farmer resilience against water scarcity, as will be discussed in the following subsections.

AGRICULTURAL WATER SCARCITY IN SOUTH AFRICA

Although Africa contributes less than other developed countries to climate change, it is the world's driest continent, facing severe water crisis. Yet above 90% of agriculture in sub-Saharan Africa is rain-fed and generally under smallholder farmers (Batino & Waswa 2011). The current water scarcity situation is projected to rise in Africa as the demand for agriculture, industrial, and urban water needs will increase by 40% before 2030 (World Water Assessment Program 2015). At the same time, agricultural output in sub-Saharan Africa must double by 2050 to provide enough food for the increasing population. Policies, stakeholder cooperation, indigenous knowledge, as well as feasible technologies, will determine the vulnerability of smallholder farmers to water scarcity (Tapela 2009). Limited knowledge of irrigation, socio-economic inequalities, political and climatic issues, water use and crop management have been highlighted as key hindrances to smallholder success (Van Averbeke 2013). Yet there is limited investment and policy guidance regarding agricultural water management such as the coordinated monitoring of the impacts of water policies and institutional arrangements at local levels in South Africa. More so, smallholder farmers' resilience to water scarcity in rural areas of the country have not received the desired attention.

Strengthening smallholder farmers' resilience in rural areas is critical for enhancing food security and local economic development. Smallholder irrigation remains a viable vehicle for improved agricultural production, household food security and rural poverty reduction (Bacha *et al.* 2011; Sinyolo *et al.* 2014). Consequently, vast government investments have been made in smallholder irrigation establishment, rehabilitation and revitalization in South Africa. Limpopo province is one of the former homelands and the breadbasket of South Africa, accounting for approximately 60% of all fruits, maize, vegetables, wheat and cotton (Steyn 2014). Approximately 33% of households in Limpopo are considered agricultural households. Despite its potential to be the agricultural and economic hub of the country, the Province is prone to severe droughts and climate change (Knox *et al.* 2012). Within the context of these water and other socio-economic and political challenges, many studies report unsatisfactory performance of smallholder irrigation schemes in the province and countrywide (Fanadzo 2012; Van Averbeke 2012). Even with many studies on crop water management in the province (e.g. Faures *et al.* 2007; Maponya & Mpandeli 2016) irrigated crop production is still low compared to water use and demand (Fanadzo 2012; Maponya & Mpandeli 2016). Thus, the

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main question arises, are smallholder farmers utilizing water management mechanisms? If yes, are these water management techniques translating to farmer resilience? What should be done better to enhance smallholder farmers' resilience against water scarcity? Using Limpopo as a case study, this paper provides answers to these questions in the following sections.

AGRICULTURAL RESILIENCE

Increasing water scarcity has redefined agricultural water management in South Africa and the world over. For this reason, researchers, agricultural practitioners and policy makers have turned their attention to resilience as a solution to enhance farming productivity under water-scarce conditions. The multidisciplinary nature of resilience makes it difficult to apply the concept without contextual understanding. Resilience is applied in ecology, psychology, engineering, business, climate change and, in recent years, agriculture water security. Each field defines resilience differently depending on context. For instance, the adaptive capacity is emphasized in psychology definitions (Kantur & Say 2015), resistive and flexibility capacity characterize ecologists' definitions (Kantur & Say 2015) and the transformative capacity is apparent in business resilience studies (Hamel & Valikangas 2003). Therefore, Kativhu *et al.* (2018) recommend that it is vital to contextualize the concept before attempting to apply it in a specific field.

In agriculture, social-ecological resilience is normally utilized to characterize farmers' adaptability during water crisis. Social-ecological resilience encompasses adaptation, learning, innovation, novelty and self-organization as well as the ability to persist with disturbances (Folke 2016). The creation of social-ecological resilience is linked to a society's ability to access critical resources (Langridge *et al.* 2006). Per Langridge *et al.* (2006), analyzing how community resilience to water scarcity is influenced by the past mechanisms to gain control and access to water. This creates different operational challenges. Firstly, it demands an understanding of historical activities, socio-economic policies and political conditions that shape a society's access to water. In practice, this is a complex process that will require rigorous researches to unearth all the facts. Secondly, relying on community perceptions falls short, as it is prone to errors due to intergenerational loss of information in a community. Apart from these challenges, Ribot & Peluso (2003) explain that access is the capacity of a community to benefit from resources such as property rights, water access regulations, distribution and availability that are controlled by socio-political and economic dimensions. Thus, qualitative studies that rely on farmer perceptions in determining resilience prowess do not adequately capture accurate data, as communities normally lack information on water access regulations, distribution and availability.

