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TRENDS ESTIMATION IN ANNUAL NUMBERS OF MERINO SHEEP AND WOOL PRODUCTION IN SOUTH AFRICA, FROM 1980 TO 2017

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ABSTRACT: The economic important value of wool in South Africa is influenced by many characteristics that meet processor capacities and consumers' preference. The study was conducted to characterize the trends of annual Merino sheep numbers, wool sales and wool auction price in South Africa, from 1980 to 2017. The data from year 1980 to 2017 was retrieved from the abstract of agricultural statistics which was published by the Department of Agriculture, Land Reform and Rural Development (DLRRD) in 2020 was used. Trends were analysed using the differences and percentage change between numbers of years in each independent variable (annual number of Merino sheep, wool sales and wool auction price). The findings indicated that there was a trend in annual number of Merino sheep, wool sales and wool auction prices. In annual numbers of Merino sheep, the highest decrease was observed from 1992 to 1993 (-1878) by 11.2 percent (%) while the huge increase was observed from 1999 to 2000 (+1177) by 10.6%. In wool sales, the findings showed that there was an increase (+5.4) from 1980 to 1982 with 7.7% while there was a decrease (-4.7) from 1982 to 1983 by 6.2%. In wool auction price, the highest increase was observed from 1986 to 1987 (+250903) by 77.2%. Regression findings indicated that all the predicted regression models were statistically significant at $P < 0.01$. However, the results suggest that quadratic ($R^2 = 90$) was the best fit model to predict the relationship between number of years and annual Merino sheep numbers. This study suggests that there was a trend in annual numbers of Merino sheep, wool sales and wool auction prices in South Africa from 1980 and 2017. Moreover, this study might help Merino sheep farmers to recognise the trends that might be helpful in planning for annual wool productions.

Keywords: Exponential, Linear, Logarithmic, Quadratic, Sheep.

INTRODUCTION

In South Africa the wool production industry continues to be an important fibre in textile trade market (Van der Merwe et al., 2020). The economic important value of wool in South Africa is influenced by many characteristics that meet processor capacities and consumers' preference (Van der Merwe et al., 2020). The quantities of wool production produced annually in South African market have declined from 1991 to 2005 (DAFF, 2018) this is resulted by increased stock theft cases and due to the meat prices that became the main source of income from sheep production. Moreover, this leads to increased crossbreeding developments with the use of terminal sires to improve growth and meat production of wool sheep breeds (Cloete et al., 2008). The wool production complements lamb production in the total income generated by farmers as when wool-type or dual-purpose dam lines are used in breeding programmes (Van der Merwe et al., 2020).

The difference in profitability of sheep breeds remains one of the most controversial discussion issues among farmers and is one of the aspects that receive little observation from researchers and scientists (Snyman et al., 2014). The reason for this is that the full implication of such a comparison is rarely taken into consideration (Snyman et al., 2014). However, farmers are continuously changing from one breed to another. The decision to change from one breed to another is mostly likely to be due to short-term financial reasons and current market trends favouring either wool or meat Snyman et al. (2014). However, to the greatest of our knowledge there is no literature documented about the trends of Merino sheep numbers and wool production in South Africa from 1980 to 2017. Hence the objective of this study was to estimate and describe the trends over time for annual Merino sheep numbers and wool production in South Africa from 1980 to 2017. This study might help Merino farmers and wool production industry of South Africa to recognize the outcomes of changes in number of years on annual Merino sheep numbers and wool production.

MATERIALS AND METHODS

Data collection

A thirty-eight years (1980 to 2017) data of annual numbers of Merino sheep and wool production from abstract of agricultural statistics (2020) was used in the study. The abstract of agricultural statistics which was compiled by

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directorate statistics and economic analysis was published in the Republic of South Africa by Department of Agriculture, Land Reform and Rural Development. Data of annual numbers of Merino sheep was presented in thousands (1000) and wool production presented in thousand tons (1000 *t*) were used for the study.

Statistical analysis

Winston (2016) and Statistical Packages for Social Sciences version 26 (SPSS, 2019) were used for data analysis. The linear, logarithmic, quadratic, exponential and power regression analyses were used to estimate the rate of curves. The following mathematical model equations were used:

Linear: $y = \beta_0 + \beta_1^* x$

Logarithmic: $y = \beta_0 + \beta_1^* \ln(x)$

Quadratic: $y = \beta_0 + \beta_1^* x + \beta_2 * x^2$

Exponential: $y = \beta_0 + \beta 1 (\beta_{2x,1} + \beta_{p+1} x_i, 1) + e_{i6}$

