

Optimal feeding systems for small-scale dairy herds in the North West Province, South Africa

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Land redistribution was legislated in 1994; it was designed to resolve historical imbalances in land ownership in South Africa. Between 2002 and 2006, a longitudinal observational study was conducted with 15 purposively selected small-scale dairy farmers in a land redistribution project in Central North West Province. Four farmers left the project over the period. For the purposes of this study, a small-scale dairy farm was defined as a farm that produces less than 500 L of milk a day, irrespective of the number of cows or size of the farm. The study was conducted in three phases. In the first phase, situational analysis using participatory rural appraisal (PRA) and observation was used to outline the extent of the constraints and design appropriate interventions. Feeds that were used were tested and evaluated. In the second phase, three different feeding systems were designed from the data obtained from PRA. These were: (1) A semi-intensive farm-based ration using available crops, pastures and crop residues with minimal rations purchased. (2) An intensive, zero-grazing dairy system using a total mixed ration. (3) A traditional, extensive or dual-purpose system, where the calf drank from the cow until weaning and milking was done only once a day. In the third phase, adoption was monitored. By July 2006, all remaining farmers had changed to commercially formulated rations or licks and the body condition score of the cows had improved. It was concluded that veterinary extension based on PRA and a holistic systems approach was a good option for such complex problems. Mentoring by commercial dairy farmers, veterinary and extension services appeared to be viable. Further research should be done to optimise the traditional model of dairy farming, as this was relatively profitable, had a lower risk and was less labour intensive.

Introduction

Land redistribution programmes may alleviate poverty by creating smaller units and semi-intensive or intensive agricultural enterprises. Small-scale dairy farming has proven to be a very successful development strategy in other countries (Bebe 2003; Draaijer 2002; Kitanyi, Miinde & Relma 2003; Omere 2003; Phelan 2003).

Available statistics from North West Province (NWP) show that there were approximately 257 000 dairy cattle, with the greatest numbers in the Central Region (175 235) and smaller numbers in the Western (59 852) and Eastern (21 873) Regions. In 2002, these cattle produced approximately 230.4 million litres of milk (12.5% of national production), with an estimated value of R304.1 million, at R1.32/L; this excluded value-added products in the form of cheese, yoghurt and milk powder. This production originated from 45 714 cows in milk daily (17.8% of the dairy herd), which translated into an average production of 14 L per cow per day (Prozesky, McCrindle & Sebei 2003).

With land redistribution and restitution strategies being implemented in South Africa, in order to redress the inequalities of apartheid, new players were entering the agricultural sector. They often had little experience or knowledge. Extension became an important tool in bringing these small-scale farmers up to a commercial level (Prozesky *et al.* 2003). There is lack of detailed information about nutrition and its relationship to productivity in the small-scale sectors on which to base recommendations for improvements. This has formed the basis for the current study, which focuses on the constraints for successful nutrition of dairy cows belonging to farmers identified by the Provincial Department of Agriculture, Conservation and Environment (DACE), with the aim of developing extension messages and skills training for both field staff and small-scale farmers.

Materials and methods

Initially, 15 small-scale dairy farms in the areas of Lehurutshe, Ramatlabama, Geysdorp, Potchefstroom, Klerksdorp and Wolmaranstad were purposively chosen for a longitudinal study to be conducted between 2002 and 2006. For the purposes of this study, a small-scale dairy farm

was considered to be one that produced less than 500 L per day, irrespective of the number of cows or size of the farm. The farmers used different farming systems and milked different breeds, including Friesland, Jersey, Brown Swiss, Bonsmara and cross-bred cows. The model system was a small-scale dairy farming system and the experimental design was based on a holistic approach and participatory rural appraisal (PRA) (Chambers 1994; Thrusfield 2005) followed by extension and impact assessment.

The first phase began in 2004, with situational analysis using PRA and observation to outline the extent of the constraints and design appropriate interventions. Feeding was identified as a constraint and feeds used by the farmers for feeding dairy cows – both supplements and roughage – were tested and evaluated.

In the second phase (2005) three different feeding systems were designed from the data obtained from PRA and the results of the feed tests, in consultation with small-scale dairy farmers, established commercial dairy farmers, state veterinary and agriculture staff, feed manufacturers and distributors and the Milk Producers Organisation (MPO). These systems were discussed with the farmers and they were asked to choose which of the three systems they would like to implement, with support of the extension and veterinary staff of NWP and the research team. The third phase (2005–2006) was field-testing of these interventions and observation of the implementation by farmers, using production records and on-farm observation of the farming system used.