Maleksaeidi & Karami (2013) define farm households' resilience under water scarcity as the capacity of a farm household to withstand water scarcity, moderating potential damages from it, maintaining the family and agricultural structure and still having the same identity as a farm household or possibly improving and advancing in self-stature by learning, creativity, adapting and coping. Such broad definitions are helpful in that they capture all aspects of resilience. However, some studies tend to focus on one or a few components of the definition; for instance, coping mechanisms are used to refer to resilience without comprehending components of the whole definition. More so, no clarity is given regarding the weight of each component mentioned in the definition. For instance, it is not clear whether farmers who apply copying strategies and those who distinctively apply creative adaptation mechanisms can attain the same resilience level. In the absence of such clarity, studies may classify short term survivalist water management strategies as resilience indicators. The definitions also omit critical resilience pillars such as threat detection and prevention capacity, which form the basis of pro-active farm-level resilience actions. As such, studies mainly cover reactive resilience capacities such as adaptation, coping and transforming when water crisis has already occurred. By building reactive resilience, there is a danger that smallholder farmers may lack the necessary

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resources to quickly adjust when water challenges escalate. It is therefore critical to infuse proactive components (threat detection and prevention) into the agricultural resilience definitions.

CHALLENGES FOR SMALLHOLDER FARMER RESILIENCE UNDER CURRENT ADAPTATION DIMENSIONS

Even though water scarcity may threaten agricultural sustainability, there is evidence (Olsson *et al.* 2004; Nuorteva *et al.* 2010) to show that agricultural societies can overcome water shortage through social-ecological resilience. A resilient agricultural system can withstand water scarcity through learning, coping and adapting, thus conserving its function and structure. Therefore, how we build resilience and understand the attributes required to make smallholder farmers adaptable and prepare for change matters. As water scarcity challenges have evolved over the years and become even more pronounced in recent years, several studies (Bindi & Olesen 2011; Iglesias & Garrote 2015) have specified different strategies used by farmers and their families to build resilience. Some have been successful, while others have fallen short in enhancing resilience among smallholder farmers.

In crop production, more studies are inclined towards adaptation as a key component of resilience response mechanisms. Because adaptation in its broadest sense encompasses both short term and long term, its use has witnessed mixed success. Mitchell (2006) cautioned that the availability of technologies and knowledge required to develop adaptive resilient water resource management systems have not translated into effective practical implementation. This is due to lack of commitment in implementation, lack of understanding of the community level vulnerability factors and lack of community capacitation with other non-farm assets and capitals necessary for reducing their vulnerability to poverty.

Studies in India, Israel, Spain and the United States have consistently shown that drip irrigation reduces water use by 30–70% and raises crop yields by 20–90% (Postel *et al.* 2001). Drip irrigation's combination of water savings and higher yields typically increases at least by 50% the water use efficiency, yield per unit water, and makes it a leading technology in the global challenge of improving crop production in the face of serious water constraints. However, the main barriers to its expansion remain the high investment cost even in the developed world (Van Averbeke 2013). As such, attempting to implement irrigation water management technologies such as drip irrigation among smallholder farmers who already lack basic financial stamina, limited human capital and poor infrastructure in the South African rural-based Limpopo province is tantamount to failure. Unless large investments are made towards leveling social inequalities, poverty and infrastructure disparities, adoption of water saving technologies to enhance smallholder farmer resilience to water scarcity will remain low.

As Pienaar (2013) note, there is evidence of success for water management systems like irrigation scheduling. Yet it requires good knowledge of the crops' water requirements and of the soil water characteristics that determine when to irrigate, while the adequacy of the irrigation method determines the accuracy of how much water to apply. Therefore, it forms the sole means for optimizing agricultural production, conserving water, improving performance and sustainability of irrigation systems. The little knowledge capacity among smallholder farmers in most rural areas like Limpopo province make the wide adoption of irrigation scheduling very complicated and, in most cases, impossible. Constant and quality farmer capacitation on implementing the technique is required first before attempting to introduce such systems. However, because in most cases government support and adoption of water management systems is informed by necessity rather than farmers' demand and needs, such systems are carelessly rolled out to farmers. When farmers are forced to abandon their proven resilience attributes and adopt new ones without proper preparation, their resilience is more compromised.

