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Smallholder sheep farmers' perceived impact of water scarcity in the dry ecozones of South Africa: Determinants and response strategies

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ABSTRACT

Water scarcity is amongst the major challenges threatening smallholder sheep production in subsistence-oriented communal farms in dryland areas. Local contextual factors are a prerequisite for effective policy development and optimisation of water resources management for smallholder sheep production. Two-hundred and fifty-two structured questionnaires were administered to investigate the contextual factors that influence smallholder farmers' perceived impact of water scarcity on sheep production in the dry ecozones of the Cape provinces in South Africa and identify their local esponse strategies. Logit regression findings showed that a unit increase in private commercially-oriented arid farms, males, education level, flock size, adapted breeds and income from livestock increased farmers' probability to perceive impact of water scarcity on sheep production. Regardless of ecozone and farm types, sheep farmers switched between water sources, provided supplementary feed and shade, used adapted b eeds and alternative markets to manage the impact of water scarcity. Interventions to build esilience to water scarcity in the surveyed areas should target sheep farmers with low adaptive capacity, particularly less educated women relying on livestock income and farming with non-adapted breeds on subsistence-oriented communal farms in the semiarid ecozone.

1. Introduction

Sheep production is one of the sustainable sources of food, income and socio-cultural wealth for farmers living in arid and semiarid areas (i.e., dry ecozones) of the world (Almeida, 2011a, 2011b; Chikwanha et al., 2021; Pollot and Wilson, 2009). Environmental stressors such as scarcity of drinking water and feed, high thermal and parasite loads (Adeniji et al., 2020; Molotsi et al., 2017; Rust and Rust, 2013) adversely reduce adaptive capacity of sheep and adversely affect their health, welfare, meat production and quality attributes (Chedid et al., 2014; Chikwanha et al., 2021; Dos Santos et al., 2019). This subsequently diminishes sustainability of livelihoods dependent on sheep farming in d y ecozones.

Globally, smallholder farmers in dry ecozones are the most vulnerable to the water scarcity challenge largely due to existence of multiple environmental stressors, lack of adaptive capacity, poor governance and little or no investments in water esources

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management (Ali et al., 2021; Cosens and Chaffin, 2016; Gandure et al., 2013). Smallholder livestock farmers are generally esource-limited, own small pieces of land and manage their animals on communal, leased or private land for food security and income (Gwiriri et al., 2019; Marandure et al., 2016). wing to their high vulnerability, response strategies aimed at optimising agricultural water use efficiency in dry ecozones should prioritise smallholder farmers.

Processes and responses farmers take to cope and/or adapt to natural hazards such as water scarcity are driven by contextual factors (Singh et al., 2018; Yu et al., 2013). Perceptions, in particular, are key in promoting smallholder farmers' actions to cope with local impacts of water scarcity (Fan et al., 2019; Hutchings et al., 2015; Muthelo et al., 2019). They are largely shaped by the individuals' attributes, their experience, the information obtained, and the cultural and ecological context in which they exist (Fierros-González and López-Feldman, 2021; van der Linden, 2015; Whitmarsh and Capstick, 2018). Disregarding farmer's perceptions of the impact of natural disasters, factors shaping them and their effects on livelihoods will miss the contextual ealities that are important in formulating appropriate adaptive technologies and policies (Alam et al., 2017; Patt and Schröter, 2008; Singh et al., 2016).

Knowledge of local perceptions and core factors influencing them are important in devising effective esponse strategies that enhance the sustainability of the dryland sheep production and consequently improve farmers' livelihoods (Abdul-Razak and Kruse, 2017; Alam et al., 2017; Singh et al., 2018). Specifically, knowing which groups among the smallholder farmers have the lowest adaptive capacity to water scarcity and the relevant determinants for these capacities could provide the basis to unmask the most effective policy and supportive strategies (Fierros-González and López-Feldman, 2021). To the authors knowledge there is limited, if any, information regarding contextual factors that influence smallholder farmers' perceptions of the impact of water scarcity on sheep production in dryland areas. This is particularly critical for smallholder-dominated and water-scarce countries such as South Africa. The aim of the current study was, therefore, to investigate the determinants of smallholder farmers' perceived effects of water scarcity on sheep production in the dry ecozones of the Cape provinces in South Africa and identify local response strategies.