The level of effective nutritional management was estimated using the body condition scores (BCS) of individual cows, measured on a one to five scale (Ferguson, Gallagan & Thomsen 1994; Gerloff 1987; Grant & Keown 1990; Hady, Domecq & Kaneene 1994; Keown 1996 1997).

When representative feed samples are tested chemically, accurate predictions of animal performance can usually be made because the nutrient requirements are published as chemical analysis results (Dugmore, Jones & Stewart 1995; Given, Axford & Omed 2000). Feeds were observed for quality and 500 g of each feed was sampled per farm for analysis. The following classes of feed were sampled:

- Hay and crop residues: types of hay or crop residues seen during the situational appraisal included lucerne (alfalfa), peanut hay and maize stover.
- Supplements.
- Commercial rations, licks and concentrates: where commercial concentrates were used alone or as part of a total mixed ration, the manufacturers' specifications were used.

The laboratory used for analysing feed was the Agricultural Research Council (ARC) Feed Laboratory at Irene, Pretoria, South Africa. The following chemical tests for feed analysis were chosen because they were available and accessible to small-scale dairy farmers in the study area:

- Dry matter (DM) analysis (Bredon, Steward & Dugmore 1995; Dugmore *et al.* 1995)
- Crude protein (Howard *et al.* 2002; Huber 1984)
- Crude fibre (Dugmore *et al.* 1995; Harris 1992)
- Total digestible nutrients (TDN) (Dugmore *et al.* 1995)
- Minerals (only calcium and phosphate) (Grant *et al.* 1997)
- Ether extract (fat) (Anderson, Grant & Mader 1995)
- Metabolisable energy (calculated) (Anderson *et al.* 1995; Church & Nipper 1984)
- Non-structural carbohydrates (Anderson *et al.* 1995; Brand, Noordhuizen & Schukken 1996; Perry, Cullison & Lowry 1999).

Data on the input costs of feed used were obtained from the farmers and recorded. A farmers' day was held in February 2005 where the results of feed analysis and advice on feeding were given to all farmers. Three systems (these are fully described under Results) to optimise dairy nutrition in the study area, based on seasonally available feeds and the observed farming systems, were developed in consultation with all stakeholders. In May 2005, the farmers were asked to choose which of the three feeding systems they would implement. Monthly, individual farm visits continued, and advice and recommendations were given to each farmer. In 2006, the implementation of the systems was recorded and evaluated.

The data were analysed using a computer spreadsheet (Microsoft Excel®, USA). As this was an observational study, counts of nominal data were used for proportionate comparison, as described by Thrusfield (2005). Each individual subject (farm) was compared before and after intervention and the proportionate difference in measurable variables (such as BCS and average milk yield per cow and per herd) was tabulated.

Results

Originally, there were 15 farmers, but over the period of 2002 to 2006 four farmers dropped out for various reasons. One female farmer left because she decided to farm with beef cattle and another because her husband died and her nearest male relative advised her to leave the project. Two of the community projects left the study, one because their two cattle died and the other because they changed their focus and concentrated on vegetables.

It was found that 73% ($n = 11$) of respondents were grazing their cattle on their own farms, with farm sizes ranging from 5 ha to 600 ha, with an average size of 259 ha. One respondent was grazing his cattle on communal land, one was on a leased farm and two practiced zero grazing (Table 1).

Table 2 shows the tested values for each ingredient used by the farmers compared with the levels as suggested by the National Research Council (NRC) (National Research Council [NRC] 1989). The proportions of the ingredients in the supplement mixtures made by the farmers were not

standardised and so the ingredients were analysed separately. It may be noted that Farm 8 and Farm 15 had rations that approached the norms for a dairy ration, if they were mixed in the correct proportions. The other ingredients were not in agreement with the suggestions of the NRC (1989) tables, which are used internationally as standards for dairy rations.

The feed sampling on farms and data analysis of results of the feed samples obtained from the farmers, as well as further observations and structured interviews on their farming systems, resulted in the design of three types of interventions (feeding systems):

TABLE 1: Land tenure, size of farm and nature of grazing used for the dairy cows.