Adaptation strategies utilized by smallholder farmers in Southern Africa are well documented. These include but are not limited to utilization of livelihood assets (Chuku & Okoye 2009); crop

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insurance, crop shares, asset smoothing and diversification in Mozambique and Uganda (Osbahr *et al.* 2008; Eriksen & Silva 2009); biotechnology and plant varieties in South Africa (Chuku & Okoye 2009); rainwater harvesting technologies in South Africa (Iglesias & Garrote 2015); soil and water conservation in Zimbabwe, Ethiopia and Zambia (Rockström *et al.* 2009); and indigenous early warning systems (Chikozho 2010). These adaptation techniques are spatially applied based on farmer capacity, availability of resources and government support systems. However, the major challenge is that some of the technologies require higher capital investments that require government support. Although South Africa provides agricultural funding to smallholder farmers under the agricultural transformation programs, the support has been, in some cases, misused or not reached farmers in deep rural areas such as those found in Limpopo. Hence, Keshavarz *et al.* (2013) warn that adopting new practices under water scarcity when farmers do not have adequate finance could significantly reduce the resilience of farm households.

Besides, most of the resilience mechanisms in South Africa are reactive, with only a few such as crop insurance and farmer cooperatives being proactive. Maleksaeidi & Karami (2013) similarly highlight that most of the climate change adaptation techniques in Southern Africa are survivalist in nature. Worth noting is the fact that adaptation capacities are impacted by various factors such as infrastructure, information resources, institutional environment, political decisions and technological capacity. More so, social inequalities influence resource availability and how smallholder farmers adapt to water scarcity. Thus, implementation of water scarcity adaptation interventions should be informed by a clear understanding of local social inequalities, economic, political influence and policy environment. In some circumstances, the capacity of farmers to adapt to climate change and water scarcity depends on farmers' perceptions (subjective resilience attributes) towards resilience options, and stakeholder cooperation.

Further, issues of sustainability and resilience are rarely integrated into the planning and implementation of adaptation policies and strategies in both public and private initiatives. More so, most studies only focus on identifying adaptation techniques without necessarily understanding the nexus between adaptation, resilience and transformation in the face of water scarcity. The ability of farmers to adapt to water scarcity and disturbances also depends on certain demographic determinants. These include age, education, sex of the household head, farm size, income and access to climate and precipitation information (Gebrehiwot & van der Veen 2013). As such, attempts to implement resilience techniques must consider those variations. Furthermore, in most Southern African countries including South Africa, the desire to address growing water scarcity has led to an overreliance on external technical expertise meant to bring knowledge and capacities to local areas (Sutherland *et al.* 2015). This perpetuates adoption of adaptation mechanisms that are not congruent with local realities.

TOWARDS TRANSFORMATIVE RESILIENCE

As shown in a range of mechanisms and associated challenges for local adoption, resilience is a contested word and how to achieve it among smallholder farmers has become central to debates. Some argue that resilience, particularly relating to 'adaptability', is biased towards only persistence (Pelling & Manuel-Navarrete 2011). Others adorn resilience as a mechanism for navigating change, and thus it is concerned with the ability to adapt and transform in the face of water scarcity challenges. Adaptability relates to the capacity to deal with change and stay within a certain state while transformation is viewed as the capacity that enables a shift from one state to another (Olsson *et al.* 2014). Walker *et al.* (2010) further explain that transformation is the ability of systems to change when confined in untenable circumstances and alternative re-configurations of the current system are ineffective. For smallholder farmers, transformation can be a response to the recognition of persistent water stress, failure of past adaptation mechanisms, policies and response actions.

As Walker *et al.* (2010) suggest, transformational change is characterized by introducing new defining state variables while losing others. For instance, smallholder farmers may completely change the type of crops they grow in response to persistent water shortages. This can be either deliberate or forced on them by the changing environment, such as climate change, which induces critical water shortages. Transformation requires collective action of diverse components such as all capitals, actor groups, networks, learning platforms, support from government, private sectors and collective action. More so, there is a need for a shift in people's perceptions, social network configurations, unit and cooperation among stakeholders as well as institutional arrangements (Smith & Stirling 2010). However, as Rodina *et al.* (2017) argue, in Southern Africa, high levels of inequality in water access and governance lead to inequity in both adaptive and transformative capacity. This undermines both state and community-led resilience efforts to agriculture water scarcity. Hence, more research, policy and community practice is required to identify mechanisms that can lead to the transformation towards water governance as a pivot for achieving resilience. In this paper, it is argued that there is need to shift from the widely applied adaptive resilience to transformative resilience. Transformative resilience will increase the sustainability of smallholder farmers considering the predicted increase in water scarcity.