2. Materials and methods

2.1. Study sites and sampling procedures

The current study received ethics approval from Stellenbosch University Humanities Research Ethics Committee (SU-HREC-10048–2019), which complies with the South African National Health Act 61 of 2003 and egulations relating to research involving human participants. A multi-stage sampling technique was used to select provinces, district and local municipalities, communities, and household heads. Firstly, three out of ten provinces of South Africa namely, Northern Cape, Western Cape, and Eastern Cape were purposively sampled based on aridity. Within each province, communities, local and district municipalities were then selected based on number of smallholder sheep farmers, sheep population and aridity, respectively. In the current study, a simple aridity index based solely on precipitation was used with "semiarid ecozone" referring to an area eceiving annual precipitation ranging between 250 and 500 mm and "arid ecozone" eceiving $<$250 mm (IPCC, 2007; Maliva and Missimer, 2012). Table 1 presents temperature and ainfall data for the study sites.

In each community, a list of households owning sheep obtained from the local Department of Agriculture, Land Reform and Rural Development extension offices was used as a sampling frame. Subsequently, a random sample of 252 household heads willing to participate in the study was drawn. Household head was, therefore, used as the unit of analysis for the current study.

2.2. Data c llection

Household heads were interviewed face-to-face using a structured questionnaire administered in the local languages (i.e., IsiXhosa or Afrikaans) by trained enumerators. A prototype of the questionnaire was drafted and subsequently pre-tested in June 2019 before being revised and administered between September and November 2019. The questionnaire sought information on farmers' socio-economic attributes, sheep flock structure, breeds and performance attributes, feeding, breeding, health and marketing management, supply and quality of drinking water for sheep using close-ended questions. Farmers' perceptions of impact of water scarcity on sheep production attributes in the past five years (2015 – 2019) were also captured. An example of the question asked in this egard was: "Has water scarcity over the past 5 years affected the body weight of your sheep?". Farmers were asked to indicate the perceived impact of water scarcity on a given dependant variable based on a three-point Likert scale where -1 = decreased, 0 = no change, $+1$ =

Table 1
Environmental conditions and sample size of surveyed areas in the dry ecozones of the Cape Provinces in South Africa.

Province	District and Local Municipality	Local municipality meteorological profile		Ecozone	Respondents
		Annual ainfall (mm)	Mean annual temperature (°C)		
Eastern Cape	Chris Hani - Engcobo	300–400	11–14	Semiarid	69
	OR Tambo - Nyandeni	470–550	17–20	Semiarid	54
Northern Cape	Namakwa - Karoo-Hoogland	100–200	17–18	Arid	30
	Pixley ka Seme - Emthanjeni	190–260	13–14	Arid	37
Western Cape	West Coast - Matzikama	30–260	17–18	Arid	31
	Central Karoo - Beaufort West	150–235	17–18	Arid	31

Sources: https://www.climatedata.eu/; https://en.climate-data.org/; https://www.worldweatheronline.com/.

increased. Thereafter, they were asked a follow-up question about the response strategies they used for each sheep production parameter perceived to have been negatively affected by water scarcity. An example of such a question was: "If body weight of your sheep decreased over the past 5 years, how did you espond?". The questionnaire had 90 questions and the average interview time was one and half hours.

2.3. Statistical analyses

All data were analysed using SAS v. 9.4 (SAS Institute Inc., 2012). Descriptive statistics (i.e., percentages) and chi-square tests were applied to summarise socio-economic attributes and determine their association with farmers' response strategies to the impact of water scarcity on sheep production. Data on sheep flock structure were analysed using the Generalised Linear Model procedure of SAS v. 9.4 with ecozone as the fixed effect and farmer within an ecozone as the random effect.

