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ESTIMATING AGRICULTURAL DROUGHT RESILIENCE OF SMALLHOLDER LIVESTOCK FARMERS IN SOUTH AFRICA

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DECLARATION

We declare that this work is an original academic research carried out by the authors.

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Abstract

Recurring drought is a major challenge to smaller holder livestock farmers. This study estimates agricultural drought resilience of smallholder livestock farms in the Northern Cape province of South Africa. This study utilized primary data collected from 207 smallholder livestock farmers and an agricultural drought resilience index (ADRI). The results revealed that only 9% of the smallholder livestock farms were resilient for agricultural drought, the rest of the farms were not resilient. It also found that the drought resilience indicator variables were positively correlated with production of livestock in dry and normal calendar years. The policy implications of these findings involve the government and key role players in the industry who should target needy smallholder farmers to build their resilience by enhancing their persistent, adaptability and transformation. Some of the assistance could mean supplying fodder, finance and other farm inputs.

Keywords: *Resilience; agricultural drought; smallholder livestock farmers; agricultural drought resilience index*

1. Introduction

Africa is vulnerable to climate change. There are prolonged and intensified droughts in Africa, and these changed, uncertain weather conditions and patterns largely challenge the welfare, yields and survival of livestock, food security, and health - related to stress, water and energy security (Orac, 2009; IPCC, 2014; Niang *et al.,* 2014). Approximately, 80% of the African population is vulnerable to drought and consequently more affected by its impact. In the African continent, 291 drought-related occasions were reported during 1990-2013, it is affecting more than 300 million people (Masih *et al*., 2014). Among the most affected from drought are smallholder-farming households (Mmatsatsi, 2007). Smallholder farmers[1] are faced with constraints such as lack of access to credit; landlessness and the cost of transport. (von Loeper *et al*., 2016). In addition to these constraints, the heavy reliance on rainfall exposes them to droughts and floods common in the region because of climatic variability.

In South Africa, production of livestock has great potential to alleviate household food insecurity and poverty (Mapiliyao *et al.*, 2012). The livestock industry contributes approximately 48% of South Africa's agricultural output and employs approximately 500,000 people nationwide (DAFF, 2016a). Land suitable for mainly extensive livestock farming in South Africa is approximately 80%, but livestock also found in areas where the animals are kept in combination with other farming enterprises (DAFF, 2018). Livestock is by far the largest sub-sector in South African agriculture; it occupies 53% of agricultural land and its contribution to agricultural production accounted for 25% to 30% (Blignaut *et al*., 2014).

Drought has also affected all the provinces of South Africa including the study area, the Northern Province of South Africa. Recently the province declared a disaster zone due to a severe drought fac~~i~~ng country since 1982. This drought causes the province a reduction of livestock production by more than 30% and some farmers lost their entire herds because of the worst drought in a century (Coleman, 2017). Livestock Farmers that are resilient are able to respond, absorb and recover from drought effects. Jones and Thornton (2009) highlighted that building resilience is essential to reducing agricultural production vulnerability to the variability of the climate.

Various existing international and national studies, such as Vetter (2009); Sallu *et al*. (2010); Banda *et al.* (2016) and Mdungela *et al*. (2017) focused on relevance and its application of resilience; ecosystem understanding, and adaptation to droughts; identifying factors that affect the resilience of smallholder crop farmers; assessing livelihood dynamics and factors that influence farmers' choices of coping strategies. To the

[1] Smallholder farmers are defined as those farmers owning small-based plots of land on which they grow subsistence crops or livestock, ~~is~~ relying almost exclusively on family labour and at subsistence level (DAFF, 2012).

knowledge of this researcher, no study has been done on the estimation of agricultural drought[2] resilience[3] of smallholder livestock farmers' in South Africa in general and Northern Cape Province in particular. This study was motivated by the aspiration to better understand the impact of agricultural drought on smallholder farmers in South Africa, specifically in Northern Cape Province of South Africa. The lowest total annual rainfall yet recorded was in 2015, which was declared the driest year in South African history since 1904. This study will contribute to the existing gap in knowledge and literature by estimating agricultural drought resilience index (ADRI). The finding of this study will be an input for policymakers and stakeholders to formulate the appropriate strategies to build the resilience of smallholder livestock farmers by enhancing their capacity to continuously change and adapt; build their capacity to continue to develop and change and live with changes, and enhance their transformability.

2. Methodology

2.1. Sampling procedure and data description

A multiple-stage sampling technique was employed. First, Northern Cape Province was chosen from the nine provinces of South Africa because it represented the main livestock-producing province. According to Statistics South Africa (Stats SA, 2016), approximately 75% of agricultural households in 2016 were involved in livestock production in the Northern Cape. The Northern Cape Province ~~of~~ was also chosen because it had been declared a disaster zone by the South African government in 2017/2018 calendar year. In the second stage four-district municipalities from the Province of Northern Cape (Dikgatlong; Magareng; Sol Plaatjie and Phokwane), were chosen randomly. Smallholder livestock farmers were selected from Northern Cape Department of Agriculture, Forestry and Fisheries (2018), who received the assistance from the government because of severe drought in the calendar year 2015 to 2016. The simple random sampling formula for a finite population was applied.

