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A Stochastic Frontier Analysis of the Performance of Livestock in the North-Eastern Cape Communal Rangelands, South Africa

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ABSTRACT

This paper examined the technical efficiency of livestock in Eastern Cape Province, South Africa, to improve the understanding of the performance of livestock production of rural households in the communal rangelands. Surveys from 120 households were used to estimate a stochastic frontier model to assess livestock production's technical efficiency (TE) amongst households in a communal production environment where rangelands are the primary source of fodder. The estimated coefficients of the stochastic frontier model indicated that livestock units (LSU) and costs of additional feed supplements positively influenced livestock output per household. Management practices such as livestock kraaling and livestock herding influenced TE positively. An average technical efficiency score of 0.79 was estimated among households, suggesting that an improvement in efficiency could be achieved if proper interventions were employed. These interventions may include programmes such as the Extended Public Work Programmes to provide livestock herding support, gender-sensitive strategies that support the inclusion of women in livestock production, and other labour inputs related to animal husbandry. Lastly, this study provided essential information in understanding livestock production and informed policy about possible interventions that could potentially improve livestock production in rangelands.

Keywords: Communal Rangelands, Livestock Production, Technical Efficiency

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1. INTRODUCTION

In South Africa, livestock such as sheep, goats and cattle are among the largest agricultural sub-sectors, estimated to contribute between 25% and 30% of the total annual agricultural outputs (Blignaut *et al.,* 2014). The livestock industry employs approximately 500,000 people nationally (DAFF, 2014) while contributing to most communal farmers' livelihoods and household food security (Meissner *et al.,* 2013). Approximately 82.3% of the land in South Africa is used for agriculture, with 68.6% for extensive livestock grazing (DAFF, 2014). Livestock farming in South Africa is a tradition within rural systems, and most of the country's natural resources are suitable for livestock production (Meissner *et al.,* 2013). This is particularly significant, considering that a third of the national livestock herd is owned by communal farmers (Gwiriri *et al.,* 2019). Livestock production further plays a significant socio-cultural and economic role in people's livelihoods in communal areas. The roles include livestock as a source of income, food, employment, manure for crop production and draft power (Smith *et al.,* 2013). On the other hand, livestock ownership confers status and prestige within the community and livestock are used to pay a bride price and provide animals for ritual slaughter (Sikhweni & Hassan, 2014).

In the communal areas of South Africa, people invest heavily in livestock production, which accounts for 80 to 90% of asset value (Meissner *et al.,* 2013). Both rural and urban-dwelling people continue to have considerably high livestock numbers in these communal areas, which is perhaps mainly related to difficulties in accessing other saving methods such as banks, thus leading to thousands of rural people using livestock to accumulate and store wealth (Taruvinga *et al.,* 2022). However, the apparent excessive number of livestock in these communal areas has deleteriously affected communal grazing resources through overstocking and overgrazing, which led to mandatory destocking (Vetter, 2013). This destocking was believed to have positively affected the quality of livestock in the communal sector and on reproduction rates, production, and market value (Vetter, 2013). However, there is debatable information on any direct evidence that this improved livestock quality and production.

Despite the relative importance of livestock production in communal areas of South Africa, communal livestock production is characterised by numerous marketing and production constraints, including a lack of financial services, limited access to additional land and water, poor access to the market, risks associated with animal health, theft and drought (Musemwa *et* *al.*, 2007) as well as high transaction costs associated with livestock marketing, which hinder household technical efficiency (Sikhweni & Hassan, 2014). There is also consistently lower productivity in communal livestock production than in commercial livestock production (Temoso *et al.,* 2016), which prevents communal farmers from participating in formal markets where higher livestock income can be generated (Musemwa *et al.*, 2007). While improving access to formal livestock marketing can assist communal farmers in earning more income, other factors limiting the ability of these communal farmers to improve their efficiency still need to be understood.

Against this backdrop, there is a lack of studies on the technical efficiency of livestock production in communal areas of the Eastern Cape, South Africa, where all beneficial livestock (sheep, goats, cattle) products are assessed for an individual household by accounting for input variation. For example, studies such as Fathelrahman *et al.* (2014) and Furesi *et al.* (2013) provide scope on the international technical efficiency attained in sheep production, while Nyam *et al.* (2020) offer the technical efficiency (TE) of sheep production in South Africa. Other international studies investigated TE of crops, dairy and mixed crop-livestock farms (Mlote *et al.*, 2013; Otieno *et al.*, 2012; Kumbhakar *et al.*, 2014) and sheep and wool sectors (Villano *et al.,* 2019). As a result, current knowledge of livestock production is insufficient to understand how communal farmers in South Africa could improve their technical efficiency and productivity based on an evidence-based analysis. This is because different livestock production strategies exist in communal areas and households resulting in different production responses unique to the production households (Nyam *et al.,* 2020). Understanding these unique responses could help develop improved strategies to increase livestock production within the South African communal livestock sector.

