EFFICIENCY ANALYSIS OF SMALL-SCALE WOOL PRODUCTION IN THE FORMER TRANSKEI, SOUTH AFRICA

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A non-parametric data envelopment analysis (DEA) is used to measure the relative efficiency of wool production on farms in the former Transkei. The agricultural activities on the farms are merely non-commercial. Wool is considered as a by-product of keeping sheep, which are slaughtered on special family occasions or sold live. A sample of farmers in three villages of the former Transkei (Mhlahlane, Xume and Luzie) was interviewed. In Luzie a shearing shed was built to organise the marketing of the wool, leading to a higher revenue from wool. The farmers however are not able to convert this into a positive gross margin. A small number of farms succeeds in maximising the production of wool given the relative large investment. The negative result of wool farming on the other farms is partly compensated by high benefits from the sales of live sheep. Also in Xume a shearing shed was built, and extension on production practices is provided. But no marketing of wool through the shearing shed was done at the time of the survey. The existence of a shearing shed should be essential for a higher retail price for wool and extension does have a positive influence on the benefits of the farms. However, the production practices are not adapted to the production of wool only, so that the use of inputs is too high for the generated output.

1. INTRODUCTION

South Africa belongs to the top-five wool producing countries in the world. The production of 52,671 Mt of greasy wool places South Africa behind Australia, New Zealand, United Kingdom and Argentina on the world market (FAO Stat, 2001). The national wool production represented in 1998 not more than one percent of the total agricultural production in terms of gross value (millions of R) (calculations from National Department of Agriculture in South African yearbook 2000/2001). This low percentage does however not reflect the socio-economic importance of sheep farming. The number of sheep in South Africa is estimated at 28.7 million, merely concentrated in Northern, Eastern and Western Cape, Free State and Mpumalanga (South African

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yearbook 2000/2001). Half of the South African sheep are Merino-breeds, known for their fine wool.

The South African wool industry, concerned about the development situation in the former homelands, launched an initiative to increase the households' returns from wool. The wool production in the former homelands is characterised by its low production efficiency and its low price. The latter is due primitive shearing and no classing. Also packaging is not up to standard. If the marketing is not organised, wool is sold to traders at very low prices. The National Wool Growers Association (NWGA) is building shearing sheds in villages throughout the former Transkei and Ciskei.

A joint initiative of the NWGA, the National Department of Agriculture, and the Agricultural Research Council (ARC) aims to improve the livelihood of the rural households by stimulating agriculture (LandCare program); in particular by developing of the small-scale wool production. The latter is stimulated by investing in shearing sheds, training in wool sorting, shearing and other farming practices. Farmers who have benefited from the programme have already achieved better prices and higher income from their wool production (Aucamp, 2000).

This paper investigates the technical and financial performance of sheep farming in the former Transkei. It is organised as follows: section two elaborates on the survey that was performed in three villages in the former Transkei. Section three compares the wool production in the area. Section four reports on use of a non-parametric data envelopment analysis to measure the relative efficiency of wool production of the farmers. The results of this efficiency analysis can be found in section five.

2. CASE STUDIES IN THE FORMER TRANSKEI: MHLAHLANE, XUME AND LUZIE

A survey was conducted in three villages in the former Transkei. These are Xume and Mhlahlane, which are part of the Tsomo[1] administrative district, in the central part of Transkei-area and Luzie, part of Mount Fletcher administrative district, in the north. In each of the villages a random sample of farmers were interviewed. In Mhlahlane (less populated), Xume and Luzie, respectively 18, 47 and 40 farmers were interviewed during which data was collected on all characteristics of sheep production.

Xume and Luzie are beneficiaries of the LandCare program of the National Department of Agriculture, which financed for the building of a shearing shed in both villages. At the time of the research, the shearing shed in Luzie was actively used. In Xume it was dormant. Mhlahlane does not have a shearing shed. The choice of the villages enables the comparison of the wool production practices in a village with an active shearing shed and subsequent marketing (Luzie), a village with no shearing shed, but with active initiative and extension (Xume) and a village with no shearing shed and no extension (Mhlahlane).