CASE STUDIES IN LIMPOPO IRRIGATION SCHEMES

We carried out two case studies in Limpopo Province under the Water security and hydrological resilience along crop value chains project funded by USAID and NRF. The case studies were aimed at understanding the area-specific water scarcity situation and resilience mechanisms at farm level as well as ascertaining the appropriateness of these techniques in managing water use. Explorative mixed study approaches were followed to obtain data in both case studies. At Luvhada, 42 farmers participated in the study while 41 farmers were drawn from the Nwanedi irrigation scheme. Two extension offices from the area were interviewed as key informants. Interview guides and questionnaires with open and close ended questions were utilized to collect data through individual interviews. Further data was collected through telephonic calls and photovoice. Qualitative data was conducted using the Atlasti 8 software (network diagrams) while the Statistical Package for Social Scientist (descriptive statistics, principal component analysis) were followed to obtain quantitative results. A snapshot of the results is presented in Figures 2 and 3 for Luvhada and Nwanedi irrigation schemes respectively.

LESSONS LEARNT AND RECOMMENDATIONS

Deepening community engagement is desirable

Because resilience is a multidimensional concept, understanding the system (i.e. smallholder agriculture) and the process through which resilience is built at both small and large scales is critical. As Rodina *et al.* (2017) suggest, understanding the process of resilience of building directly influences the outcomes. Therefore, deepening engagement, enhancing inclusivity and active participation of the concerned communities and necessary actors is desirable (Biggs *et al.* 2012). Government investments for smallholder farmers have been on hydrology and engineering aspects of irrigation schemes, while the social and distributive issues have largely been ignored (Fanadzo 2012). In most cases, individual characteristics of irrigators have received little attention in irrigation schemes, leaving many irrigators water insecure. Deepening community engagement allows for understanding adaptation priorities in relation to socio-economic inequalities. The target should be reducing poverty to improve

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Water security situation

Luvhada is a situated in a rural area between the Nzhelele River and Mphephu resort, Vhembe District, South Africa. Lulumba fountains are perennial and its main source of agricultural water. The water is cool when it reaches the field. The scheme has about 79 members, each owning 0.4 ha. The main crops grown include maize, beans, onions, sweet potatoes, cabbages and groundnuts. The local market radius for their farm produces covers Louis Trichardt, Musina, Thohoyandou and Biaba towns. Since the scheme was established in 1965. The scheme relies on the furrow irrigation system. Because pumping water through electrical pumps is very expensive, scheme members rely on diverting water from the fountains through canals and furrows to irrigate their crops (van Koppen et al. 2017). The major water challenges in the area included:

- Limited water supply as the fountain does not produce enough water to allow for irrigation expansion
- Inadequate water storage facilities such as tanks to reserve water for use during dry periods
- Competition for water use between farmers and domestic users leading to conflicts
- Damaged furrows and canals leading to water loss through infiltration

Furrow irrigation at Luvhada irrigation scheme

.

Farm level resilience mechanisms

The following farm level resilience mechanisms were revealed:

- Regular canal maintenance to reduce water leakages
- Reduction of area under cultivation to meet fountain water supply capacity especially in hot seasons
- Scheduling irrigation to equally distribute water among farmers
- Growing drought resistant crops e.g. ground nuts, sweet potatoes and early maturing maize varieties

These mechanisms are survivalist in nature, as they neither translate to increased crop production nor reduce water usage. Thus, the following recommendations were made:

- Farmer capacitation is required to increase adoption of water saving irrigation technologies, understanding water saving techniques and facilitate transformation
- Provision of financial and human resource to enhance the adoption of water management infrastructure and farmer skilled labor.
- Place more emphasis on strengthening indigenous knowledge embedded in the farming communities.

Figure 2 | Luvhada irrigation scheme, Limpopo, South Africa.

the response capacity of rural farmers. Barua *et al.* (2014) similarly suggest the need to integrate adaptation within development and poverty reduction programs. Doing so equips communities with financial, physical, social and human capitals, which enhances their capacities to respond to water scarcity and climate change.