Providing knowledge of TE is important to improve the potential of a communal livestock system, thus increasing economic growth and decreasing poverty in livestock-dependent rural households. Given the differences in livestock production among different households, the study mainly focuses on identifying households likely to benefit from interventions, enabling them to become more successful at livestock production and improve their food security (Battese *et al.,* 2004). Specifically, this paper aimed to provide an understanding of the TE application in rangeland management to improve livestock production in communal rangelands of the Eastern Cape, South Africa, and identify factors for possible improvements to the household capacity. For example, identifying households with high technical efficiency levels and adjusting their production inputs and strategies could help improve communal agricultural sector competitiveness (Villano *et al.,* 2010), which can also increase income generation from livestock.

2. METHODOLOGY

2.1. Study Site Description

The study was conducted near the town of Cala in the Eastern Cape Province, South Africa, on farms that had previously been under freehold tenure but were transferred to communal tenure during the 1970s as part of the homeland policy of the former Transkei Government. It is in quaternary river catchments T12A and S50E (Figure 1), is traditionally administered by local chiefs and headmen, and is in Sakhisizwe Local Municipality. The vegetation is described as *Drakensburg foothill moist grassland* incised by gorges with dry forest (Mucina & Rutherford, 2006). Dominant grasses are hardy perennial species such as *Sporobolus africanus, Heteropogon contortus, Eragrostis plana* and *Aristida congesta,* which form grass swards (Mucina *et al.,* 2006). The primary land use practices include livestock production and crop farming for subsistence household use. The main livestock that households keep are cattle, sheep and goats, while the main crops are maize, pumpkins, potatoes and cabbages. Also important to mention is that most households keep chickens and pigs, horses and donkeys, which are excluded in this study. The study site receives a long-term mean annual rainfall distribution of 654 mm (Schulze *et al.*, 2008). The mean potential evaporation and annual soil moisture stress is 1638 mm and 68%, respectively (Schulze *et al.*, 2008). The geology is mostly mudstone and sandstone of the Tarkastad Subgroup and the Molteno Formation, as well as Jurassic Age dolerites. Dominating soils are well-drained soils of > 800 mm depth, with sedimentary parent material of 15–55% clay content representing soils from Clovelly, Griffin and Oak Dale (Mucina& Rutherford, 2006).

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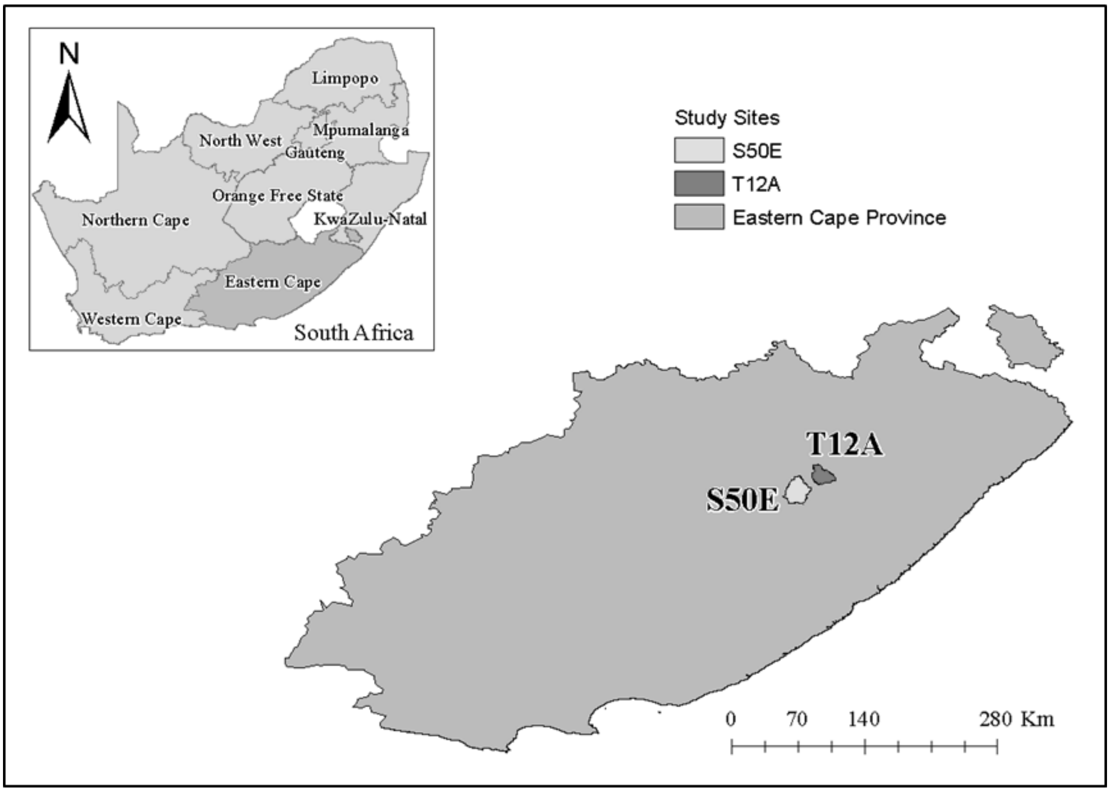

FIGURE 1: Location of the Study Sites in Quaternary River Catchment T12A and S50E

2.2. Sampling and Data Collection

This study collected data from participating households that were purposefully selected based on significantly clearing invasive alien plants (IAPs) to restore rangelands. There was evidence of removing these plants to restore the cleared areas to grasslands available for communal livestock grazing. Initially, summary information on each village (including but unlimited to the number of dwelling units, population size, gender of head of household (HoH), dwelling type, and household income) was downloaded from the 2011 South African National Census database (Stats SA, 2011) to help stratify sample distribution across wealth categories. From this assessment, dwelling type, which provides a range of categories strongly linked to household income, was selected as an appropriate household wealth index. These categories, when used together with the gender of HoH, would permit the extension of the results more widely.