Xume, Luzie and Mhlahlane are poor rural areas, where the agriculture is the main productive activity. Other characteristics are poor infrastructure, difficult access and lack of (or even non-existing) labour markets. Perret (1999) describes the community of Xume as ageing and local born, stricken by severe poverty, economically mostly dependent on welfare and resorting of different sources of income and activity. Stock-keeping and production of wool are the major agricultural activities. A PRA survey in Xume revealed the following (Khanya, 2000): lack of domestic water, fencing, irrigation water, electricity and purchasing power, poor roads, many livestock diseases, poor access to health services, high incidence of seasonal diseases and HIV/AIDS, a lack of skills and a lack of attention to street children and orphans.

3. CHARACTERISTICS OF WOOL PRODUCTION

Perret (1999) (also in Perret *et al* (2000)) conducted a study in the same area and identified six household typologies. Three of the six are determined by the households' involvement in farming. In Xume, the farm household types are described as follows:

- *Stock-keepers pensioners*: the main source of income is pension. They produce sheep and goats mainly to be slaughtered for own consumption. Exceptionally lambs are sold locally. Wool is sold to speculators;

- *Part time stock-keepers*: the main source of income is derived from the husbands' work outside the community, sending remittance on a monthly basis to the household. These households also produce sheep and goats for own consumption and sell wool the speculators;

- *Full-time farmers*: although the income is supplemented with occasional jobs and remittances, the households make their living mostly through

agriculture. The crops grown are for own consumption. Young animals and wool are sold at the market.

Most households own some cattle or sheep, however only a minority can be regarded as commercial farmers. According to Perret (1999) only 13 percent of the interviewed households in Xume are identified as full-time farmers.

Wool is a raw cash product. It can be harvested as a by-product without the destruction of the capital. As sheep do not have to be slaughtered for their wool, wool can be considered a sustainable cash resource of the households. However, the absence of local knowledge on how to make use of the wool limits effective marketing of the produce. Furthermore, a large number of sheep are stolen or killed by jackals and dogs. This is due to the prevailing land tenure system, whereby the sheep graze on communal lands. These pastures are not fenced or divided into camps. The sheep are running lose, often not being herd, and not brought into a fold for the night. Low retail price and low wool production result in low income from wool.

The average flock size of the farmers in the survey ranges from 47 in Mhlahlane to 96 in Xume. Table 1 shows the comparison of structural characteristics of the wool production over the three studied villages. The interviewed farmers indicate the sales of wool as the most important reason for keeping sheep. Other purposes mentioned are local status, cash fund and source of main income.

Table 1: Comparison of key characteristics of wool production in three villages in Transkei

Average number of	Mhlahlane (n = 18)	Xume (n = 47)	Luzie (n = 40)
sheep per farmer	47.2	96.9	76.1
farmers with local breed	16 (88 percent)	46 (98 percent)	10 (25 percent)
farmers with Dohne Merino	2 (12 percent)	1 (2 percent)	30 (75 percent)
hours grazing per day	8.2	8.0	10.9
farmers giving extra feed	7 (38 percent)	7 (15 percent)	30 (75 percent)
farmers dipping	n.a.	24 (51 percent)	36 (90 percent)
farmers sorting the wool	1 (5 percent)	0 (0 percent)	29 (72 percent)

Based on the input and output data given by the farmers in the survey, a gross margin is calculated for each farm. Two outputs of sheep farming are considered: sale of wool and of live sheep. Inputs include costs for deworming, dipping, inoculation, castration of lambs, feeding, personnel and shearing. Table 2 compares the averages of main costs directly accountable to wool production and gross margins in the three villages.

Table 2. also gives the results of One-way Anova tests, which are computed to test the hypothesis that the mean values of the costs of the farmers in the three villages are equal[2]. A high F value supports the rejection of the hypothesis, indicating that the mean values are not equal. A F-value with ** rejects the hypothesis at a 95 percent confidence interval, and a * refers to a 90 percent confidence interval.