Code	Tenure	Size (Ha)	Nature of grazing
1	Own farm	475	175 ha veld† grazing
2	Own farm	5	5 ha veld grazing
3	Communal	Communal	Communal grazing and 3 ha planted with lucerne
4	Own farm	300	160 ha veld grazing
5	Own farm	340	339 ha veld grazing and 1 ha planted pasture
6	Own farm	600	50 ha planted pasture and 250 ha veldt grazing
7	Own farm	450	150 ha veldt grazing and 300 ha crop residues
8	Own farm	294	34 ha veld grazing and 260 ha crop residues
9	Own farm	118	114 ha veld grazing and 4 ha crop residues
10	Zero grazing	330	2 ha allocated for dairy cattle (zero grazing)
11	Own farm	21	10 ha veld grazing and 4 ha planted pasture
12	Own farm	200	200 ha veld grazing
13	Own farm	80	20 ha veld grazing, 20 ha planted pasture and 40 ha crop residues
14	Leased farm	114	114 ha veld grazing
15	Zero grazing	339	339 ha for fodder, maize and silage production

†, Veld, South African natural grasses.
Ha, hectare.

TABLE 2: Deficiencies in the rations used by farmers ($n = 11$) sampled at the end of the dry season (2004), in comparison to National Research Council (1989) recommendations for dairy feeds.

Farm Code	Ration Ingredient	Protein	Calcium	Phosphorus	Crude Fibre	TNC
1	Mixture (Maize stalk, groundnut, molatek, ground maize).	6.42	0.58	0.08	21.45	20.39
	Maize stalk	1.91	0.12	0.02	31.08	9.76
2	Chicken litter, sunflower, sorghum	17.27	0.96	0.72	23.74	10.65
5	Maize stalk, ground maize	3.22	0.25	0.05	31.62	8.61
6	Salt lick	5.25	-	-	-	-
7	Cabbages	2.40	0.51	0.03	1.54	4.15
8	Maize stalk, bean residue, sunflower, ground maize	4.88	0.52	0.08	28.41	10.04
	Bone meal, salt, winter lick, Kalorie 3000	3.21	2.08	0.52	-	-
	Multi lick 21	18.84	3.63	0.14	6.63	39.30
9	Maize stalk, ground maize	5.25	0.04	0.08	16.41	35.30
	Winter lick, salt	7.97	1.65	0.04	1.80	5.65
12	Sunflower, maize stalk	23.04	1.11	0.64	5.35	36.88
13	Sunflower, maize stalk	7.79	0.72	0.35	21.83	7.12
14	No supplement fed	-	-	-	-	-
15	Production lick	23.82	2.26	0.67	7.18	24.80
	Nutri Lick	25.72	1.11	0.19	8.77	21.43
	Nutri Melk	14.81	0.92	0.55	9.78	33.28
	Cow peas	7.19	0.52	0.11	37.83	10.82
	Peanut hay	11.45	0.55	0.16	21.97	19.18
	Tef	5.53	0.18	0.06	32.73	9.19
NRC recommended % for dairy rations		NRC* 13–15%	NRC* 0.8%	NRC* 0.5%	NRC* 18–20%	NRC* 65–68%

NRC, National Research Council; TNC, total nutrients content.

- For the intensive dairy production systems, where there was a large area of cropland, the feeding system suggested was linked to seasonal fodder flow and enterprise analysis. Experts in farm design, commercial dairy farmers in the area and feed suppliers were consulted and a fodder flow programme (including planting schedules) was designed. This was called *Option A*.
- For those farmers who were buying in ingredients and mixing their own feeds, a total mixed ration (TMR) was designed, in consultation with feed suppliers and manufacturers, which would be more economical, of better quality and better balanced than the feed currently being utilised. This was called *Option B*.
- For the group of farmers using a more traditional, dual-purpose type of dairy system where the cattle were grazing natural or planted pastures and supplemented mainly in the dry season, a production lick was designed that would meet their requirements. This was called *Option C*.

These three options are contrasted in Table 3. The nutritional data of options mentioned above are shown in Table 4.

The feed had relatively high moisture content and so the cows were fed twice a day (approximately 21 kg per cow per feed). The total DM of the feed represented in Table 5 was 19 kg and this would be suitable for a cow producing 19 kg of milk per day. The income from the milk was R2.00 per litre, so total income was R36.00 and the profit per cow per day was R15.90. The feed produced on farm was used mainly as roughage and a concentrate bought from the local farmer's co-operative provided the protein and minerals (Senwes Veevoer [Pty] Ltd, North West Province).