One hundred and twenty (120) households were sampled across two villages based on their representation of several dwelling types, respondent availability and willingness to participate in the survey from November 2015 to January 2016 and May 2016 to August 2016. Ethics approval was acquired from Rhodes University’s Research Ethics Committee, and a consent form was provided before the interviews requesting the authorisation of the entire household. Only one respondent declined to participate in the survey, and a willing respondent was replaced. The HoH was interviewed, and the most senior person was interviewed in cases where the HoH was absent. With the help of a local research assistant, data were collected through a face-to-face interview during both data expedition periods. The questionnaires were administered in the local language, isiXhosa, and responses were translated into English. There was one enumerator for each household to conduct the interviews.

Data collected included information on livestock holdings' the cost of buying livestock feed, and livestock management activities such as kraaling and herding. Information on the livestock outputs such as milk, draft power, hides/wool or mohair, manure and offtake were also collected. All data were captured using Kobo-collect, an Android-enabled application.

2.3. Estimating Values of Livestock Outputs and Inputs

Livestock forms a vital component of agriculture worldwide, providing service outputs and cultural values (Haileslassie *et al.,* 2009). However, in this study, only offtake, milk, manure, skin/hides/wool, traction or draft power were considered livestock-beneficial outputs.

2.3.1. Outputs

Manure: Manure production was calculated using dry weight, daily dung production of 3.3 kg/day/TLU for large animals and 2.4 kg/day for small ruminants for the annual average livestock holdings (Descheemaeker *et al.,* 2010; Bekele *et al.,* 2017). The nutrient composition was estimated based on the nutrient content of 18.3 g N/kg, 4.5 g P/kg and 21.3 g K/kg on a dry weight basis (Bekele *et al.,* 2017). The monetary equivalence of manure to artificial fertiliser was extrapolated from the nutrient contents and price of Limestone Ammonium Nitrate (LAN) (28)

Milk production: Annual milk production was estimated as a function of the number of lactating cows, lactation period and milk production in litres/day/cow in a household herd per year (Haileslassie *et al.,* 2009). The figures used for the lactation period and daily milk production were part of the data collected in the study. The total milk produced per cow was converted into monetary values of South African Rand (ZAR) based on the value of milk at a farm gate price.

Offtake: The study summed the value of all annual livestock sales, gifted and slaughtered per household and converted these into local currency value (ZAR) to measure livestock production efficiency (Tada *et al.,* 2012). This is common in studies such as Kebebe *et al.* (2015). Offtake included sales from sheep, goats and cattle.

Fibre production: Fibre production was estimated based on the annual income derived from selling hides/wool in formal markets, as reported by households.

Traction power: Following Haileslassie *et al.* (2009), traction power was estimated based on the daily hiring cost of draft animals (e.g. oxen) and the number of working days per year spent on ploughing and threshing.

2.3.2. Livestock Inputs

Herding/labour was estimated based on the amount spent on livestock herding per annum. Different households had varying amounts of paying a herder based on the number of livestock and whether the herder lodged at their premises and provided food for them.

Additional feed: the cost of additional feed was estimated based on the amount (ZAR) spent on buying additional feed for livestock annually. As reported by households, additional feed was bought for lactating and sick animals during the winter season when grazing grass is mostly unavailable from the rangelands. The types of feed, as reported by the households, included lucerne and mineral licks.

2.4. Wealth Status Classification Criteria

In post-data collection, an analysis of the multiple criteria focused on physical ownership of key assets and their anticipated values at the time of the study was used rather than precarious annual cash income (Bekele *et al.,* 2017) in livestock-owning households. This analysis was conducted to classify wealth categories among households before statistical analysis. Ownership of houses with brick buildings and corrugated iron, thatched roofs, traditional buildings, livestock types, livestock numbers and technical efficiency scores were used as indices of wealth (Table 1). However, it was impossible to set an absolute cut-off point for each criterion; hence, it was evident that overlap in the range of values for set criteria would occur. The contributions were assessed together as a group of households under one criterion of the three wealth categories following Bekele *et al.* (2017). The national census data were also used to define the categories of dwelling type (Stats SA, 2011).