A multivariate ordered logit model was performed to identify factors influencing farmers' perceptions of the impact of water scarcity on sheep production. The model predicted log odds of being at a cut-off point versus being at a lower o higher category of the ordered outcomes (Fullerton, 2009). The core dependent ordered variables were farmers' responses to the impact of water scarcity on sheep production attributes coded: −1 = decreased, 0 = constant (no change) and + 1 = increased. Independent variables (determinants) comprised of farm ecological factors, household demographic and socio- economic attributes (Table 2) previously eported to influence farmers perceptions of the impact of climate change on livestock production (Ado et al., 2020; Asrat and Simane, 2018; Debela et al., 2015; Fierros-González and López-Feldman, 2021). The model included independent variables whose maximum likelihood estimates converged only and had non-significant score test for proportional odds assumptions. Selection of independent variables that were incorporated in the model was done using the forward selection model option embedded in LOGISTIC procedure of SAS v. 9.4. The ordered logit model used was as follows:

$$Log\left(\frac{p_i(Y \le m|x)}{p_i(Y < m|x)}\right) = \tau_m - x\beta(1 \le m < M)$$

where, m = category (ordered category: −1 = decreased, 0 = no change (constant) and 1 = increased); x = effect of the determinant of farmer's perception outcome; τ = cut-off point; β = vector of logit coefficients; τ_m = log odds of being in category m or a lower versus a higher category (M) where the ordering of cut points was constrained to $\tau 1 < \tau 2 \ldots < \tau M - 1$. Since estimated coefficients and exponentiated coefficients (i.e., odds ratios) neither represent the actual magnitude of change nor the probabilities; marginal effects were derived to explain the effects of independent variables in terms of probabilities, which is specified as follows:

Table 2
Description of independent variables used to create a logistic regression model for factors influencing farmers' perceptions of the impact of water scarcity on sheep production in the Cape Provinces in South Africa.

Independent variable	Description of independent variables
Ecozone	Location of the household (Dummy, Semi-arid = 1, A id = 0). Impact of water scarcity and climate change on livestock production is location-specific (Asrat and Simane, 2018; Destaw and Fenta, 2021). Thus, sheep farmers are likely to have location-specific perceptions of impacts of water scarcity.
Farm typology	Type of farm owned by the head of household (Dummy, 1 = Subsistence-oriented communal farm, 2 = commercially-oriented private farm). The diversity of smallholder farms is large and has wide implications for the understanding farmers perceptions of the impact of climate change and esponse strategies (Shukla et al., 2019).
Gender	Gender of the head of household (Dummy, 1 = Male, 2 = Female). Males often have greater access to means of production and are more informed and experienced than women (Asrat and Simane, 2018; Deressa et al., 2011). Subsequently, male-headed households are expected to have positive perceptions of the impact of water scarcity on sheep production.
Age	Age of the head of household in years [Categorical, 1 = young adult (<30 years), 2 = adult (31–49 years), 3 = old (50–69 years), 4 = very old (>70 years)]. On one hand, age of the household head is a proxy for farming experience, on the assumption that the household's knowledge and experiences of climate change and water scarcity issues increases as the household head grows older (Ali et al., 2021). On the other hand, farmers over 70 years old tend to be more isk averse and vulnerable to memory loss and decline in physical energy. Subsequently, the farmers perceived impacts of water scarcity on sheep production could be ambiguous.
Education level	Level of education attained by the head of the household [Categorical, 1 = more educated, 2 = less educated]. Education has been positively associated with farmers' climate change perceptions and esponse strategies (Asrat and Simane, 2018; Deressa et al., 2009).
Source of income	Main source of household income (Dummy, Livestock = 1, Other = 0). Income from livestock reduces vulnerability of farmers to climate change and water (Abafita and Kim, 2014). It has been positively associated with farmers perception of climate change and adaptation strategies in the wet ecozones, but negative associations were reported in the dry ecozones (Asrat and Simane, 2018).
Flock size	Number of sheep owned by the head of household (Continuous). Households with more sheep produce more meat and milk for direct consumption and have better chance to earn more income from selling sheep meat and wool which assist them to purchase food during water scarcity (Gemechu et al., 2016; Sani and Kemaw, 2019). In that egard, owning more sheep was expected to have positive effects on farmers water scarcity perceptions.
Breed	Type of breed owned by the head of household (Dummy, Adapted = 1, Non-adapted = 0). Breed of sheep is expected to influence the management level equired to optimise production during climate change (Molotsi et al., 2020). Adapted breeds were expected to positively influence farmers perceptions of water scarcity while non-adapted breeds were anticipated to have a negative influence of farmers water scarcity perceptions.

$$x_1, \frac{1}{N}\sum_{i=1}^{N}\frac{\beta.p_{i.}(1-p_i)}{100}$$

Marginal effects measure the projected change in the probability of a particular choice being made with respect to a unit change of the independent variable from the mean (Greene, 2020). In this egard, the marginal effect in the current study was interpreted as the change in the probability that the household head will perceive impact of water scarcity on sheep production for a unit change in the independent variables.