Using the EconoTGR (Senwes Veevoer (Pty) Ltd, North West Province) total mixed ration (Table 6) below, the estimated

consumption per day for a cow of 600 kg with a BCS of three and a milk production of 19.0 kg per day would require a dry matter intake of 16.6 kg per day. The approximate ratio of concentrate to roughage at this feeding level would be: EconoTGR 14 kg plus eragrostis hay 4.5 kg per day. The cost per day would be R22.10 and if the milk were sold at R1.80 per litre, the profit margin would be R12.10 per cow per day. According to information obtained from the EconoTGR label, the composition of the TMR was: protein 15 (minimum); calcium 1; phosphate 0.4 and fibre 20 (maximum).

The ingredients for feeding *Option C* the traditional method based on supplementation of natural grazing, are shown in Table 7a, with purchased licks in Table 7b.

The lick described in Table 7b was obtained from the local farmers co-operative at Mafeking (Animal Health and Feed Distribution Company Ltd, Mafeking); Leo Superkos Ltd (CC) produced it. Cows in milk should be supplemented with this 'summer lick' at a level of 1.5 kg per cow per day. As it had a higher energy level, the cost was R74.00 for 50.0 kg. The winter lick was for non-productive animals such as bulls, or given to pregnant cows in winter, if fed with good-quality roughage such as lucerne or maize stover with cobs. This winter lick (R71.00 for 50.0 kg) was used for maintenance to supplement minerals and protein on poor winter grazing. Energy levels were low, but non-protein-nitrogen and minerals were higher, so it was fed at only 400 g – 500 g per animal per day. For the summer lick, the cost for 1.5 kg was R2.13. If the cow was feeding a calf and the owner got 5 L a day from one milking

TABLE 3: Feeding options.

Characteristics	<i>Option A: Intensive and crop based</i>	<i>Option B: Small scale, Total mixed Ration</i>	<i>Option C: Traditional and dual purpose</i>
Average size of farm (Hectares)	400 hectares and above	< 5 hectares per cow	Portion of land > 5 hectares per cow
Infrastructure	Milking parlour Milking machine Crush pen Drinking and feeding troughs Electricity	Milking parlour Milking machine Crush pen Drinking and feeding troughs Electricity	Crush pen Drinking and feeding troughs
Risk level	High risk, for example drought	High risk, due to high capital inputs	Low risk, due to low inputs and cattle can easily be sold
Labour	Very intensive	Labour intensive	Not labour intensive
Cash flow and credits opportunities	Very important because of inputs required seasonally to plant crops	Very important because of monthly feed costs	Less important because inputs are low and sporadic – buy licks or supplement or roughage only when needed
Marketing strategy	Formal channels	Formal and informal	Mainly informal
Breeds	Friesland, Jersey	Friesland, Jersey	Cross breeds, Indigenous, Simmentaler, Brown Swiss (Dual purpose)
Estimated lactation length (days)	300	300	270
Weaning period	0 – 5 days	0 – 14 days	6 – 8 months
Price per calf at sales	R100 – R250	R100 – R150	R1900 – R2500
Source of feed	Mainly farm grown mixed ration	Total mixed ration purchased	Grazing and supplements
Amount of feed fed per cow per day	According to milk produced per milking	20 kg per day per cow (TMR feed @ R1.60 /Kg)	500g* daily during milking or lick supplementation in kraal
Feed cost per cow per day	R10.42 per cow day (for 20 L† per day)	R32.00 (For 20 L†)	R1.00 (cost of lick-grazing at no cost as they are on communal grazing or state land)
Hours spent on grazing	4 h – 8 h hours per day	Zero grazing	8 h – 12 h
Number of milking per day	2 – 3	2 – 3	1
Estimated litres per cow per day	20 L – 40 L	20 – 40 L	5 L – 10 L
Estimated price per litre of milk	R1.60 – R2.00	R3.00 – R4.00	R3.00 – R4.00
Estimated average milk produced per lactation or cow (L)	6000 L – 12 000 L	6000 L – 12 000 L	1350 L – 2700 L
Estimated feed costs per cow per year (365 days)†	R3803.30 per year for 20 L per day	R11 680.00 for 20 L per day	R365.00 irrespective of production level
Annual medication and maintenance costs/cow‡	R250.00	R250.00	R50.00
Estimated income per cow per annum (Rands)†	R9 600.00 – R24 000.00	R18 000.00 – R48 000.00	R4050.00 – R10 800.00
Estimated minimum profit§ per cow per annum (Rands)	R5696.70	R6220.00	R4635.00

†, Estimates based on 20 L, as no cows in study had achieved 40 L per day.