TABLE 1: Livestock Wealth Classification Criteria

Criteria	Better-off (n=33)	Medium (n=33)	Poor (n=54)
Livestock holdings			
No. of cattle	>8	4-8	<4
No. of Sheep	>15	10-15	1-10
No. of Goats	>15	10-15	1-10
Dwelling type			
Traditional	No	Yes	Yes
Bricks	Yes	Yes	No
Technical efficiency	> 0.7	0.4-0.69	0.1-0.39

2.5. Stochastic Frontier Production Function Analysis (SFA)

Household agricultural production is aimed at maximising production. Because of this, the study used the SFA method (Aigner et al., 1977; Meeusen & Van Den Broeck, 1977) to examine input-output relationships and obtain efficiency indicators. The method was extended by Kumbhakar *et al.* (1991) to introduce the determinants of technical efficiency into the model. The model also proposes that an inefficiency effect u_i be expressed as a clear function of the vector of a firm-specific random error and variables in a single-stage stochastic frontier. Battese and Coelli, (1995) provide a frontier model with output-oriented technical efficiency specified as:

$$Y_i = X_i \beta + v_i - u_i \qquad (1)$$

where:

Y_i is a scalar output of the i^{th} household; X_i is a vector of input quantities, and β is a vector of parameters to be estimated; v_i is a random variable which is assumed to be i.d. $N(0, \sigma_v^2)$, and independent of the u_i and u_i is equal to a non-negative random variable, which is assumed to account for technical inefficiency in production and assumed to be independently distributed as truncations at zero of the $N(0, \delta_u^2)$. The estimation of equation 1 provides variance estimators, estimators for β_j and other relationships as denoted as:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \qquad (2)$$

$$\gamma = \sigma_u^2 / \sigma^2 \qquad (3)$$

where:

$\sigma^2, \sigma_v^2, \sigma_u^2$ are the overall variance of the model, variance of the random error and variance of the technical inefficiencies, respectively. Gamma (γ) measures the proportion of the total output made on the frontier function, which is attributed to technical efficiency and has a value between zero and one.

The empirical model [4] is defined as:

$$lnY_i = \beta_0 + \beta_1 lnX_{1i} + \beta_2 lnX_{2i} + \beta_3 ln\, X_{3i} + \beta_4 X_4 + \beta_5 X_5 + v_i - u_i \qquad (4)$$

where:

ln= denotes natural logarithm (base); Y_i is the total value of livestock outputs for the i^{th} household (1,2,3…n); β_0 is an intercept and is constant; $\beta_{i,}$ are the parameters of regression coefficients of the i_{th} variable; $X_1$is the total labour hired and used in the production of livestock outputs; X_2 is the total livestock household holdings, which was a conversion of a livestock unit (LSU)[5]; X_3 is the total cost of livestock feed; X_4 is the dummy variable for livestock sales during the year; X_5 is the dummy variable to account for the households that provided supplementary feeds.

The input variable X_1 is expected to positively affect the total value of livestock output per household, where households that hire more labour to look after the animals have increased TE. Resources in the communal systems are spatially heterogeneous, and herding enables the best access to them, particularly during the dry season when additional resources such as crop residues become available. The input X_2 higher livestock holdings are expected to increase the total value of livestock outputs generated per household. X_3 is expected to positively affect livestock output as more money is invested in buying additional feed for livestock, which may reduce livestock deaths because of hunger and insufficient feed from natural rangelands.

[4]We assume a Cobb-Douglas to represent the production technology as frequently done in the related literature (Bravo-Ureta *et al.*, 2007). This choice is predicated on the fact that the C–D satisfies key regularity conditions derived from economic theory. The trans log production function is an alternative. However, this functional form violates key theoretical properties, including inactivity, strong input and output disposability, and input and output closedness (Villano *et al.*, 2019). The trans log satisfies strong disposability of inputs and outputs when all second-order coefficients are zero, but if such is the case, the trans log becomes the C-D (O'Donnell, 2012).

[5] LSU is calculated as 0.8 for cattle, 0.15 sheep and 0.10 for goats.

2.6. Technical Inefficiency Model

Following Battese and Coelli (1995), the study employed an inefficiency effects model that allows the simultaneous factors affecting technical inefficiency and the estimation affecting the output. Here, the inefficiency effects component that u_i is truncated normal distribution and the mean value is expressed as:

$$\mu_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} \qquad (5)$$

where:

$\delta_{0,}$ is the intercept; δ_i are unknown parameters to be estimated representing the effects of i^{th} variable on the level of inefficiency; $Z_1$is the household head age in years; Z_2 is the gender of the household head; Z_3 is the type of dwelling that the respondents live in; Z_4 is the proportion of households who provide additional livestock feed; Z_5 is the proportion of households that kraal their animals; Z_6 is the proportion of households that have herders to look after livestock. The choice of the variables included in the inefficiency model is informed by the literature and also based on the production characteristics in the communal rangeland environments.

Z_1= age of the household head is expected to influence technical efficiency. Older people are not easily convinced to adopt new technology and innovation (Tipi *et al.*, 2009). As they grow older, they cannot look after livestock independently. On the other hand, young household heads are more easily convinced to adopt an innovation and are still active enough to care for the animals. However, with the lack of interest in youth to be involved in agriculture, age can harm household efficiency.

Z_2= it is expected that the gender of a household head may affect technical efficiency positively or negatively, depending on the socioeconomic characteristics of a household (Musemwa *et al.*, 2007). Male-headed households are expected to perform better than female-headed households due to the gender role in livestock production. However, the pressure on women to provide for the household can also lead to female-headed households performing better. There are also some unidentified reasons for this.

Z_3 = it is expected that dwelling type, which was used as a proxy for wealth (Bekele *et al.*, 2017), because of rural-urban linkages in rural households, may positively affect technical efficiency. However, the study acknowledges that some indicators, such as the inclusion of ownership of consumer white goods, motorcars, tractors and children educated to

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tertiary/university level, would have strengthened the confidence levels of this variable but was very limited.