3. Results

3.1. Farmers' demographic attributes and sheep production data

Ecozone and farm typology significantly influenced most variables in the current study. These two variables were, however, confounded since all the smallholder farmers in the semiarid ecozone were on subsistence-oriented communal farms, while those in the arid ecozone were on commercially-oriented private farms. These two variables were, therefore, matched (Pourhoseingholi et al., 2012). There were more male participants (86%) on commercially-oriented private farms in the arid ecozone than those on subsistence-oriented communal farms in the semiarid ecozone (59%). More than half of the respondents were aged between 50 and 70 years, and either had primary o no formal education and derived their income from livestock sales (67%), government social g ants (35%) and pension (33%) regardless of ecozone and farm typology. Overall, farmers on commercially-oriented private farms in the arid ecozone had larger ($P \leq 0.05$) land sizes than those on subsistence-oriented communal farms in the semiarid ecozone (1678 ± 178.8 vs 205 ± 128.9 ha).

Farmers on commercially-oriented private farms in the arid ecozone had g eater ($P \leq 0.05$) sheep numbers than those on subsistence-oriented communal farms in the semiarid ecozone (Table 3). Dorper (67% of the respondents) followed by Meatmaster (15%) were the most common breeds on commercially-oriented private farms in the arid ecozone (67% of the respondents), while the Merinos (i.e., Merino, Dohne Merino and South African Mutton Merino, 40%) followed by non-descript crossbreds (27%) were dominant on communal subsistence-oriented farms in semiarid ecozone. Water and feed intakes, lambing percentage and interval, milk yield and meat prices were similar ($P > 0.05$) across ecozones and farm typologies (Table 3). Sheep mature body weight, number of lambs weaned and age at first lambing were greater ($P \leq 0.05$) on subsistence-oriented communal farms in the semiarid ecozone while number of lambs born alive, sheep mortality and sales were lower ($P \leq 0.05$) than those on commercially-oriented private farms in the arid ecozone (Table 3). Majority of commercially-oriented private farms in the arid ecozone used boreholes (47% of the e-spondents) as the major sources of water for their sheep whereas subsistence-oriented communal farms in the semiarid ecozone (53%) used streams, rivers, and dams.

3.2. Perceived impacts f water scarcity on sheep production

There were more farmers ($P \leq 0.05$) on subsistence-oriented communal farms in the semiarid ecozone (85% of the espondents) who experienced water scarcity than those on commercially-oriented private farms in the arid ecozone (64%). Low ainfall was mentioned as the major reason causing water scarcity on commercially-oriented private farms in the arid ecozone (44% of the re-spondents) and subsistence-oriented communal farms in the semiarid ecozone (75%). A unit change from subsistence-oriented

Table 3
Sheep flock structure and production parameters (least square mean ± standard error) in the smallholder dryland areas of South Africa.

Dependant variables	Farm typology and ecozone		Farm typology and ecozone P-value
	Private commercially-oriented arid farms	Communal subsistence-oriented semiarid farms	
Flock size	$85.6^{a} \pm 12.5$	$56.1^{b} \pm 10.1$	0.048
Water intake per animal per day (L)	5.68 ± 0.60	5.73 ± 0.52	0.9482
Feed intake per animal per day (kg)	4.55 ± 0.88	5.77 ± 0.72	0.2804
Mature sheep weight (kg)	$52.0^{b} \pm 2.24$	$59.2^{a} \pm 1.97$	0.0161
Number of lambs born alive per ewe per annum	$1.41^{a} \pm 0.05$	$1.13^{b} \pm 0.04$	<0.0001
Lambing percentage	88.4 ± 2.31	87.2 ± 1.90	0.6972
Number of lambs weaned per ewe per annum	$53.5^{b} \pm 2.82$	$65.0^{a} \pm 2.27$	<0.0001
Lambing interval (months)	10.2 ± 0.35	10.2 ± 0.29	0.9725
Age at first lambing (years)	$16.2^{b} \pm 0.76$	$21.6^{a} \pm 0.61$	<0.0001
Milk yield per ewe per day (L)	1.35 ± 0.17	0.96 ± 0.17	0.1269
Number of sheep deaths (mortality) per annum	$6.24^{a} \pm 0.80$	$3.91^{b} \pm 0.61$	0.0220
Number of sheep sold per annum	$18.1^{a} \pm 2.77$	$9.39^{b} \pm 2.18$	0.0144
Sheep meat price (Rands per kg)	147.4 ± 55.1	148.1 ± 44.27	0.9340