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Agricultural water scarcity situation	Farm level resilience mechanisms
Nwanedi irrigation scheme is situated in the north of the Southpansberg Mountains, about 40km northeast of Tshipise in Vhembe District of Limpopo Province, South Africa. This site consists of approximately 300 smallholder farmers who grow irrigated vegetables mostly tomatoes. The area is under threat from increased droughts and water insecurity. Most members at the scheme are producing about 100 tonnes of tomatoes per person per hector (ha) or 1000 square metre (1000m2). Most farmers own between 10 to 100 ha and they produce mainly for sale. The site consists of two dams namely the Luphephe (14.0 million m3 total capacity) and the Nwanedi (5.1 million m3 total capacity), and one perennial river called the Nwanedi River (catchment area of 897 km2) (Janse van Vuuren et al. 2003). Farmers directly draw irrigation water from the river using the drip irrigation system. Results revealed the following water scarcity challenges in the area: • Water waste through over irrigation and leaking pipes • High temperatures leading to high water evaporation from the river and evapotranspiration from crops • Poor irrigation infrastructure preventing efficient water conveyance • Competition for water between farmers and domestic users leading to conflicts • Unequal water distribution as farmers at the lower tail of the river receive little or no water when the river flow declines. • Lack of water storage preventing reservation of water for use in dry seasons to easy pressure on the river	Results at Nwanedi irrigation scheme highlighted the following farm level resilience mechanisms: • Supplementing river water with boreholes were soil salinity is not a problem • Irrigation at night when evaporation and evapotranspiration is low • Reducing farming area to meet river water supply capacity • Growing drought resistant crops to reduce water usage during hot seasons (August-November) • Premature harvesting particularly when water demand exceed supply at a time • Total suspension of farming especially when dam levels are low to sustain crop irrigation Although strategies such as growing drought resistant crops and reducing farming area helped to reduce water use, they negatively impact yields. On the other hand, irrigation at night resulted in over irrigation as pumps are left unattended until morning. Premature harvest and suspension of farming activities is not sustainable. Thus, most of the adaptation mechanisms do not contribute to smallholder farmer resilience in the long run. This case study show that, even where water saving irrigation technologies such as drip irrigation is used, farmer management and knowledge determines water use efficiency. More so, other socio-economic and environmental factors such as high temperature may result in more water use even when water saving techniques are applied. Thus, extensive farmer education is critical to promote not only the uptake of water efficient technologies but their accurate operationalization at farm level. Increasing local knowledge sharing, stakeholder cooperation and capacitation of extension personnel with water management knowledge is key to successfully implementation of mechanisms that promote smallholder farmer resilience in particular area.

Figure 3 | Nwanedi irrigation scheme, Limpopo, South Africa.

Situational analysis

As Sinyolo *et al.* (2014) hint, information about how water security status varies across irrigating households, and the extent to which this relates to socio-economic and institutional variables, is required. This helps to find ways of understanding the plight of the poor farmers regarding water security. Using such information, effective water management institutions can be established to

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target priority groups at both new and revitalised irrigation schemes in the province and South Africa at large.

Increasing knowledge exchange

In our two case studies, extension officers working in the area were identified. However, they lacked knowledge and operational capability in agricultural water management. The absence of guidelines for farm level water management make matters worse. The solution would be to increase knowledge exchange in the area and region. This include facilitating knowledge of diffusion from higher learning institutions about crop water needs, yields to water use ratios, on-farm versus attainable efficiency and on-farm water efficient irrigation technology training. It is necessary to increase partnerships between higher learning agricultural institutions especially those carrying out studies in the area and smallholder farmers to increase knowledge transfer.

Develop context-based resilience measurement tools

Monitoring adaptive and transformative capacities of farmers over time is crucial in attaining resilience. Most researches focus on designing generic indexes and frameworks for assessing resilience. However, because of the variations in historical, socio-economic and socio-ecological features of different localities, there is a need for context-based and grounded approaches (Rodina *et al.* 2017). Kativhu *et al.* (2018) also illustrated that there is no universal metric for measuring resilience. As such, measuring water scarcity resilience will require appropriate metrics that capture the complex dimensions of social systems to inform decisions.

Recognize indigenous knowledge

Social-ecological resilience scholarship highlights the importance of indigenous knowledge in understanding the transformation process (Berkes *et al.* 2008). Yet much of the contemporary work on climate change and water resilience often neglects traditional knowledge on vulnerability and response mechanisms that have spurred local communities for centuries. For instance, Rodina *et al.* (2017) note that colonial regimes of Southern Africa historically silenced the voices of African people, resulting in the loss of insights into the creative forms of adaptive strategies for building resilience to water-related challenges. Because many local people lived resilient lives in the face of water challenges without external knowledge sources and support, it is vital to tap into the wealth of knowledge, experience and capacities that exist in the irrigation schemes.

Utilizing hydrological opportunities

Hydrological processes directly influence water availability; engaging with the unpredictable nature of change in water systems is equally important in the quest to attain resilience. Dunn *et al.* (2016) suggested a shift towards complexity thinking in water governance that accounts for variability and progressively unpredictable socio-hydrological dynamics. As such, it is plausible to argue that exploring the socio-hydrological and water governance systems in an area can inform resilience understanding. For instance, the existence of hot springs in the Lulumba mountains might be evidence of groundwater reserves that can be explored in the area. Distinctively, the case study carried out in Nwanedi revealed that most of the groundwater was saline, thus making it unfeasible to drill boreholes. Therefore, hydrological assessment would highlight groundwater options available in certain areas. Groundwater will provide amicable solutions to surface water crisis in the future especially in areas like Limpopo, which lies in the Limpopo river basin.