To calculate appropriate sample sizes for a survey, for continuous and categorical data formulae were developed by Cochran (1997). The questionnaire that was used, collected both continuous and categorical data; thus, to ensure that the sample size is

[2] **Agricultural drought** is a shortage of water (precipitation) during the growing, which is abrupt on production (IPCC, 2012).

[3] **Resilience** is the ability to persist, adopt, transform (in this study agricultural drought) and the capacity to live with change either incremental or abrupt and continue to develop (Folk *et al*, 2010).

appropriate, the calculation for categorical data will be used to calculate the sample size (Bartlett *et al.*, 2001). The detail of the equation illustrated in appendix.

Based on the formula (refer appendix) 207 smallholder livestock farmers were selected from Northern Cape Province of South Africa for a face-to-face interview from July- September 2018 using a structured questionnaire.

2.2. Data analysis and method

The collected data were analysed using Principal Components Analysis (PCA) to aggregate four production and consumption related indicators into the agricultural drought resilience index (ADRI). PCA is a method applied to reduce a large set of variables to smaller variables by taking into consideration the variance of original data or variables (Holland, 2008; Beaumont, 2012). The analysis was done using the Statistical Package for the Social Sciences (SPSS) software.

In this study, four variables were utilized in the PCA. The proposed variables are livestock production by smallholder farmers in a normal year without agricultural drought (LVPNYWOAD), livestock produced with agricultural drought (a bad year) (LVPWAD), the number of months a household consumes food produced by the household in a normal year (without agricultural drought) (NMHCFNWOAD), and the number of months a household consumes food produced by the household in a bad year (with agricultural drought) (NMHCFWAD).

The four indicators ((LVPNYWOAD, LVPWAD, NMHCFNWOAD, and NMHCFWAD) will aggregate into an agricultural drought resilience index (ADRI) using the formula:

$$ADRI = W_n P_n + W_d P_d + W_{cn} M_n + W_{cd} M_d \quad (1)$$

Where: ADRI denoted agricultural drought resilience index.

W represents weights derived from the component loadings from the first principal components. The data from which the components will be derived to have a zero mean and unit variance

WnPn denotes the weight for livestock production in a normal year (without agricultural drought) multiplied by the actual amount of livestock production produced in good year (without agricultural drought);

WdPd represents the weight of livestock production in a drought year (with agricultural drought) multiplied by the actual amount of livestock production produced a drought year (with agricultural drought);

$W_{cn}M''$ denoted the weight for the number of months a household remains with household-produced food multiplied by the number of months the household consumes household-produced food in a normal year (without agricultural drought)

$W_{cd}M_d$ represents the weight for the number of months a household remains with household-produced food during a drought year multiplied by the actual number of months a household remains with household-produced food in a drought year.

All variables are expected to correlate positively with drought resilience. This is because an increase in any one of the variables was expected to be associated with an improvement in the well-being of the farming household.

3. Results and discussion

3.1 Estimation of the Agricultural Drought Resilience Index (ADRI)

Table 1 presents the correlation matrix of variables used in the construction of ADRI. The highest correlation exists (0.585; 0.884) between Production of livestock in a drought year and Production of livestock in a Normal year and Months household consume food in a drought year and Months household consume food in a normal year respectively. This result was expected due to variables that highly correlated measure the same construct. The first two variables (PLNY and PLDY) are an indicator of production and the rest two variables (MHCNY and MHCDY) indicators of consumption.

Table 1 Correlation matrix for variables utilized in construction ADRI

	PLNY	PLDY	MHCNY	MHCDY
Production of livestock in Normal year (PLNY)	1			
Production of livestock in Drought year (PLDY)	0.585	1		
Months household consume food in normal year (MHCNY)	0.067	0.126	1	
Months household consume food in drought year (MHCDY)	0.084	0.012	0.884	1

The Bartlett's test of sphericity was conducted on data in order to assess whether they are suitable or not for using a PCA. The main aim of the test was to test the hypothesis that the variables used in PCA were not inter-correlated. As the result indicated in Table

2, the null hypothesis is, the inter-correlation matrix is an identity matrix and the reduction of variables rejected because the inter-correlation matrix did not drive from a population. We conclude that variables are ~~suitability~~ suitably correlated to warrant the application of PCA because of the inter-correlation and that the correlation did not result from a sampling error.

Table 2 Results of the Bartlett's test of sphercity

Bartlett test of sphericity	
Chi-square	644.86
Degree of freedom	21
P-value	0.0000
Kaiser -Meyer-Olkin measure of sampling adequacy (Determinant of the correlation matrix)	0.549

Another measure used to decide either PCA applicable or not was Kaiser -Meyer-Olkin (KMO) measure of sampling adequacy. The KMO value is 0.549 fall above the threshold value of 0.5, therefore allowing a PCA to apply on the data. The high value of KMO implies that the degree of common variable among the variables is very large, this means if PCA applied, the components will account for a fair amount of variance. Therefore, the data met the minimum requirement of KMO and Bartlett's test of sphericity, as a result, the data were considered suitable for dimension reduction using PCA.