[a-b]Least square means with different superscripts in the same row are significantly different ($P \leq 0.05$).

communal farms in the semiarid ecozone to commercially-oriented private farms in the arid ecozone increased the likelihood of farmers' water scarcity impact perceptions for cleanliness and safety of drinking water for sheep, mortality, disease and parasite prevalence and sheep prices by percentage points anging from 0.5 to 0.9 (Table 4). The marginal effect of farmers' perceptions of the impact of water scarcity on the number of lambs weaned was likely to decrease ($P \leq 0.05$) by 0.4% for every one percent change f om communal subsistence-oriented farming in the semiarid ecozone to private commercially-oriented farming in the arid ecozone. Fa m typology and ecozone did not influence ($P > 0.05$) farmers' perceived impact of water scarcity on water sources, distance to water sources, age at first lambing, number of lambs born alive, lambing percentage, number of lambs weaned, lambing interval, milk yield, mature sheep weight, carcass fatness, sheep prices and sales.

One percent rise in male participants increased ($P \leq 0.05$) farmers' chances to perceive impact of water scarcity on water safety, number of lambs weaned and milk yield by 0.1, 0.9 and 0.8 percentage points, respectively (Table 4). The likelihood of farmers to perceive the impact of water scarcity on water cleanliness, milk yield and sheep prices correspondingly increased ($P \leq 0.05$) by percentage points of 0.3, 0.6 and 0.9 with a unit enhancement in education level (Table 4). For every one percent growth in income from livestock, the probability of farmers' perceptions of impact of water scarcity on cleanliness and safety of drinking water for sheep increased ($P \leq 0.05$) by 0.4 and 1% in that order (Table 4). A unit increase in flock size was likely to increase ($P \leq 0.05$) farmers' perceptions of the impact of water scarcity on milk yield by 0.4 percentage points (Table 4). The possibility of farmers to perceive the impact of water scarcity on distance to water sources and lambing percentage, espectively, increased ($P \leq 0.05$) by 0.8 and 0.6% with one percent increase in non-adapted breeds (Table 4). Age did not influence ($P > 0.05$) farmers' perception of the impact of water scarcity on all the dependant variables included in the logit model.

3.3. Farmers' responses to impacts f water scarcity on sheep production

Most farmers, irrespective of ecozone and farm typology switched between water sources, used off-farm water sources, harvested rainwater into storage tanks and drilled boreholes or wells to increase drinking water availability for their sheep (Fig. 1). There were more farmers on commercially-oriented private farms in the arid ecozone who used clean water sources, covered, and shaded wate points to cope with the challenge of declining water quality than those on subsistence-oriented communal farms in the semiarid ecozone ($P \leq 0.05$; Fig. 1). Majority of farmers on commercially-oriented private farms in the arid ecozone provided supplementary feed, water and shade and used adapted breeds to cope with the negative effects of water scarcity on sheep production than those on subsistence-oriented communal farms in the semiarid ecozone ($P \leq 0.05$; Fig. 1). To cope with negative impacts of water scarcity on sheep marketing, most farmers on commercially-oriented private farms in the arid ecozone explored alternative marketing channels and provided supplementary feeds whilst those on subsistence-oriented communal farms in the semiarid ecozone withheld sales, reduced prices for live sheep and meat, and waited for the festive season ($P \leq 0.05$; Fig. 1).