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Adopting renewable energy

The need for renewable solar energy for irrigation pumps is desirable in Limpopo to explore the high temperatures in the area. High cost of diesel and electric powered irrigation pumps limits the adoption of water-efficient irrigation systems like drip and sprinkler irrigation (Van Koppen & Schreiner 2014). Limpopo province is situated in a hot region, and thus the establishment of solar irrigation systems helps to exploit the solar coverage while unlocking the use of water efficient irrigation systems that are absent in most schemes. High initial cost for assembling solar irrigation pumps necessitate the need for government to provide equipment subsidies to smallholder farmers. There is also need for government to provide necessary irrigation equipment desired by smallholder farmers rather than financial grants which can easily be diverted towards other non-agricultural purposes.

CONCLUSION

Smallholder farmer resilience is still a premature concept with limited visibility in many studies across South Africa. Most agricultural studies focus on one or a few components of resilience (i.e. coping, adaptive capacity or flexibility) without looking at the concept in its totality as depicted in the definition. Thus, most studies use coping and/adaptation capacity to reflect the resilience capacity of smallholder farmers. Furthermore, most of the existing adaptation mechanisms do not translate into farm-level resilience to water scarcity in Limpopo due to socio-economic inequalities, limited knowledge capacity and partial need based support services. Like the rest of South Africa, resilience mechanisms identified in Limpopo were more survivalist in nature, as most of them (such as reducing farming area, irrigation at night and scheduling irrigation) did not result in increased productivity. Worth noting is the fact that water-efficient technologies cannot be successfully implemented without proper farmer capacitation and strict water management regulations at farm level. Therefore, to enhance resilience, improvements in information exchange, support services, stakeholder cooperation and hands-on farm-level capacity building are required to enhance the appropriate adoption of both indigenous and external water saving irrigation technologies. Investments in indigenous knowledge trusted by communities should also be made to promote adoption and preserve local knowledge.

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AUTHOR CONTRIBUTIONS

The authors' role in this work are: S. Kativhu: reviewed literature and write up; M. Mwale: reviewed the full paper, added inputs and made available funds for the study; J. Zuwarimwe: reviewed the paper, and added inputs.

CONFLICT OF INTEREST

There is no conflict of interest.

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REFERENCES

Bacha, D., Namara, R., Bogale, A. & Tesfaye, A. 2011 Impact of small-scale irrigation on household poverty: empirical evidence from the Ambo District in Ethiopia. *Irrigation and Drainage* **60**, 1–10.

Barua, A., Katyaini, S., Mili, B. & Gooch, P. 2014 Climate change and poverty: building resilience of rural mountain communities in South Sikkim, Eastern Himalaya, India. *Reg Environmental Change* (14), 267–280. https://doi.org/10.1007/s10113-013-0471-1.

Batino, A. & Waswa, B. S. 2011 New challenges and opportunities for integrated soil fertility management in Africa. In: *Innovations as Key to the Green Revolution in Africa: Exploring the Scientific Facts* (Bationo, A., Waswa, B., Okeyo, J. M., Maina, F. & Kihara, J., eds). Vol. 1, pp. 3–20. https://doi.org/10.1007/978-90-481-2543-2.

Berkes, F., Colding, J. & Folke, C. (eds) 2008 *Navigating Social–Ecological Systems: Building Resilience for Complexity and Change*. Cambridge University Press, Cambridge, UK.

Biggs, R. F. R., Westley, R. & Carpenter, S. R. 2012 Navigating the back loop: fostering social innovation and transformation in ecosystem management. *Ecology and Society* **15**(2), 9–25. https://doi.org/10.5751/es-03411-150209.

Bindi, M. & Olesen, J. E. 2011 The responses of agriculture in Europe to climate change. *Regional Environmental Change* **11**(1), 151–158.

Chikozho, C. 2010 Applied social research and action priorities for adaptation to climate change and rainfall variability in the rainfed agricultural sector of Zimbabwe. *Physics and Chemistry of the Earth* (35), 780–790. https://doi.org/10.1016/j.pce.2010.07.006.

Chuku, C. & Okoye, C. 2009 Increasing resilience and reducing vulnerability in sub-Saharan African agriculture: strategies for risk coping and management. *African Journal of Agricultural Research* **4**, 1524–1535.

Department of Agriculture, Forestry and Fisheries (DAFF) 2011 *About Livestock and Crop Production*. Pretoria, South Africa.

Department of Agriculture, Forestry and Fisheries (DAFF) 2015 *National Irrigation Strategy for South Africa*. Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa.