Table 2: Statistical comparison of some key-characteristics for sheep production in 3 villages in Transkei (Rand per sheep)

	Mhlahlane (n = 18)	Xume (n = 47)	Luzie (n = 40)	F
Cost of deworm	1.3	4.6	9.0	17.25**
Cost of dipping	0.00	0.68	10.30	35.70**
Cost of inoculation	4.06	4.63	8.69	6.78**
Medical cost	5.39	9.92	28.04	23.78**
Revenue from wool	2.76	1.68	13.13	45.10**
Gross margin for sales wool	-5.53	-9.50	-18.83	3.82**
Gross margin for sales of wool and sheep	6.41	17.12	29.98	2.38*
Gross margin for sales of wool and sheep, (incl. sheep bought as input)	4.31	4.65	22.80	1.99

Farmers in Xume and Luzie have distinctively larger flocks. The farmers in Luzie show a better management of the production (e.g. higher numbers of Dohne Merino, extra feeding, more deworming, inoculation, dipping occur). Luzie is the only of the three villages with a shearing shed in operation securing for a higher wool price. Due to the organisation of harvest and post harvest handling and the organisation of the wool sales through the shearing shed, the average price of the wool in Luzie (R3.09/kg) is much higher than the average price in Mhlahlane (R1.01/kg) and Xume (R1.08/kg).

The overall bad financial results for wool production should be interpreted with care. The gross margin takes into account all costs for sheep farming, which are not all to be attributed to the production of wool. It gives an indication of the overuse of inputs in Luzie as well as for the importance of the sales of sheep as income source. The wool is still considered as a by-product so that wool sales on its own are not financially viable.

The physical condition of the sheep can be improved by extra feeding and more intensive inoculation, dipping and deworming. This enhances the production of wool, the quality, and the selling price of the sheep, resulting in a higher cash flow. The best farms are those that apply appropriate technologies. Moreover an increase in the number of grazing hours per day can have a positive effect on the condition, if more deworming and inoculation is applied. The revenue of wool, expressed per sheep, is positively correlated to the number of hours grazing per day (Pearson correlation: 0.421**) and to the expenditures of feed per sheep (Pearson correlation: 0.625**). A better physical condition of the sheep increases the meat production that will increase the selling price per sheep (Pearson correlation between price of a sheep and the expenditures of feed per sheep is 0.632**). It will also increase the reproduction and diminish the need to buy sheep. The possibly larger flock and the increased retail price result in an even higher cash flow.

The higher use of inputs is beneficial to the total production. However considering wool production only, the high average costs in Luzie would indicate an overshoot of the inputs used. It is not possible to give conclusive indications of good practices on the basis of the analysis of gross margins. The farmers in Luzie generate a higher output from the sales of wool than do farmers of the other two villages. But this is not reflected in the gross margin for wool production, as the farmers in Luzie spend relatively more on inputs per sheep. These costs are covered by better sales of sheep, generating a relatively higher gross margin for sheep production as a whole. One can therefore not conclude on the basis of the non-equal gross margins, if the existence of a shearing shed contributes to the success of wool farming. Therefore a relative comparison of the efficiency of farms is required.

4. EFFICIENCY ANALYSIS

The farmers producing wool in Luzie receive the best extension and marketing support, and hence the best prices per kg of wool. Paradoxically, this does not reflect in their gross margin of wool production. This indicates

that the farmers overshoot on their use of input, in case only wool production is considered. The negative result is offset by the sales of live sheep. This shows that the productivity of the wool production on the farms in Luzie is low.

Total factor productivity is defined as the ratio of all outputs of a firm to all inputs that it uses (Coelli *et al*, 1999). A firm is considered efficient when the benefits of all economic activities is maximised (Tregarthen & Rittenberg, 2000). Allocative efficiency results from a well-selected input combination to produce a quantity of output at a minimum cost (Farrell, 1957). Farrell (1957) also introduced the concept of technical efficiency as the *ability of a firm to obtain a maximal output form a given set of inputs, given the production technology.* Our paradox and its underlying reasons can be confirmed by a low technical efficiency of the farms in Luzie relative to the farms in Xume and Mhlahlane, and reversibly for the allocative efficiency.