‡, Estimated from PRA.

§, Milk sales plus calf less maintenance and feed (lowest figures used).

¶, Farmers used the 'winter lick'.

L, litres

TABLE 4: Ingredients of recommended feed for *Option A: Field Crops on farm.*

Type of feed	DM† (%)	Crude protein	Crude Fibre	Calcium	Phosphorus	TDN
Cowpea hay	90.00	18.54	23.22	1.21	0.29	55.98
	100.00	20.60	25.80	1.34	0.32	62.20
Japanese Radish (late autumn – roots)	5.04	1.03	0.34	-	-	4.03
	100.00	20.60	6.70	-	-	80.00
Maize (dough stage – silage)	30.00	2.10	7.70	0.07	0.06	19.50
	100.00	7.00	25.70	0.23	0.20	65.00
Lucerne (not wilted)	24.70	4.10	7.95	0.35	0.08	13.58
	100.00	16.60	32.20	1.42	0.32	55.00
Peanut hay	90.00	12.33	20.97	1.12	0.13	50.00
	100.00	13.70	23.30	1.24	0.14	55.10

†, DM indicates whether the figure is on a dry matter basis (100%) or 'as fed', the moisture is then subtracted.

TDN, total digestive nutrients; DM, dry matter.

Source: Bredon *et al.* (1995)

at a selling price of R4.00 per litre, the profit would be R20.00 minus R2.13 = R17.87 per cow per day. However, it was observed that the farmers were using only about 500 g – 700 g per day and, thus, the cost per cow per annum was estimated to be R365.00.

Financial records, which include farmers' everyday costs, are tabulated in Table 8. No detailed financial records were kept, except by Farmer 15. It can be seen that some of the farmers used grass (veld) grazing, whilst others kept their cows on crop residues, depending on the season. Crop residues were only available in winter.

TABLE 5: Ration formulation for Option A: Example of ration worked out for Siyaya project.

Ingredient	Mass (kg) as fed†	Price
Silage (maize at dough stage)	20	R4.00
Japanese radish	10	R0.30
Cowpea hay	3	R2.40
Peanut hay	2	R0.80
Nutrimilk Opti 21%® Senwes Veevoer (Pty) Ltd.	7	R12.60
Total	42	R20.10

†, Total DM from the 42kg as fed is 19kg.
DM, dry matter.

TABLE 6: Ingredients of recommended feed for Option B: Meadows Feeds (Pty) Ltd., EconoTGR® ingredients.

Ingredient	DM†	Crude Protein	Crude Fibre	Calcium	Phosphorus	TDN
Cotton seed	90.00	19.99	20.70	0.14	0.68	80.91
	100	22.21	23.00	0.16	0.76	89.90
Molasses	73.00	3.50	-	0.66	0.08	54.97
	100	4.80	-	0.90	0.11	75.30
Molasses meal (powder)	90.00	2.79	0.54	-	-	68.49
	100	3.10	0.60	-	-	76.10
Lucerne (wilted)	36.20	6.30	11.40	0.51	0.12	21.50
	100	17.40	31.50	1.41	0.33	59.40
Soyabean (straw)	88.90	3.91	41.16	1.30	0.05	38.58
	100	4.40	46.30	1.46	0.06	43.40
Maize meal	88.70	8.70	0.62	0.01	0.14	81.16
	100	9.80	0.70	0.01	0.16	91.50
Cottonseed hulls	92.30	3.88	43.01	0.14	0.09	38.00
	100	4.20	46.60	0.15	0.10	41.20
Sunflower hulls (mature)	22.30	1.60	8.89	0.35	0.04	10.39
	100	7.00	39.00	1.53	0.18	45.60
Eragrostis hay	44.30	39.80	14.61	0.11	0.05	25.47
	100	9.00	33.00	0.25	0.11	57.50
Meadow Feeds TGR® Concentrate	Information not provided					

†, DM indicates whether the figure is on a dry matter basis (100%) or 'as fed', the moisture is then subtracted.
TDN, total digestive nutrients; DM, dry matter.

TABLE 7a: Ingredients for option C: feed value of natural grazing in winter and summer.