Dunn, J., Chambers, S. K. & Hyde, M. K. 2016 Systematic review of motives for episodic volunteering. *Voluntas* **27**, 425–464.

Eriksen, S. & Silva, J. 2009 The vulnerability context of a savanna area in Mozambique: household drought strategies and responses to economic change. *Environmental Science & Policy* (12), 33–52. https://doi.org/10.1016/j.envsci.2008.10.007.

Fanadzo, M. 2012 Revitalisation of smallholder irrigation schemes for poverty alleviation and household food security in South Africa: a review. *African Journal of Agricultural Research* **7**(13), 1956–1969.

Faures, J. M., Svendsen, M., Turral, H., Berkhoff, J., Bhattarai, M., Caliz, A., Darghouth, S., Doukkali, M., El-kady, M. & Facon, T. 2007 *Reinventing Irrigation*. International Water Management Institute, Colombo, Sri Lanka.

Folke, C. 2016 Resilience. *Ecological Sociology* **21**(44), 253–267.

Gebrehiwot, T. & Van der Veen, A. 2013 Farm level adaptation to climate change: the case of farmer's in the Ethiopian highlands. *Environmental Management* **52**, 29–44.

Hamel, G. & Valikangas, L. 2003 The quest for resilience. *Harvard Business Review* **81** (9), 52–65.

Human Science Research Council 2015 *Economic Performance and Development: State of Poverty and its Manifestation in the Nine Provinces of South Africa*. Report.

Iglesias, A. & Garrote, L. 2015 Adaptation strategies for agricultural water management under climate change in Europe. *Agricultural Water Management* **155**, 113–124.

Kantur, D. & Say, A. I. 2015 Measuring organizational resilience: a scale development. *Journal of Business Economics and Finance* **4**(3), 2146–7943.

Kativhu, S., Mwale, M. & Francis, J. 2018 Approaches to measuring resilience and their applicability to small retail business resilience. *Problems and Perspectives in Management* **16**(4), 275–284. https://doi.org/10.21511/ppm.16(4).2018.23.

Keshavarz, M., Karami, E. & Vanclay, F. 2013 The social experience of drought in rural Iran. *Land Use Policy* (30), 120–129. https://doi.org/10.1016/j.landusepol.2012.03.003.

Knox, J. W., Hess, T. M., Daccache, A. & Wheeler, T. 2012 Climate change impacts on crop productivity in Africa and South Asia. *Environmental Research Letters* **7**(3). https://doi.org/10.1088/1748-9326/7/3/034032.

Langridge, R. J., Christian-Smith, K. A. & Lohse, K. A. 2006 Access and resilience: analyzing the construction of social resilience to the threat of water scarcity. *Ecology and Society* **11**(2), 18–35. https://doi.org/10.5751/es-01825-110218.

Maleksaeidi, H. & Karami, E. 2013 Social-ecological resilience and sustainable agriculture under water scarcity. *Agroecology Sustainable Food System* (37), 1–29. https://doi.org/10.1080/10440046.2012.746767.

Maponya, P. & Mpandeli, S. N. 2016 Drought and food scarcity in Limpopo province, South Africa. In *2nd World Irrigation Forum 6-8 November 2016*, Chiang Mai, Thailand.

Mears, R. R. & Blaauw, P. F. 2010 Levels of poverty and the poverty gap in rural Limpopo. *Acta Commercii* **3**, 89–106.

Mears, R. R., Jagals, P., Greyling, L. & Blaauw, P. F. 2008 Demographic characteristics of selected rural villages in the Nwanedi River Basin. In: *Paper Read at the 2nd Biennial International Conference on Creating, Developing and Delivering Value in Africa in the Global Context*, Value 2008, 26-28 May 2008, Sun City, North West Province, South Africa.

Mitchell, V. 2006 Applying integrated urban water management concepts: a review of Australian experience. *Environmental Management* (37), 589–605. https://doi.org/10.1007/s00267-004-0252-1.

Namara, R. E., Hanjra, M. A., Castillo, G. E., Ravnborg, H. M., Smith, L. & Koppen, B. V. 2010 Agricultural water management and poverty linkages. *Agricultural Water Management* (97), 520–527. https://doi.org/10.1016/j.agwat.2009.05.007.

Water Practice & Technology Vol 15 No 4
doi: 10.2166/wpt.2020.068

Nuorteva, P., Keskinen, M. & Varis, O. 2010 Water, livelihoods and climate change adaptation in the Tonle Sap Lake area, Cambodia: learning from the past to understand the future. *Journal of Water and Climate Change* **1**, 87–101.