Power: $y = \beta_0 * x^{\beta 1}$

The analysis of residuals was included to identify a typical dataset; these data were recognized by plotting the residuals against the values predicted by the equations. A typical data was eliminated if the corresponding values of the student residuals were outside the range of −2.5 to 2.5. The accuracy of the models was evaluated by the determination coefficients (r^2) and mean squared error (MSE) (SPSS, 2019). Lastly the goodness of fit criteria was performed to check the best model in this study. The following criterions were used:

$$R^2 = 1 - \left(\frac{SST}{SSE}\right) \quad ; \quad RMSE = \sqrt{\frac{SSE}{N - p - 1}} \quad ; \quad AIC = N \, Ln\left(\frac{SSE}{N}\right) + 2p \quad ; \quad BIC = N \, Ln\left(\frac{SSE}{N}\right) + p \, Ln \, N$$

Where, R^2 = coefficient of determination; SST = is the total sum of square; SSE = is the residual sum of square; RMSE = is the residual mean square error; N = is the number of observations; P = is the number of parameters in the regression equation; AIC = is the Akaike information criterion; BIC = is the Bayesian information criterion; Ln = is the natural logarithm in calculator.

RESULTS AND DSICUSSION

Descriptive statistics

The study was conducted to investigate the trends of annual Merino sheep numbers and wool production using different regression models (linear, logarithmic, quadratic, exponential and power). The descriptive statistics was computed to examine the summary of the dataset. Table 1 indicates the descriptive statistics of the data used in the study. The summary revealed that there were only thirty-eight observations (n = 38) on the annual Merino sheep numbers and wool production used for the study. Results further recognized that the annual Merino sheep numbers had the minimum number of 10466, maximum number of 20009, average of 13769, and standard deviation of 2909.12 while wool sales had a minimum number of 18.00. While revealing the maximum number of 76.30, average of 45.71 and standard deviation of 16.88. Our findings are in agreement with the reports of Ngambi and Belete (1999) that recognised that mohair production had a trend in Lesotho between 1935 and 1990.

Table 1 - Descriptive statistics of annual Merino sheep numbers and wool production

Statistics	N	Minimum	Maximum	Mean	Std. Deviation
Year	38	1980	2017	1998.50	11.11
Merino sheep numbers (n)	38	10466.00	20009.00	13769.58	2909.12
Wool sales (t)	38	18.00	76.30	45.71	16.88
Wool value (R)	38	161099.30	3408712.60	948974.92	836565.31
Auction price(R/Kg)	38	2.29	113.37	26.81	28.36

n: numbers; t: tons; R: rand; R/kg: rand per kilogram; kg: kilogram; Std. Deviation: Standard deviation.

Differences and percentage changes in annual Merino sheep numbers

In this study, annual number of Merino sheep differences and percentage changes were also computed from 1980 to 2017. The results of annual Merino sheep numbers (Table 2), differences and percentage change were calculated from 1980 to 2017. The results of annual Merino sheep numbers indicated that there were trends between years from 1980 to 2017 in the number of Merino sheep in South Africa. The highest decrease was observed from 1992 to 1983 (-1878) by 11.2% while the huge increase was observed from 1999 to 2000 (+1177) by 10.6%.

Differences and percentage changes in annual wool sales production

Results of differences and percentages changes in annual Merino sheep wool sales in South Africa from 1980 to 2017 are shown in Table 3. The findings showed that there was an increase (+5.4) in annual Merino sheep wool sales from 1980 to 1982 with 7.7% while there was a decrease (-4.7) from 1982 to 1983 by 6.2 %.

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Differences and percentage changes in annual wool value

Results of annual wool value production (Table 4) indicated that there were trends between years from 1980 to 2017 in the annual wool value in South Africa. The highest decrease was observed from 2002 to 2003 (-299702.3) by 28.0% while the huge increase was observed from 1986 to 1987 (+250903) by 77.2%.

Differences and percentage changes in wool auction price

The results of annual auction price (Table 5) indicated that there were trends between years from 1980 to 2017. The highest increase was observed from the year 2000 to 2001 (+8.5) by 55.0%, while the highest decrease was noticed from the year 1985 to 1986 (-1.8) by 35.3%.

Table 2 - Annual Merino sheep numbers and percentage change from one year to the next

Year	Annual number of Merino sheep (n)	Difference	Trend	Percentage Change
1980	20009			
1981	19335	-674		3.4
1982	19036	-299		1.6
1983	17660	-1376		7.2
1984	16551	-1109		6.3
1985	16045	-506		3.0
1986	16353	308		1.9
1987	16087	-266		1.6
1988	16161	74		0.5
1989	17644	1483		9.12
1990	17916	272		1.5
1991	17057	-859		4.8
1992	16762	-295		1.7
1993	14884	-1878		11.2
1994	14470	-414		2.8
1995	13331	-1139		7.9
1996	12862	-469		3.5
1997	12185	-677		5.3
1998	12264	79		0.7
1999	11072	-1192		9.7
2000	12249	1177		10.6
2001	11463	-786		6.4
2002	12265	802		7.0
2003	11801	-464		3.8
2004	11383	-418		3.5
2005	11771	388		3.4
2006	11643	-128		1.1
2007	11552	-91		0.8
2008	11612	60		0.5
2009	11473	-139		1.2
2010	11251	-222		1.9
2011	11163	-88		0.8
2012	11256	93		0.8
2013	11328	72		0.6
2014	11125	-203		1.8
2015	11037	-88		0.8
2016	10722	-315		2.9
2017	10466	-262		2.4