4. Discussion

The observation that a unit change from communal subsistence-oriented semiarid farms to private commercially-oriented arid farms increased the likelihood of farmers' water scarcity impact perceptions for water quality, sheep production and marketing attributes could be related to the differences in farmers' resources ownership, type of breeds kept, farm management practices and climatic conditions. By virtue of their private land tenure, large land size and more financial resources, commercially-oriented private farms are less vulnerable to water scarcity than subsistence-oriented communal farms with small farmland and limited financial

Table 4
Marginal effects on the determinants of farmers' perceptions of the impact of water scarcity on sheep production in the smallholder dryland areas of South Africa.

Independent variables	Dependant variables	Margin	Standard error	z	P>|z|	[95% Conf. Interval]	
Farm typology and ecozone	Water cleanliness	0.004637	0.000796	5.82	0.001	0.003076	0.006192
	Water safety	0.005633	0.001688	3.34	0.001	0.002325	0.008944
	Number of lambs weaned	−0.004214	0.000417	10.1	0.001	0.005031	0.007338
	Mortality	0.004637	0.079651	5.82	0.001	0.030759	0.061824
	Disease prevalence	0.006226	0.001726	3.61	0.001	0.006119	0.009282
	Parasite prevalence	0.008808	0.010313	2.85	0.393	0.290218	0.314050
	Sheep prices	0.005655	0.017413	3.25	0.001	0.022429	0.090683
Gender	Water safety	0.001457	0.000476	3.06	0.002	0.003689	0.004243
	Number of lambs weaned	0.008515	0.009561	2.55	0.003	0.005412	0.006158
	Milk yield	0.007720	0.005549	3.19	0.001	0.002351	0.004132
Education level	Water cleanliness	0.002543	0.000462	3.37	0.007	0.007158	0.009561
	Milk yield	0.005518	0.001723	3.19	0.001	0.012284	0.036762
	Sheep prices	0.009287	0.004812	4.60	0.006	0.000461	0.006226
Source of income	Water cleanliness	0.004118	0.002438	1.69	0.006	0.012856	0.023250
	Water safety	0.009568	0.001270	2.25	0.003	0.001244	0.00306
Flock size	Milk yield	0.004357	0.003476	3.06	0.002	0.003268	0.00512
Breed	Distance to water source	0.008446	0.002578	3.11	0.001	0.001803	0.00359
	Lambing percentage	0.005841	0.002133	1.98	0.027	0.002841	0.00400

*$P \leq 0.05$.