Type of Feed	Crude protein	Crude fibre	TDN	ME (MJ)
Summer veldt grazing†	10	26	57	8.5
Winter veldt grazing†	3	36	45	6.7

†, Rain fall region.
TDN, total digestive nutrients.
ME (MJ), metabolisable energy (mega joules).
Source: Neitz (2000)

TABLE 7b: Ingredients for recommended feed for option C: Lick supplements for summer and winter.

Type Of Feed	Protein (min) g/Kg	Protein From Urea %	Calcium g/Kg	Fibre g/Kg	Phosphorus g/Kg	Energy MJ/Kg	Urea (Max) g/Kg
Summer Lick†	200	67.45	22	100	10	8.5	-
Winter Lick†	400	86.10	45	50	15	-	120

†, Information obtained from feed tag: Leo Superkos C.C. Super Summer lick® Reg No V14846 and Super Cattle Lick® Reg. No. V12850 (Act 36/1947).
Note: This information is for the feed 'as fed', the DM 100 figures are unavailable.

Table 9 shows the weekly milk production of the farmers in 2005 and 2006. Although there is not much change in the milk produced, the main reason for this was the sudden increase in the price of beef, which made the traditional option more viable if the calf was allowed to drink. The milk levels measured were obtained in addition to the calf drinking milk. However, the figures are not very reliable, as certain workers who milked the cows were illiterate. In May 2005, the average live-weight price for a 200 kg weaner was R10.00 to R12.00 per kg. By May 2006, this had risen to R12.00 to R15.00, with top weaners reaching R17.50 per kg.

A better reflection of the effect of the farmers paying more attention to the feeding of their cows as the study period progressed was the body condition score (BCS), as shown in Table 10.

Discussion

All of the farmers studied had different types and sizes of land and breeds of cattle, and therefore were not easy to compare. They are not similar to commercial farmers, where all the cows are the same breed and size and milked in the same way. However, they present a more realistic picture of

the informal dairy sector. The results obtained are valuable, in that they show a great deal of variation in what is loosely called the 'small-scale farmer'.

One of the most important aspects of dairy farm management is the capacity to think and plan ahead. The dairy farmer must be able to visualise and plan for the number of tons of maize or lucerne required for his herd in the following year (Kinsey 1993). The present study's results agree with previous research that suggested this capacity might not be present in resource-limited farmers (Boyazoglu 1997). The main constraint identified during the present study is that the farmers had neither the knowledge nor experience needed to run a highly technical farming business. This resulted in a very haphazard and unplanned approach to record keeping and nutrition. There was no forward planning and the approach was reactive – only buying feed at the last minute when it had run out. This aspect was addressed by extension and mentoring; by 2006, seven of the farmers had begun to use fodder flow planning and culling of non-productive cows. The skills adopted by all farmers proved to be aging of cows by examination of teeth, as well as recording the birth of calves in order to determine calving percentages and length of lactation. However, milk recording remained a problem, as the workers were not always literate.

TABLE 8: Estimated feed cost per year per farmer (no costs allocated for farm produce) in 2006.

Farm Code	Feed type		
	Concentrates	Roughage	Lick
1	R1200.00	Farm produce	0
2†	0	Natural grazing	R5000.00
5	R1200.00	Farm produce	0
6†	0	Natural grazing	R1600.00
7†	0	Natural grazing, crop residues	R1200.00
8†	R2000.00	Farm produce and crop residues	0
9†	0	Farm produce on smallholding	R800.00
12†	0	R300.00	R1000.00
13†	0	Farm produce and crop residues	R1000.00
15	R27 375.00	R1500.00 purchased hay and farm produce	0

†, Only supplementing during dry season (from June to October) and sometimes only milking cows from the natural grazing (thorn-bushes and veld grasses).

TABLE 9: Weekly milk production 2005 to 2006.

Farmer Code	Milking sessions	TOTAL production per week, range (L)		Daily production per cow (range) litres	
		2005	2006	2005	2006
1	2	980 L – 2016 L	875 – 1330	7 L – 12 L	7 L – 9 L
2	1	90 L – 490 L	42 – 70	3 L – 3.5 L	2 L – 4 L
5¶	2	168 L – 1190 L	60 – 80	8 L – 10 L	6 L – 7 L
6	1	504 L – 1512 L	394 – 591	1 L – 8 L	3 L – 4 L
7‡	1	560 L – 1220 L	525 – 1120	5 L – 8 L	4 L – 8 L
8†	†	42 – 83	‡	3 L – 5 L	-
9	1	168 L – 672 L	‡	8 L – 16 L	-
12	1	105 L – 840 L	80 – 144	3 L – 11 L	3 L – 5 L
13	2	140 L – 490 L	340 – 540	5 L – 10 L	5 L – 13 L
14§	§	§	§	§	§
15	2	1232 L – 3403 L	1448 – 4438	11 L – 25 L	6 L – 25 L

†, Sold his dairy cows, farming with crops and kept only three cows for home use.