Z_4 = it is expected that additional feed will harm technical efficiency. This is because households can provide feed to livestock to a point where the maximum growth is reached, after which they start losing weight; hence, technical efficiency decreases.

Z_5 = it is expected that cattle and sheep kraaling will negatively and positively impact technical efficiency. Kraaling reduces the chances of animals being stolen and exposed to predators overnight in the rangelands, and it allows monitoring livestock numbers and easy access to livestock handling. However, Nowers *et al.* (2013) state that kraaling contributes negatively because animals regularly stay confined until mid-morning, reducing prime early-morning grazing.

Z_6 = it is expected that livestock herding will increase technical efficiency because herders will move the animals to the most productive parts of the rangelands and can control them when it is time for kraaling at night. However, the decrease in the interest in herding among the youth and mandatory schooling of young children may have a negative effect on technical efficiency.

2.7. Statistical Analysis

Descriptive statistics were used to describe key variables in this study. Technical efficiency was estimated using the Frontier 4.1 programme (Coelli & Battese, 1996) and verified in R, to find the maximum likelihood estimates for parameters of the stochastic frontier production function. We employed likelihood ratio tests (LR) to test the specification and inclusion of variables in the empirical model. Before analysing the data, we tested for the presence of inefficiency and found that the use of the stochastic frontier model is a sufficient representation of the production technology ($LR = 15.69$, $\chi^2_{(0.05,1)} = 2.706$) [6]. Secondly, we tested for the inclusion of inefficiency variables as defined by equation 6. We found sufficient evidence to

[6] The LR test statistic λ=2[ln {L(Ha)-L(H0)}], where L(H0) is the value of the log likelihood function for ordinary least squares and L(Ha) is the value of the log likelihood function for the stochastic frontier production function. The value of λ has Chi-square distribution with the number of degrees of freedom equal to the number of restrictions imposed.

suggest that the inefficiency variables are significant predictors of the mean inefficiency (LR = 18.13, $\chi^2_{(0.05, 8)} = 14.853$) [7]

3. RESULTS

3.1. Socioeconomic Characteristics of Households

The results revealed that 65% and 35% of the respondents were females and males, respectively. Of the sampled households (n=120), 14% of the respondents were between 41-50 years old. The youngest respondents (4%) were younger than 30, while 43% of the respondents were over 51 years old (Table 2). Of the respondents, 62% lived in houses made of bricks, while 38% lived in mostly mud, wood, thatch grass and bits of brick. The results revealed that 82% of the respondents used labour to look after their livestock (Table 2). The results showed that 57% of the respondents provided additional feed, while 43% relied solely on grassland for livestock grazing. The results also showed that 90% of the respondents kraaled their animals at night, while only 10% left them in the field (Table 2).

TABLE 2: Socioeconomic Characteristics of the Households That Were Interviewed

Description	Frequency (n=120)	Percentage (%)
Gender		
Females	78	65
Males	42	35
Age		
≤ 30	5	4
31-40	47	39
41-50	17	14
51-60	24	20
≥ 61	27	23
Dwelling type		
Brick building	74	62
Traditional building	46	38
Labour		

[7] The LR test statistic λ=2[ln {L(Ha)-L(H0)}], where L(H0) is the value of the log likelihood function for the stochastic frontier model without inefficiency effects L(Ha) is t the value of the log likelihood function for the stochastic frontier production function with inefficiency effects. The value of λ has Chi-square distribution with the number of degrees of freedom equal to the number of restrictions imposed.

Yes	98	82
No	22	18
Additional feed		
Yes	68	57
No	52	43
Kraaling		
Yes	108	90
No	12	10

3.2. Parameters of Ordinary Least Square and Maximum Likelihood Estimates

The results of ordinary least squares (OLS) and maximum likelihood estimates (MLE) are presented in Table 3. These results show that the estimated coefficients for main inputs (livestock unit and feed cost) are positive. The coefficient for labour was negative but not significant ($p< 0.001$) and was inconsistent with our theoretical expectations. This result indicates that productivity output decreases with an increase in labour input, suggesting that labour, which can affect livestock productivity, can be increased to the point of no return where maximum growth has been reached, and eventually, the output decreases. The results suggest that an increase of 1% in both livestock units and feed will increase livestock productivity outputs by 0.25% and 0.06%, respectively. The inefficiency variables were included in the analyses to assess whether they influence the technical efficiency of the household or not. A negative coefficient indicates decreased inefficiency, and a positive coefficient indicates increased inefficiency. The results revealed inefficiency variables in the analysis of the stochastic frontier, which indicates coefficients for the provision of feed to be positive, suggesting that increasing these variables will decrease technical efficiency. These results indicate that this resource may be reallocated elsewhere in the production line and used in other activities to support livestock production. At the same time, rangelands are properly managed to continue to provide feed throughout the year. Additionally, the inefficiency variable, gender, indicated by a negative sign, showed that female-headed households have an increased TE than male-headed households. Lastly, households living in brick buildings and those kraaling and herding their livestock, as indicated by a negative sign, have high TE.