Table 3 - Annual wool sales and percentage change from one year to the next

Year	Merino wool sales (t)	Difference	Trend	Percentage Change
1980	70.2			
1981	75.6	5.4		7.7
1982	76.3	0.7		0.9
1983	71.6	-4.7		6.2
1984	69.6	-2.0		2.8
1985	65.5	-4.1		5.9
1986	60.8	-4.7		7.2
1987	61.3	0.5		0.8
1988	65.6	4.3		7.0
1989	68.9	3.3		5.0
1990	74.6	5.7		8.3
1991	58.4	-16.2		21.7
1992	53.7	4.7		8.1
1993	50.3	-3.4		6.3
1994	43.6	-6.7		13.3
1995	45.2	1.6		3.7
1996	43.0	-2.2		4.9
1997	39.8	-3.2		7.4
1998	39.4	-0.4		1.0
1999	35.3	-4.1		10.4
2000	33.5	-1.8		5.1
2001	33.2	-0.3		0.9
2002	31.5	-1.7		5.1
2003	32.8	1.3		4.1
2004	32.5	-0.3		0.9
2005	31.8	-0.7		2.2
2006	32.8	1.0		3.1
2007	32.5	-0.3		0.9
2008	31.5	-1.0		3.1
2009	32.9	1.4		4.4
2010	31.5	-1.4		4.3
2011	30.1	-1.4		4.4
2012	33.0	2.9		9.6
2013	33.6	0.6		1.8
2014	33.4	-0.2		0.6
2015	31.4	-2.0		6.0
2016	32.3	0.9		2.9
2017	18.0	-14.3		44.3

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Table 4 - Annual wool value and percentage change from one year to the next

Year	Wool value (R)	Difference	Trend	Percentage Change
1980	161099.3			
1981	222385.1	61285.8		38.0
1982	214381.6	-8003.5		3.6
1983	230485.9	16104.0		7.5
1984	320593.0	90107.1		39.1
1985	339631.3	19038.3		5.9
1986	325002.7	-14628.6		4.3
1987	575905.7	250903.0		77.2
1988	785480.4	209574.7		36.4
1989	699624.2	-85856.2		10.9
1990	521393.0	-178231.2		25.5
1991	441703.7	-79689.3		15.3
1992	340583.6	-101120.1		22.9
1993	343572.1	2988.5		0.9
1994	521725.2	178153.1		51.9
1995	452139.7	-69585.5		13.3
1996	545368.7	93229.0		20.6
1997	524802.4	-20566.3		3.8
1998	411997.2	-112805.2		21.5
1999	439955.3	27958.1		6.8
2000	519995.9	80040.6		18.2
2001	798693.4	278697.5		53.6
2002	1069361.2	270667.8		33.9
2003	769658.9	-299702.3		28.0
2004	646769.4	-122889.5		16.0
2005	614924.8	-31844.6		4.9
2006	951667.9	336743.1		54.8
2007	1212695.3	261027.4		27.4
2008	931227.7	-281467.6		23.2
2009	1178772.9	247545.2		26.6
2010	1373248.7	194475.8		16.5
2011	1788030.3	414781.6		30.2
2012	2048430.2	260399.9		14.6
2013	2266820.0	218389.8		10.7
2014	2293887.1	27967.1		1.2
2015	2736102.2	442215.1		19.3
2016	3034218.5	298116.3		10.9
2017	3408712.6	374494.0		12.3

Table 5 - Annual auction price and percentage change from one year to the next

Year	Auction price (R/kg)	Difference	Trend	Percentage Change
1980	2.29			
1981	2.94	0.7		28.4
1982	2.81	-0.1		4.4
1983	3.22	0.4		14.6
1984	4.6	1.4		42.9
1985	5.18	0.6		12.6
1986	3.35	-1.8		35.3
1987	9.39	6.0		180.3
1988	11.98	2.6		27.6
1989	10.15	-1.8		15.3
1990	6.98	-3.2		31.2
1991	7.56	0.6		8.3
1992	6.34	-1.2		16.1
1993	6.83	0.5		7.7
1994	11.97	5.1		75.3
1995	10.01	-2.0		16.4
1996	12.68	2.7		26.7
1997	13.19	0.5		4.0
1998	10.45	-2.7		20.8
1999	12.45	2.0		19.1
2000	15.52	3.1		24.7
2001	24.05	8.5		55.0
2002	34	10.0		41.4
2003	23.49	-10.5		30.9
2004	19.92	-3.57		15.2
2005	19.36	-0.6		2.8
2006	29	9.6		49.8
2007	37.31	8.3		28.7
2008	29.56	-7.8		20.8
2009	35.84	6.3		21.2
2010	43.58	7.7		21.6
2011	59.38	15.8		36.3
2012	61.88	2.5		4.2
2013	68.16	6.3		10.2
2014	68.63	0.4		0.7
2015	87.57	18.9		27.6
2016	93.8	6.2		7.1
2017	113.37	19.6		20.9