As our interest is to compare the better farms with the less performing farms, we opted for a frontier analysis[4]. Farms operating on the frontier are considered to be efficient. For all other farms, the efficiency can be described relative to the frontier. Charnes *et al* (1978) introduced a "data envelopment analysis" (DEA) to calculate the efficiency frontier introduced by Farrell (1957). This non-parametric model does not require an econometric estimation of a parametric function, which is necessary if inefficiency is measured using a stochastic frontier (introduced by Aigner *et al*, 1977 and Meeusen & Van den Broeck, 1977). Both DEA and stochastic frontier analysis can be applied to cross section data (Coelli *et al*, 1999).

In this paper, the Data Envelopment Analysis (DEA) method is used. It measures efficiency from a piecewise-linear production frontier, drawn by enveloping the data points representing farms that are technical efficient (Charnes *et al*, 1978). The points are calculated in separate linear programming models that maximise for each farm the output over input ratio, given a set of input constraints (Charnes *et al*, 1978, Otsuki & Reis, 1999 and Coelli *et al*, 1999). The DEA model introduced by Charnes *et al* (1978) assumed constant returns to scale and was input oriented. Banker *et al* (1984) published the application of a variable returns to scale model. Allocative efficiency is calculated when prices of inputs and outputs are taken into account.

A DEA model computes relative efficiency scores. It calculates an (technical or allocative) efficiency score for each farm relative to the most efficient farms in the sample (which are attributed a score of 1). The model used for this article

accounts for variable returns to scale. As shown in the gross margin analysis, some farms are using more inputs than would be optimal to reach a certain output. As we can not assume the output to rise accordingly to the use of inputs, variable returns to scale model is used. The model is output-oriented as farmers are assumed to be output maximisers and input minimisers.

Based on Coelli *et al* (1996, 1999) the following models are assumed and tested:

Technical efficiency of all farms with variable returns to scale: (efficiency is defined as the ratio of weighted sum of output over the weighted sum of inputs)

$$\text{Max TE} \quad \text{s.t.} \quad X\lambda \leq X_i$$
$$Y\lambda \geq TE_i Y_i$$
$$\lambda \geq 0 \;\&\; \sum\lambda = 1$$

λ: 105 x 1 vector of weights; X: input vector of 5 x 105 matrix; Y: output vector of 1 x 105 matrix

Allocative efficiency of all farms with variable returns to scale:

$$\text{Max AE} \quad \text{s.t.} \quad X\lambda \leq X_i$$
$$Y\lambda \geq AE_i Y_i$$
$$\lambda \geq 0 \;\&\; \sum\lambda = 1$$

λ: 105 x 1 vector of weights; X: input vector of 11 x 105 matrix; Y: output vector of 5 x 105 matrix

Although farmers also have other agricultural activities, the analysis focuses on sheep production. In the model for technical efficiency the output is assumed to be kg wool per sheep[5]. The breed, the number of times of dipping, inoculation and deworming in a year and the number of hours grazing a day are considered as inputs. The revenue of the farm is taken (in Rand) as output in the model to calculate the allocative efficiency. Selling and buying sheep appear to have a large influence on the cash flow. All variable cash inputs that are used in the sheep production are taken into account.

The efficiency scores are calculated using two different computer programmes: (1) DEA-solver (www.emp.pdx.edu/dea) to calculate the efficiency within a village. This programme is limited to an entry of 50 farms.

(2) EMS (Efficiency Measurement System, Scheel, 2000) in which the efficiency of 105 farms can be calculated.

An economic efficiency of a farm can be calculated by multiplying the technical and allocative efficiency. But this falls beyond the scope of this article.