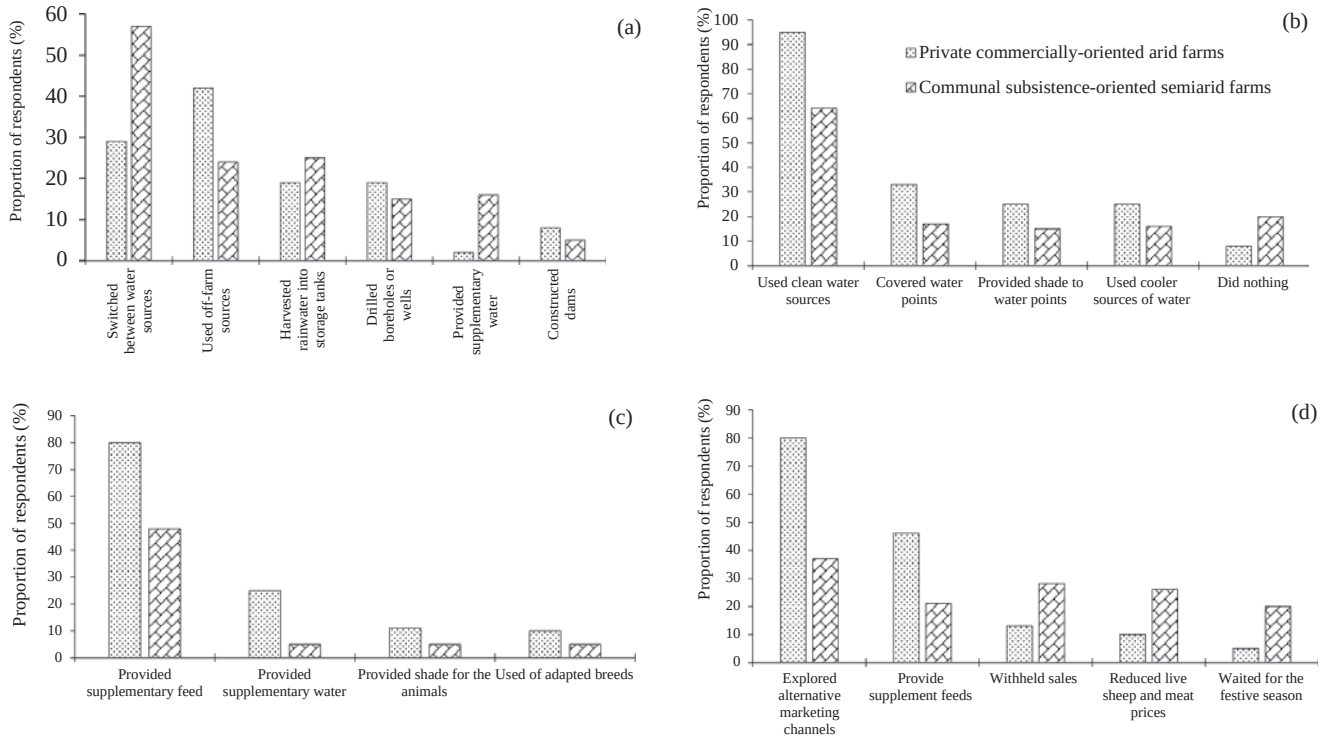

Fig. 1. Response strategies used by sheep farmers to cope with decreases in (a) water availability, (b) water quality, (c) sheep production and (d) marketing in the smallholder dryland areas South Africa.

resources (Aguilar et al., 2021; Gandure et al., 2013; Mapiliyao et al., 2012; piyo et al., 2015). Previous findings eported that farmers with larger land sizes have greater capacity to diversify and invest in climate change and water esource management infrastructure and technologies than those with small land sizes (Abdul-Razak and Kruse, 2017; Ali and Erenstein, 2017; Defiesta and Rapera, 2014). As eported in the current study and previous studies (Mdletshe et al., 2018; Mthi and Nyangiwe, 2018; Nguyen et al., 2016), commercially-oriented farmers on private land rely on underground water for their sheep whereas subsistence-oriented farmers on communal land ely on surface water sources. Surface water sources usually dry up in the dry season due low precipitation and high evaporation rates, and are insufficiently protected compared to ground water (Sasakova et al., 2018). Hence, they are less reliable and more prone to contamination by physical debris, dissolved materials and pathogens making the water dirty and unsafe to d ink (Sharma and Bhattacharya, 2017).

Adapted breeds such as Dorper and Meatmaster that were dominant on commercially-oriented private farms in the arid ecozone have long, slim legs, which allow them to walk long distance (Milne, 2000; Mohapatra and Shinde, 2018; Molotsi et al., 2020), and produce more lambs than non-adapted breeds (Molotsi et al., 2017; Schoeman, 2000), espectively. Contrary, majority of subsistence-oriented communal farmers in the semiarid arid ecozone owned exotic breeds and non-descript crossbreds, which are less adapted to their socio-economic and environmental conditions. This concurs with the current esults indicating that farmers who farmed with non-adapted breeds had high probability of perceiving increases in distances to water sources and decreases in lambing percentages over the past five years. Furthermore, subsistence-oriented communal farming is associated with uncontrolled mating which often result in inbreeding depression (Gizaw et al., 2014), and failure to synchronise lambing with growing season when vegetation is sufficient to meet nutritional requirements for the lactating ewes and their lambs (Ercanbrack and Knight, 1991; van Wyk et al., 2009).

The finding that change in ecozone and farm typology jointly influenced smallholder farmers' perceived impact of water scarcity on sheep drinking water quality and marketing could also be attributed to poor management practices that was reported in communal subsistence-oriented semiarid farms (Mapiliyao et al., 2012). These practices include uncontrolled communal rangeland grazing and mating, poor management of water resources, animal health and marketing, which all negatively affect sheep productive performance (Ben Salem, 2010; Gowane et al., 2017; Mdletshe et al., 2018).

The reported influence of ecozone and farm typology on farmers' perceptions of the impact of water scarcity on prices of live sheep may be attributed to differences in costs of production (e.g., water, feed, and drugs) and marketing. Commercially-oriented fa mers often market their sheep formally through auctions and abattoirs and incur more transaction costs (e.g., transportation, communication, and legal costs) than subsistence-oriented farmers who market their animals informally to local consumers and middlemen (Khapayi and Celliers, 2016; Mapiliyao et al., 2012; Morakile et al., 2021).