Regression analysis between parameters

The regression analysis between number of years and independent variables (annual Merino sheep numbers, wool sales and auction price) shown in Table 6. Four goodness of fit criteria (R^2, RMSE, AIC and BIC) were used to select the best regression model. The results indicated that all the predicted regression models were statistically significant at $P < 0.01$. The results of this study showed that quadratic model ($R^2 = 90$) was the best model to predict the relationship between number of years and annual Merino sheep numbers. Our results are in agreement with the findings of Tyasi (2021) who revealed that regression analysis suggested that quadratic model is the best fit model to explain the trend in both annual number of Angora goats and mohair production in South Africa between 1981 and 1987. Furthermore, exponential model showed a higher R^2 (0.86) and lower RMSE (0.02) for the estimation of association between number of years and wool sales. Moreover, our findings are agreement with results of Keskin et al. (2009) in Konya Merino sheep

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who revealed that quadratic and gompertz models showed the best fit to growth of Konya Merino lambs by having higher R^2 values, lower MSPE and non-auto correlation. The findings further recognized that power model with R^2 of 0.94, RMSE of 0.07, AIC of -99.41 and BIC of -96.19 was the best model to explain the relationship between number of years and auction price. Keskin et al. (2009) further revealed that these models can be used for predicting live weight at later ages from early partial live weight data.

Table 6 - Regression models to describe the relationship between parameters

Model	Equation	R^2	RMSE	AIC	BIC	P-value
Between number of years and annual Merino sheep numbers						
Linear	$Y=492275-23943X$	0.84	1421428.74	540.30	543.57	0.001
Logarithmic	$Y=4E+06-5E+05\ln(x)$	0.84	1411295.33	540.03	546.43	0.001
Quadratic	$Y=3E+07-28110x+6.97x^2$	0.90	1421428.74	540.30	543.57	0.001
Exponential	$Y=6E+18e^{-0.02x}$	0.86	0.01	-193.53	-190.26	0.001
Power	$Y=3E+115x^{-33.74}$	0.86	0.01	-193.53	-190.26	0.001
Between number of years and wool sales production						
Linear	$Y=2829.4-13929x$	0.84	46.75	148.05	151.32	0.001
Logarithmic	$Y=21216-2786\ln(x)$	0.84	46.42	147.78	151.05	0.001
Quadratic	$Y=158350-157.04x+0.04x^2$	0.84	46.75	148.05	151.32	0.001
Exponential	$Y=8E+27e^{-0.03x}$	0.86	0.02	147.78	-144.51	0.001
Power	$Y=1E+201x^{-60.45}$	0.86	46.75	-148.33	-144.51	0.001
Between numbers of years and auction price						
Linear	$Y=4354.2+2.1921x$	0.74	216.91	206.37	209.64	0.001
Logarithmic	$Y=-33226+4375.4\ln(x)$	0.74	218.45	206.63	209.91	0.001
Quadratic	$Y=455063-457.58x+0.115x^2$	0.74	215.37	206.10	209.37	0.001
Exponential	$Y=2E-81e^{0.09x}$	0.94	0.07	-96.28	-96.13	0.001
Power	$Y=0x^{188.69}$	0.94	0.07	-99.41	-96.13	0.001

CONCLUSIONS

The current study focuses on characterization of the trends for annual Merino sheep numbers, wool sales and wool auction price in South Africa from 1980 to 2017. The study concluded that there was a trend in annual number of Merino sheep, wool sales and wool auction price from 1980 to 2017. All the regression techniques used to predict the relationships between numbers of year with annual number of Merino sheep, wool sales and wool auction price were statistically significant. The study concluded that quadratic, exponential and power models were the best fit models to predict the relationship of number of years with annual number of Merino sheep, wool sales and auction price respectively. The current study might help Merino sheep farmers for annual wool production planning.

DECLARATIONS

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Authors' contribution
Lubabalo Bila designed the manuscript, analysed data and wrote the final manuscript. Thobela Louis Tyasi supervised the manuscript and edited the final manuscript. Zenzile Peter Khetsha revised the manuscript. All the authors read, revised, and approved the final manuscript.

Conflict of interest
Authors declare no conflict of interest.

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