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TABLE 3: A Stochastic Frontier Production Function Parameter and Ordinary Least Square (OLS) and Maximum Likelihood Estimate (MLE)

	OLS			MLE		
Variables	Co-eff	St. Error	t-ratio	Co-eff	St. Error	t-ratio
Constant	16.903	4.731	3.573	13.700	2.714	5.048
Labour	-0.834	0.545	-1.531	-0.445	0.307	-1.448
Livestock unit (LSU)	0.256	0.109	2.348	0.161	0.091	1.765
Cost of feed	0.066	0.062	1.061	0.070	0.057	1.236
Dummy for sold stocks	0.722	0.292	2.469	0.724	0.271	2.672
Dummy for supplementary feeding	0.294	0.193	1.525	0.422	0.219	1.926
Constant				1.153	1.258	0.916
Age				0.491	0.860	0.570
Gender (1= Female)				-1.743	0.760	-2.294
Dwelling (1= Brick)				-2.580	1.096	-2.355
Additional-feed (1=Yes)				1.813	0.765	2.369
Kraaling (Yes= 1)				-1.053	1.286	-0.818
Herding (Yes= 1)				-1.205	0.655	-1.841
Sigma square				0.947	0.268	3.527
Gamma				0.460	0.116	3.982
Log likelihood	-145.68			-136.61		

3.4. Distribution of Technical Efficiency Scores Among the Different Households

The frequency distribution of technical efficiency levels is presented (Figure 2). The results showed that household livestock production achieved, on average, 79% estimated efficiency level, ranging from 15% to 93%, with a wide range of efficiency variation among households. About 63% of the households had a technical efficiency level ranging from 81% to 93% and are mainly female-headed households. Only 11% of the respondents had a technical efficiency level ranging from 51% to 70%. About 6% of the households could only achieve 10% to 50% technical efficiency. The results further revealed that 20% of the households achieved a technical efficiency level between 71% and 80%.

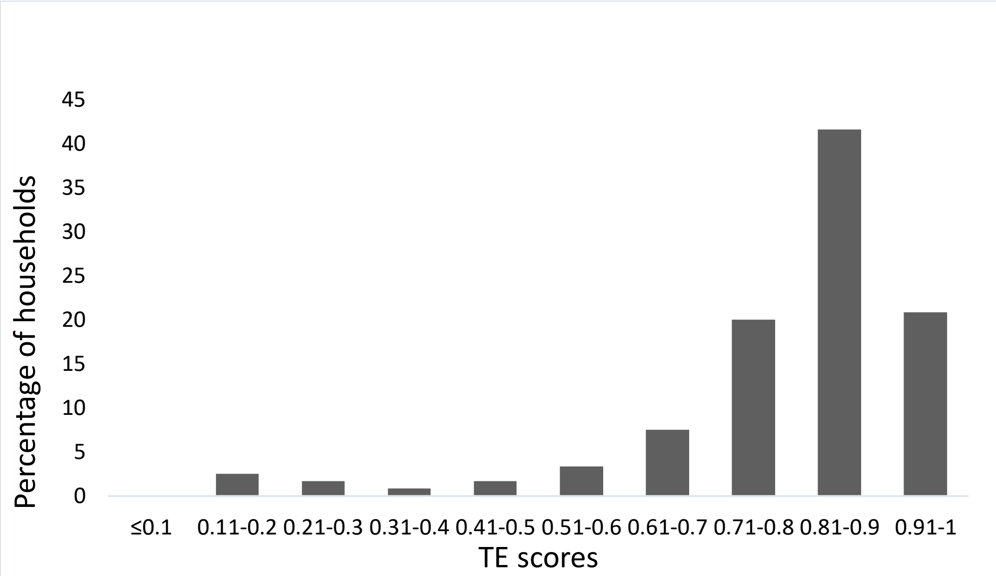

FIGURE 2: Distribution of Technical Efficiency in the Study Area.

3.5. Frequency of Performance Based on the Post-Analysis Performance Classification

Figure 3 shows the post-analysis results of performance group categories based on an individual household wealth status regarding livestock holdings, technical efficiency and dwelling type. The poorly performing households numbered 45% (n= 54) of the sampled households. In this group, householders mainly reside in traditional buildings made of wattle and mud and consist of more females (29%) than males (16%). The poor-performing group had a low livestock-derived output and invested in livestock production through labour exchange. The middle performing group, 28%, obtained moderate outputs with labour and additional feed having been invested. This group of individual households resided in mixed buildings of traditional and brick houses and had livestock holdings of between 4-8 cattle and more than four small stock. This group comprised 18% females and 10% male-headed households. Of the interviewed households that fell into the better-off group (27%), more household heads were females than males (18% and 9%, respectively). In this category, householders resided mainly in brick buildings and had more livestock than the other groups.