5. RESULTS

5.1 Technical efficiency

Overall, the technical efficient farms are situated in Luzie and Xume, while Mhlahlane is counting more inefficient farms. This can be explained by the fact that Mhlahlane is not a beneficiary of the LandCare project, and does not have access to a shearing shed and technical assistance.

The average technical efficiency of the total sample is 42.3 percent. The average technical efficiency[6] in Mhlahlane, Xume and Luzie are respectively 37.4, 46.2 and 39.8percent. In Mhlahlane, more farms are inefficient relative to the best performing farms in the sample. This indicates a suboptimal production on these farms as we assumed the farmer to be an output-maximiser at a given a quantity of inputs. Inefficient farms do not reach the hoped-for result. Irrespective of the existence of a shearing shed and extension service, a large number of farms performed less good compared to the best.

A One-way Anova test confirms the hypothesis of equal means of the technical efficiency over the villages. The farmers in Luzie do, on average, not perform better than the farmers in the other villages. Given the farms of Luzie form the frontier, the gap between efficient and inefficient farms in Luzie is large. This is confirmed in a DEA frontier model for the respective villages.

Using the DEA solver programme, it is possible to investigate on the factors influencing the efficiency rates for the farms in each of the villages separately. For the farms both in Luzie and Xume, two distinct groups can be identified: a small group of farms with efficiency between 70 and 100 percent, and a larger group with efficiency around 25 percent.

An analysis of the farms in Xume (where 10.6 percent of the farmers are efficient at 100 percent score) shows that more efficient (or less inefficient) farms are characterised by practises of dipping and grazing. Dipping can be a remedy against the severe losses due to sheep scab. Flocks are easily

contaminated in the communal grazing areas, so that regular dipping is essential.

In Luzie, 12.5 percent of the farms score a technical efficiency higher than 70 percent, the gap between the group of efficient and inefficient farms is larger than in Xume and Mhlahlane. Some farms produce a high output relative to the inputs used, while a group of farms do not produce at a hoped-for level or overshoot on the use of inputs.

5.2 Allocative efficiency

In the calculation of the allocative efficiency the cash flow of the total farm (sheep and wool) is taken into account. A second analysis is done omitting the benefits of selling and buying sheep to compare the farms on the wool production. And in a third exercise a ratio of the cash flow for every farm and the number of sheep is considered as output.

The average allocative efficiency of the total sample and all revenues taken into account is 70.4 percent. For the farms in Mhlahlane, Xume and Luzie, the average allocative efficiency (all farms considered) is respectively 57.7 percent, 58.6 percent and 89.9 percent. Compared to the averages of the technical efficiency, it is clear that although farms are not technical efficient, they still can be allocative efficient. This is especially true for the farms in Luzie.

The farms of Luzie envelop the largest part of the efficiency frontier as 80 percent of the farms are allocative efficient, and only a very few are less than 50 percent efficient. The frontier envelops also the 40 percent best farms from Xume and the 38 percent best farms from Mhlahlane. The other farms from Mhlhalane and Xume are equally spread over the efficiency spectrum. In the lower half relatively more farms from Mhlahlane are found. A number of farms in Luzie do not reach the potential output given the inputs invested, but can overcome part of the gap with the best farms by a good marketing. The better market conditions for wool in Luzie result in a better allocative performance relative to the farms in Xume and Mhlahlane. The shearing shed is essential for a higher wool price. Of the farmers member of the shearing shed, 84.2 percent can be considered as allocative efficient managers. This confirms the importance of a well-functioning shearing shed as marketing outlet for wool.

In a separate DEA model for the farms in Mhlahlane 44.4 percent of the farms is allocative efficient (all revenues considered). This is higher than the number

of farms being technically efficient. The relative inefficiency of the rest of the farms is due to a low selling price of the wool, low income from the sales of ewes and heifers and the high costs for inoculation and castration. The number of efficient farms in Mhlahlane further decreases when the efficiency is calculated per sheep. Only 22 percent of the farms are considered to be efficient. The reasons for not being efficient are similar to those above. If only wool production is considered very few farms are efficient, and the majority compute efficiencies below 25 percent. This would indicate that a small number of farms (34 percent) can maximise the production of wool, while for the bulk of the farms, wool is a by-product to be sold. Low income and high costs contribute to the findings of farms operating inefficient.