Olsson, P., Folke, C. & Hahn, T. 2004 Social-ecological transformation for ecosystem management: the development of adaptive co-management of a wetland landscape in southern Sweden. *Ecology and Society* **9**(4), 2–27. Available from: http://www.societyandecology.org/vol9/iss4/art2/.

Olsson, P., Galaz, V. & Boonstra, W. J. 2014 Sustainability transformations: a resilience perspective. *Ecology and Society* **19**(4), 1–25. http://dx.doi.org/10.5751/ES-06799-190401.

Osbahr, H., Twyman, C., Adger, W. & Thomas, D. 2008 Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique. *Geoforum* (39), 1951–1964. https://doi.org/10.1016/j.geoforum.2008.07.010.

Pelling, M. & Manuel-Navarrete, D. 2011 From resilience to transformation: the adaptive cycle in two Mexican urban centers. *Ecology and Society* **16**(2), 11–30.

Pienaar, P. L. 2013 *Typology of Smallholder Farming in South Africa's Former Homelands: Towards an Appropriate Classification System*. Stellenbosch University, Stellenbosch, South Africa.

Postel, S., Polak, P., Gonzales, F. & Keller, J. 2001 Drip irrigation for small farmers. A new initiative to alleviate hunger and poverty. *Water International* **26**(1), 3–13.

Ribot, J. & Peluso, N. L. 2003 A theory of access. *Rural Sociology* **68**(2), 153–181.

Rijsberman, F. R. 2006 Water scarcity: fact or fiction? *Agricultural Water Management* (80), 5–22. https://doi.org/10.1016/j.agwat.2005.07.001.

Rockström, J., Falkenmark, M., Karlberg, L., Hoff, H., Rost, S. & Gerten, D. 2009 Future water availability for global food production: the potential of green water for increasing resilience to global change. *Water Resources Research* **45** (7). https://doi.org/10.1029/2007wr006767.

Rodina, L., Baker, L. A., Galvin, M., Goldin, J., Harris, L. M., Manungufala, T. M., Musemwa, M., Sutherland, C. & Ziervogel, G. 2017 Water, equity and resilience in Southern Africa: future directions for research and practice. *Current Opinion in Environmental Sustainability* **26**(27), 143–151. https://doi.org/10.1016/j.cosust.2017.09.001.

Sinyolo, S., Mudhara, M. & Wale, E. 2014 Water security and rural household food security: empirical evidence from the Mzinyathi district in South Africa. *Food Security* **6**, 483–499.

Smith, A. & Stirling, A. 2010 The politics of social–ecological resilience and sustainable socio-technical transitions. *Ecology and Society* **15**, 11–30.

Statistics South Africa 2015 *Inequality Trends in South Africa: A Multidimensional Diagnostic of Inequality, Quarterly Report*.

Steyn, G. 2014 *Provincial Statistics Indicators*. Limpopo province, South Africa.

Sutherland, C., Scott, D. & Hordijk, M. 2015 Urban water governance for more inclusive development: a reflection on the 'Waterscapes' of Durban South Africa. *European Journal of Development Research* **27**, 488–504.

Tapela, B. 2009 *Report to CGIAR Challenge Program Project 66 Water Rights in Informal Economies*. International Water Management Institute and Institute of Poverty, Land and Agrarian Studies, South Africa Pretoria/Cape Town.

Van Averbeke, W. 2012 Performance of Smallholder Irrigation Schemes in the Vhembe District of South Africa. *Problems, Perspectives and Challenges of Agricultural Water Management* **21**, 413–438.

Van Averbeke, W. 2012 Performance of smallholder irrigation schemes in the Vhembe District of South Africa. In: *Problems, Perspectives and Challenges of Agricultural Water Management* (Kumar, M. D., ed.). InTech, Rijeka, South Africa.

Van Averbeke, W. 2013 *Improving Plot Holder Livelihood and Scheme Productivity on Smallholder Canal Irrigation Schemes in the Vhembe District of Limpopo Province*. WRC Report no TT566/13. Pretoria, South Africa, Water Research Commission of South Africa, p. 285.

Van Koppen, B. & Schreiner, B. 2014 Moving beyond integrated water resource management: developmental water management in South Africa. *International Journal of Water Resources Development* **3**, 35–50. https://doi.org/10.1080/07900627.2014.912111.

Walker, B. H., Sayer, J., Andrew, N. L. & Campbell, B. 2010 Should enhanced resilience be an objective of natural resource management research for developing countries? *Crop Science* (50), 10–19. https://doi.org/10.2135/cropsci2009.10.0565.

World Water Assessment Programme 2015 *Water for A Sustainable World*. Available from: www.fao.org/nr/water/docs/escarcity.pdf.