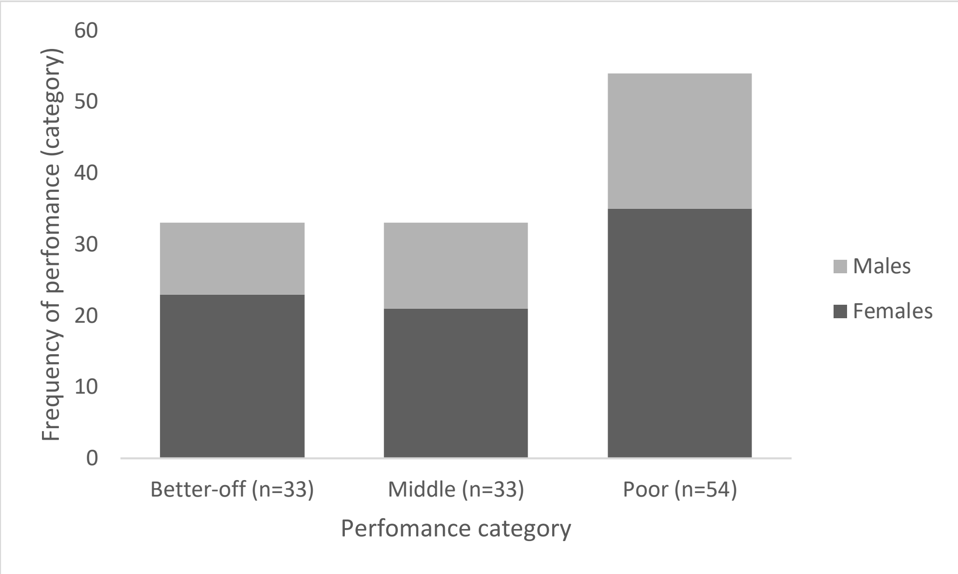

FIGURE 3: Frequency of Productivity Performance By Gender of the Household Head

4. DISCUSSION

4.1. Household Characteristics

There were generally more female-headed households (65%) that participated in this study than the male-headed households (35%) (Table 2). A possible explanation could be related to males being out and working in towns. Besides, perhaps these respondents were widows. The figures are similar to those of Sikhweni and Hassan (2014), who reported more female participants than males involved in communal livestock farming. Musemwa *et al.* (2007) and Spies (2011) also reported many female participants being engaged in livestock farming in the communal areas of the Eastern Cape and Free State Provinces, respectively. The age of the household head was another important criterion, with many individuals ranging from 51- 60 (20%) to more than 61 (23%) years of age (Table 2). Similar results were found by Kunene (2010) in northern KwaZulu-Natal Province and Masuku and Sihlongonyane (2015) among smallholding farmers in Swaziland, who recorded that most farmers fell into the age group of 50–60 years. These results suggest that there is a likelihood that older farmers have more knowledge and interest in the farming of livestock and could have younger people, often grandchildren, in their households who can care for livestock after school hours. The participants also reported that they provide labour for livestock handling and that most of the labour is provided by the household members, where children are used to herd cattle after school. According to Cousins (1996), this arrangement also helps an individual gain livestock ownership because of the experience of animal husbandry they gain at a young age. However, mandatory schooling has reduced the number of children who are now available to work as herders, so it is mostly elderly people who look after livestock during school hours. In both villages, 68% of the households provide additional feed for livestock. These households only provide feed during the dry season. The animals that benefit from the feed are only those that are calving, those already in calf and those that are sick. The reason for such a limit could be the fact that these people are unemployed and rely on livestock sales (mostly informal), while their adult children, who are often migrant workers, focus on household development (building additions, repairs and maintenance), which are unrelated to livestock production.

4.2. Inefficiency Model Estimates

The results of the MLE represent both productivity and inefficiency variables measured in the study. The productivity variables measured in the study include livestock holdings, labour and feed cost, while age, gender, dwelling type, livestock kraaling and livestock herding were inefficiency variables. All these variables were found to influence livestock productivity and households' ability to attain livestock goods and services. Contrary to the findings of this study, Hangara et al. (2011) found that high livestock numbers led farmers to generate more livestock outputs, such as offtake, implying that larger herd sizes could influence the TE of households in the communal area. In this study, higher livestock numbers were found in male-headed households, but higher TE was recorded in the female-headed households with less livestock. However, this study reported that providing additional feed and increased head size could increase livestock productivity.

On the other hand, labour was reported to be a significant variable. Still, it could be provided to a certain level, such that livestock graze in areas with more grazing biomass. Similar results are reported by Temoso *et al.* (2015), who recorded that the provision of both hired and family labour provided positive results in livestock productivity. Temoso *et al.* (2015) also reported that the feed and livestock holding costs influence livestock productivity. These results are not significant but have a positive influence on the productivity of livestock.

Table 3 represents the technical inefficiency effects model whereby a negative coefficient indicates that the variable positively affects technical inefficiency (i.e., it has increased TE). The age of the household head was positive, which, in this case, meant a decrease in the TE of the household. These results imply that, although older people have more knowledge and interest in livestock keeping, they struggle with the physical responsibilities of livestock farming. As they grow older, they also do not easily adapt to innovation and technology. At the same time, the gender of the household head was recorded as influencing the TE, which was denoted by a negative sign. These results revealed that female-headed households attained higher TE than male-headed households in this study.

Furthermore, these gender-based increases in the technical efficiency in female-headed households dominate the highest efficiency group (Table 3). According to a study conducted by Yisehak (2008) in Ethiopia, gender is an important component in the labour share of livestock production systems. Both males and females have different responsibilities related to animal production, with some level of variation in involvement from household to household. In smallholder livestock production, males are mostly responsible for decision-making and general herd management, while females contribute more to labour, feed inputs, and managing sick animals and calves (Yisehak, 2008).