The reasons for observed change in ecozone and farm typology with increased perceptions of the impact of water scarcity on sheep mortalities, disease and parasite prevalence might be linked to differences in climatic conditions and farmer resource possessions. Warm and moist conditions prevalent in the semiarid ecozones are favourable for proliferation of disease pathogens and parasite vectors (Marufu et al., 2011; Meissner et al., 2013; Rust and Rust, 2013). Furthermore, the non-adapted breeds (i.e., exotic and non-

descript crossbreds) kept by subsistence-oriented communal farmers tend to carry heavy parasite loads, which often results in high mortality due to lack of financial resources to pay for medicines, vaccines, extension and veterinary services bills (Mapiliyao et al., 2012; Mpofu et al., 2020). In addition, continuous grazing commonly practised in the communal areas consistently expose animals to a combination of pathogenic, thermal, nutritional and water stresses (Kumar et al., 2013; Rapiya et al., 2019).

The positive association between gender and farmer perceptions of the impact of water scarcity on sheep drinking water safety, number of lambs weaned, and milk yield was expected. Relative to female-headed households, male-headed ones have more access to information, esources, technologies, and socioeconomic opportunities (Abdul-Razak and Kruse, 2017; Ali and Erenstein, 2017; Asrat and Simane, 2018; Singh et al., 2018) that may positively influence water quality, weaning rates and milk yield.

The finding that a unit increase in education level of the household head increased farmers' perceived impact of water scarcity on water cleanliness, milk yield and sheep prices was anticipated. Education has been eported to increase farmers' perceptions egarding climate change due to its contribution to increased production and marketing efficiency and adoption of appropriate technologies (Asrat and Simane, 2018; Deressa et al., 2009; Fierros-González and López-Feldman, 2021). The observation that farmers' perceptions of the impact of water scarcity on drinking water quality for sheep was positively affected by the source of income of the household head could be related to the livestock farmers' ability to prioritise investment in water resource management technologies and infrastructure to secure their livestock-based livelihoods (Abafita and Kim, 2014; Asrat and Simane, 2018). The result that a unit increase in flock size increased the probability of farmers to perceive impact of water scarcity on milk yield was attributed the strong correlation between these two variables. Large flocks produce more milk for lambs, human consumption, and sales, which could reduce farmers vulnerability to water scarcity (Gemechu et al., 2016; Sani and Kemaw, 2019).

Farmers provided a menu of response strategies including management of water, feed, and animal esources to mitigate adverse effects of water scarcity on sheep production. That information could form the basis for formulating effective water scarcity policies for smallholder sheep farmers in the surveyed areas. Such policies should focus on enhancing the resilience and adaptive capacity of smallholder sheep farmers through provision of capital to purchase production inputs, improve information and communication technologies, develop water infrastructure and technologies, and establish water resource management training institutions as mentioned by the farmers in the current study.

5. Conclusions

Findings indicate that the likelihood of farmers to perceive the impact of water scarcity on sheep production increased with a percent increase in private commercially-oriented arid farms males, education level, adapted breeds and flock size. Households responded to water scarcity through adopting a diverse array of esponse strategies including switching between water sources, provision of supplementary water, feed, and shade, use of adapted breeds and alternative markets irrespective of ecozone and farm types. It was concluded that current findings identified contextual factors determining farmers' perceptions of impacts of water scarcity on sheep production, which should be considered when formulating resilience and adaptive capacity enhancing technologies and policies for smallholder farmers in dry ecozones. These results highlight the importance of integrating farmers' perceptions of impact of water scarcity on livestock production into agricultural water resource management policies. In addition, they inform mainstreaming of climate esilience into policy by further providing evidence that ecological and socioeconomic variables interact to shape farmers' perception of impact of water scarcity and vulnerability.

CRediT authorship contribution statement

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Authors' contributions

TH: Writing - Original draft preparation. AM and KD: Supervision and editing. OCC, TM and BJA: Editing. CM: Conceptualisation, Supervision, Editing and Funding acquisition.

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