Table 3 shows the result of un-rotated PCA. As indicated in Table 3 each of the variable standardized to have a mean zero and a variance of one. For the three variables used, the total variance that must be explained is 5.00. Since a variable can only account for one unit of the variance, a useful variable must account for more than one unit of variance or must have an eigenvalue of greater than one. The first principal component explains 33% of the total variance, while the second 24%, the third 21% of the total variance, which is considered fair enough to use further analysis.

Table 3 Results of un-rotated PCA (N=207; Component 3)

Component	Eigen value	Proportion	Cumulative
1	2.304	0.329	0.269
2	1.672	0.239	0.523
3	1.433	0.205	0.667

The components were compared to *a priori* expectations to choose the variable in constructing ADRI. In order to select the variable to utilize, it is essential to obtain eigenvectors. The value for the intersection of each variable and component presented in

Table 4 represents eigenvector or component loadings. The components meet the prior expectations of the sign and then may be used in construction of the ADRI.

Table 4 Eigen vector from PCA

	Component 1	Component 2	Component 3
Production of livestock in Normal year	0.722	0.56	0.223
Production of livestock in Drought year	0.097	-0.599	0.591
Months household consume food in normal year	0.009	-0.051	-0.691
Months household consume food in drought year	0.019	0.028	0.009

Using formula 1and results from table 4; the ADRI was generated using:

ADRI= 0.722*Production of livestock in Normal year + 0.097*Production of livestock in Drought year +0.009*Months household consume food in normal year + 0.019*Months household consume food in drought year (2)

The formulae shown in equations 1 and 2 applied to the data (207 Survey sample household respondents) to generate ADRI. Table 5 illustrates the summary statistics for ADRI for Northern Cape Province.

Table 5 Summary statistics for ADRI for Northern Cape Province and District municipalities

	N	Mean	Stand. Dev.	Min	Max
ADRI	207	-6.31	6.90	-2.43	6.69
ADRI > 0	18	0.51	1.87	0.14	6.69
ADRI < 0	189	-7.00	6.88	-2.43	-0.008

As indicated in table 5, an average household resilience index in the Northern Cape Province was -6.31; this result implies that the average household in the Northern Cape Province is not resilient for agricultural drought. Furthermore, the result confirms that only 18 smallholder livestock farmers, accounting for 8.7% were resilient–for agricultural drought, the rest of 82.7% (189 smallholder livestock farmers), were not resilient for agricultural drought. This implies that the farmers need assistance from the government in regards to finance fodder and farm inputs during the dry spell and through the farmer's organization and cooperation's famers should learn each others, specifically from resilience farmers how they resist agricultural drought using different strategies.

4. Conclusions and recommendations

Based on these findings, it is observed that only 18 smallholder livestock farmers, accounting for 8.7% of the sample, were resilient for agricultural drought, the rest of 82.7%, accounting for 189 smallholder livestock farmers were not resilient for agricultural drought survival. It was also found that the drought resilience indicator variables revealed positively correlation with production of livestock in dry and normal calendar years; this implies 8.7% of the households that were resilient are more likely to have more production than non-resilient farmers. The policy implications of these findings lies in the government and key role players in the industry should target needy smallholder farmers by supplying fodder, finance and farm inputs to enhance their resilience towards agricultural drought. Moreover, through the farmer's organization and cooperation's famers should learn each other's, specifically from resilience farmers how they resist agricultural drought using different strategies.

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Appendix

To calculate the sample size the following equation utilized:

Total sample size calculated using:

$$M_{"} = \frac{\%^{\&}*()}{*\&} \qquad (3)$$

Where: M_0 = sample size

u = is the level of risk the researcher is willing to take (margin of error may exceed the acceptable margin of error)- for the selected alpha level

(f)(i) = estimate of variance = 0.25 (maximum possible proportion (0.5)*1-maximum possible proportion (.5) produces maximum possible sample size)

e = acceptable margin of error for proportion being estimated = .05

Alpha level (u) of 1.65-estimated variance of 0.5 and an error level of .05 were used; the formula would look as follow:

$$M_{"} = \frac{(,..⁄)^{\&}*(1.⁄)(1.⁄)}{(1.1⁄)^{\&}} = 272 \qquad (4)$$

Resulting in a sample size of 272 respondents (indicating that the sample size exceeds 5% of the population), hence, the correctional formula (Equation 3) of Cochran (1977) applied to calculate the final sample size:

$$M_{,} = \frac{5_6}{,7\frac{8_6 \quad 9:9;<=}{>?:@}} \qquad (5)$$

$$M_{,} = \frac{ABA}{,7\frac{\&C\&}{DED}} = 207$$

Where M_o sample size, M_1 is final sample size

Table 6 Number of farmers who reived assistance from government and sampling procedure

Local Municipality	Number of farmers	Share of farmers (Number of farmers/Total)	Number of sample (percentage *total sample size (207))
Dikgatlong	347	40%	83
Magareng	119	14%	29
Sol Plaatjie	263	30%	62
Phokwane	139	16%	33
Total	868		207

Source: Northern Cape Department of Agriculture, Forestry and Fisheries (2018) and Author's calculation