Furthermore, this study used a dwelling type, an accepted index used by Statistics South Africa to measure household wealth. The inefficiency model estimates showed that dwelling type, indicated by a negative value sign (Table 3), is associated with increased technical efficiency. The study recorded 62% of the households were brick buildings, and 38% were traditional buildings. These results imply that there may be absent family members who are migrant workers directly involved in the household development via remittances and kinship contributions. The absent family members become involved in household development by assisting in building a household when they start earning an income. Almost every household (90%) kraals their livestock at night. The coefficient for kraaling and livestock herding, indicated by a negative value (Table 3), suggests that both kraaling and herding increase technical efficiency. According to Temoso *et al.* (2015), livestock kraaling and herding in communal areas is possibly motivated by the need to minimise the impact of losses due to theft and predation. While livestock herding also reduces theft and predation, it has cost implications for communal farmers. Kraaling and herding are crucial in keeping animals away from predation and theft. They increase technical efficiency but cause soil compaction and increase soil erosion and run-off. However, evidence suggests that livestock herding in other communal areas of South Africa and Lesotho improved livestock performance and rangeland use and management (Samuels *et al.*, 2007).

4.3. Technical Efficiency Scores

The study estimated a mean TE score of 0.79, implying that, on average, households produce 79% with given inputs. This was contrary to Thirtle *et al.* (2003) and Bahta *et al.* (2015), who recorded lower TE scores of 0.25 for communal livestock production and 0.49, respectively, while similar findings (0.79) were found by Temoso *et al.* (2016) in communal beef production. This study did not exploit the analytical potential of a 'compare and contrast' of the conditions and variables of households. About 93% of the households had a score above 0.5. These results imply that more interventions related to livestock husbandry are essential to improve livestock production in the communal livestock sector. Of the households that obtained 93% of TE, 21% received more than 91% of the technical efficiency level. This study showed that the age of the household head and the provision of additional feed to livestock may decrease technical efficiency. Tipi *et al.* (2009) claim that the age of a farmer may have both a positive and negative influence on technical efficiency. Depending on whether experienced, older farmers are slower to accept new technologies than young farmers. Bahta and Baker (2015) further argue that younger farmers are now more efficient, possibly because of their degree of commercial establishment, product marketing management, and utilisation of human and social capital through effective input.

Furthermore, when the animal is provided with additional feed, it grows and reaches a point where there is no further growth, after which the weight drops, leading to low offtake value and decreased livestock outputs, thus reducing technical efficiency. The results also suggest a need for intervention related to livestock husbandry to reduce the livestock water footprint and improve TE. Furthermore, non-profit commodity organisations such as the National Woolgrowers' Association (NWGA) could be encouraged to intervene.

4.4. Determinants of Technical Efficiency in Different Performance Profiles

According to the results obtained from the performance profile, 45% of households performed poorly. This group was composed of households with low livestock numbers, lived in traditional buildings and obtained low technical efficiency scores. The underlying reason for such outputs could be inefficiency variables such as those documented by Masuku and Sihlongonyane (2015). Such factors are documented as production constraints affecting farmers' production efficiencies. They include a lack of information about livestock farming,

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poor market information, unavailability of inputs (high feed cost, veterinary services, and reliable labour), and a shortage of water and feed. All these factors were equally observed in the study site during data collection. However, those that stood out were that people do not have enough information about livestock husbandry because they keep their animals just because the land is freely available to run livestock, and it is a tradition to own livestock. The middle-performing group achieved moderate livestock production. Most households in this category generated moderate livestock outputs and resided in wattle and brick buildings.

The better-performing households constituted 27% of the sampled households. This household group comprised individuals with higher livestock numbers and lived in brick buildings. Better-off performing households were mostly headed by females (18%) rather than males (9%). These were surprising results because men are expected to have more knowledge than women about livestock and, hence, are expected to produce more. On the other hand, females in rural areas are often under pressure to provide for their households with money from livestock sales. These results provide an opportunity for any interventions that may be useful in improving technical efficiencies to focus on women whom this study perceived as better managers of money and the household domestic finances, partly through their greater involvement in clubs, church groups and burial societies.

5. CONCLUSION AND POLICY IMPLICATIONS

The findings of this study revealed that more women than men participated in the survey, possibly because men were working or seeking work in urban areas. The estimated mean technical efficiency for the study shows an opportunity for improvement in the households performing above 70% at the technical efficiency level. This can be achieved by narrowing the gap between the best-performing households and the poor-performing households by using the interventions that the Extended Public Work Programmes runs to provide livestock herding and labour perhaps and by increasing advice and support that encourage livestock herding, especially to poor households that live in traditional dwelling houses made up of mud.

Lastly, these results may encourage policymakers to focus policy-targeting interventions more on gender-sensitive strategies that encourage female participation in livestock production, as the results suggest more TE in female-headed households. Furthermore, these results provide a need for the communal people to properly manage their rangeland to improve the fodder resource and reduce the money spent on buying additional feed for livestock. Proper rangeland management can be practised through supported traditional rangeland practices, with the traditional leadership enforcing the rules. This traditional practice has been largely abandoned in the communal areas of the Eastern Cape Province and could be revived. This study offered an opportunity to identify differences in the productive performance of different households that own livestock, provided results that can be used to extend frontiers, and thus provide directions for policy interventions that can improve technical efficiency.

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