‡, None of workers can read or write.

§, Stopped milking due to his chronic illness.

¶, Conflicts amongst the beneficiaries.

L, litres.

According to Lanyasunga *et al.* (2005) feed must be routinely evaluated using standardised testing methods. Ration balancing becomes more challenging where natural or planted pastures are used for grazing (Church & Nipper 1984). The main objective of evaluating feed is to provide all nutrients, particularly protein, energy and mineral levels, in amounts required for optimum production in a cost-effective way (Moughan, Verstegen & Visser-Reyneveld 2000). In the present study, chemical analysis was done on the concentrates and roughages used by the farmers. These were found to be very low in protein and energy. Minerals were deficient and the feed itself was of very poor quality and palatability. It was not surprising that the BCS of the cows was initially low and that mortalities occurred in winter. Lack of adequate quantity and quality of feed is recognized as a major constraint to milk production and reproductive performance (Guthrie & West 1994; Harris 1992; Spikes 1999). In winter, it was observed that protein-energy malnutrition and phosphate deficiencies could cause mortality when insufficient or poor-quality feed was provided to the pregnant dairy cows. It was realised that a radical shift in the quality of feed would have to be a priority and this was achieved in July 2006, when evaluation showed that most of the farmers had changed to balanced, purchased rations or supplements after local suppliers had been identified. Culling out old cows by looking at their teeth was also adopted by all farmers and applicable where no records of the ages of cows were available. Another extension success, adopted by all farmers, was the introduction of Japanese radish as an affordable green feed, at the suggestion of Dr Hendrik Geldenhuys, one of the mentors. This shift in farmer behaviour improved feed conversion, production and health of the cows. In Table 10, it can be seen that the average BCS of the cows increased from May 2003 when the study began to May 2006 when it ended.

According to Bembridge and Tapson (1993) it is essential that an integrated but decentralised rural or informal livestock production system is linked to the local markets and agro-industries. Bebe (2003) maintained that sustainable dairy development required a good infrastructure and effective support service and institutions. This precept was followed during the present study, with involvement of provincial

TABLE 10: Mean body condition score of cows.

Code	03 May	04 May	05 May	06 May
1	2.5	2.0	2.0	3.0
2	3.0	3.0	2.0	3.0
5	2.5	2.5	3.0	3.0
6	2.5	2.5	2.0	3.0
7	2.0	2.5	2.0	3.0
8	3.0	3.0	2.5	-
9	3.0	3.5	3.5	2.5
12	3.0	2.5	2.5	3.0
13	2.5	2.5	2.0	2.5
14	2.5	2.5	3.0	-
15	2.5	2.5	2.0	3.0
Average	2.64	2.64	2.41	3.00

agricultural and veterinary services, as well as mentorship by commercial farmers. Although three choices were given to the farmers and sufficient extension and mentoring given by experts, *Option A* and *Option B* were not implemented. They tended to revert back to what they knew and understood best – a low-input, low-output system with relatively high profit margins and flexibility that could meet the changes in the relative price of meat and milk. Interventions improved the general management of feeding, but did not manage to change farmers to the model for small-scale farmers used elsewhere in the world, that is *Option B*, TMR.

In the NWP of South Africa, which is a summer rainfall area, grazing alone is sufficient for supporting a daily milk production of 5 L – 7 L per 500 kg beef cow in summer. The protein and Metabolic Energy (ME) content of veld grazing in summer are 11% and 9.5 MJ/kg DM, respectively. In winter, veld grazing has a protein content of less than 5% and a metabolic energy content of less than 8 MJ/kg DM, which is not adequate to meet the maintenance requirements of cattle (Erasmus, Smith & Cronje 2000). In the present study, it was seen that dairy cows on veld grazing with correct supplementation, managed in the traditional way (*Option C*), could produce sufficient milk to raise a calf as well as 3 L – 9 L of milk per day once they were receiving commercial rations or supplements. It was, however, difficult to confirm the accuracy of the milk production figures, as milk recording was not always reliable. All cows in the project calved in 2005 and 2006, which was an unrecorded improvement in fertility, as the calving percentage was not specifically recorded in 2003. In later discussions, it was realised that fewer than half the cows in the project had calved that year. The sale of these calves was factored into the profits (Table 3).