Xume counts 43 percent allocative efficient farms. A number of farms is not technically efficient but is allocative efficient and the gap between efficient and inefficient farms diminishes. The factors involving the lower efficiency are the low income from wool sales, and sales of animals and high costs of veterinary care. High costs for labour and extra feed explain the relative low efficiency of some of the farms. Considering the wool production separately, the analysis shows that the number of efficient farms decreases. The low income from wool, the high costs for shearing and veterinary care further decrease the allocative efficiency.

In Luzie, the number of allocative efficient farms is higher than in Xume and Mhlahlane. In Luzie 75 percent of the farms are considered allocative efficient when the total sheep production is considered, which is very high compared to Xume and Mhlahlane. This clearly shows the importance of the shearing shed for marketing and dispatching information. When expressed per sheep, 55 percent of the farms in Luzie are 100 percent allocative efficient. The inefficient farms have relatively higher costs for medical care, shearing and feeding costs. If the selling and buying of sheep are not taken into account, the number of efficient farms further decreases to 37.5 percent, expressing the importance of the sales of sheep for the revenue of the farms. The factors inducing inefficiency are the labour costs, and as before the costs for shearing, medical care and feeding.

6. CONCLUSION

The efficiency analysis identified the factors influencing the production of wool in rural former Transkei. The relative low number of technical efficient farms in Luzie confirms the conclusion of the gross margin analysis. Wool production is not the main activity, and is considered as a by-product. A large

number of farms does not produce the feasible output given the inputs invested. The returns to input merely come from the sales of live sheep. Wool production in Luzie generates a higher average return relative to Xume and Mhlahlane, which is accountable to the operations of a shearing shed. The gross margin analysis confirms the high input level of the farms in Luzie. This calls for more extension on production practices if the farmers envisage a specialisation in wool production.

Not only above mentioned factors are problematic to the less efficient farmers. An even longer list of problems is withholding the farmers to upscale their business to a commercial level. Farm-level problems, mostly due to a lack of knowledge of the farmer and a lack of financial means to buy the necessary products and feed, cause a low wool production. Some of those problems and also problems causing a low price for the wool are due to the institutional arrangements and the village organisation. Villagers are linked by a strong traditional community feeling, aiming at providing a livelihood for all and reducing risk of hunger. But globalisation and integration of the villages into the economy obliges the farmers to commercialise to have a viable business. Producing wool would be an obvious option, because it is a raw cash crop, which can generate income on a sustainable base.

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NOTES

1. *The name of the districts have been changed since the survey took place. The district of "Tsomo" was renamed to "Intsika Yetu" and "Mount Fletcher" has changed to "Elundini". For this paper, the names of the districts at time of the field work will be used*

2. *The F-statistic for the comparison of the cost data was compiled on logtransformed data, in order to fulfil the statical requirement of normality of the distribution.*

3. *The calculation of Pearson correlations was conducted in SPSS to measure the linear relationship between two variables. A ** indicates that the correlation coefficient is significant at 0.01 level.*

4. *Total factor productivity can, for example, also be measured by least-squares econometric production models and total factor productivity indices, but these models are most applied to time-series data and not cross section data and do assume all firms to be technically efficient (Coelli et al, 1999). Therefore they are not applicable to the current analysis.*

5. *We could opt for other output measures such as total farm output in kg wool adjusted for quality differences, but no data was available on the quality of the wool sold. The wool originating from Mhlahlane and Xume was not classed by the farmers and known at Cape Wools as Ciskei/Transkei character (Cape Wools SA, 2000). For Luzie the quality of the wool is reflected by the difference in retail price (and income). The mean is 3.9 R/kg and standard deviation 1.44, suggesting the effect of difference in quality to be minor.*

6. *All farms entered in the calculation.*

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