Three dairy farming systems have been described in South Africa: dual purpose (extensive or traditional farming systems), semi-intensive and intensive (Maree & Casey 1993). In the dual-purpose system, low-producing indigenous or crossbred cows, used for both milk and calf production, were kept on extensive grazing with supplementation during winter (Bembridge & Tapson 1993). Although the dual purpose cow and traditional farming system had been phased out of commercial dairy farming by the time the present study took place, it was still being used in a modified form by small scale and communal farmers for combined

milk and meat production. Although this system is suitable for crossbred cows, the present study agreed with previous authors that high producing modern dairy cows, such as Holsteins, would require feeding above this level (Erasmus *et al.* 2000).

In intensive dairy farming systems, more animals per unit of land are kept in a well-managed manner mainly on zero grazing. In intensive dairy systems, cows are fed a full feed ration or total mixed ration (TMR) (Levirich 1997; McCullough 1994; Meissner 1993). However, the best economic returns from using TMR depend on the use of high-producing cows. This system is not suitable for low-producing dairy cows, as the inputs – feed, labour and infrastructure – are high (Miller, Polan & Soriano 2001). Although two farmers opted for a TMR system during the study, they found that the high cost of inputs was not sustainable and they reverted to a low-input, low-output system.

Farmers in the project became risk averse, this was partly because the promised state funding was often delayed and farmers did not have the financial resources to pay for electricity or purchase feed for the cows when things went wrong. Major expenses, such as repairs to the vehicles, feed mixers or tractors, were beyond their means. In addition, the price of meat increased dramatically, which meant that the traditional option became more profitable in 2006 and it was less labour-intensive to market the milk through the calves. It was therefore concluded that the traditional or dual-purpose option was probably a good idea for those with few cows and sufficient grazing.

One of the major problems not foreseen was the conflict seen between beneficiaries on community project farms. Economically, these farms cannot work because the profits are insufficient to provide a living wage for all the people who are on the farm. At Farm 5, for instance, there were originally 74 beneficiaries on a farm that had previously supported one farmer, his family and six labourers. With the number of cows, it was only possible to produce for home consumption and then there was no money to buy feed for the cows. This resulted in severe conflict and a high turnover of beneficiaries between 2002 and 2006. A similar problem occurred on Farm 15, although they had a larger herd and could sell the milk. It can be concluded that these farms are not good models for land redistribution, as it is impossible for beneficiaries to earn a living wage, no matter how hard they work.

Conclusion

It can be concluded that all three models are good options for small-scale farmers. The farmers in the project, however, preferred the low-input, low-output traditional model (*Option C*). This is probably because it has the lowest risk, and due to the constraints described in this study. Per cow income was also nearly two thirds of the high-risk intensive dairy farming models (*Option A* and *Option B*). It is recommended that the following be considered (Manzana 2007):

- Extension officers should receive extra training in dairy production if there are dairy farmers in their areas, as this is a highly specialised type of extension. They should also work closely with veterinarians, animal health technicians and the health inspectors.
- Further research should be done to optimise the traditional model, as this is relatively profitable, has a lower risk and is less labour intensive. It is probably a good way of increasing food security, particularly in families where only one or two members have an income from a pension or part-time employment. The prices realised from informal sales of milk and calves can give a stable income.
- The community farms should be economically evaluated in terms of each beneficiary being able to get a living wage out of the projected profits of the farm.
- The MPO and other stakeholders should give very specific training to new dairy farmers, based on the models that were used in the present study. It is essential that farmers be taught to look forward and adopt a proactive attitude. They must also understand that quality, balanced rations are the key to success – poor rations are expensive rations, because they result in unhealthy cows and poor production.
- Ongoing and effective monitoring and evaluation of extension, using PRA, is an effective instrument for any project sustainability.

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Competing interests

The authors declare that they have no financial or personal relationship(s) which may have inappropriately influenced them in writing this article.

Authors' contributions

P.M. (University of Pretoria) was the student who wrote the MSc thesis from which this article was written; C.M.E.M. (University of Pretoria) was the supervisor. J.S. (University of Pretoria) and L.P. (University of Pretoria) were co-researchers for the project at University of Pretoria, Faculty of Veterinary Science, Department of Paraclinical Studies.

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