DAIRY FARMING IN KENYA: RESOURCES AND NITROGEN FLOWS

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Introduction

The central highlands of Kenya are characterised by a large variation of agricultural activities including cultivation of cash crops, vegetables and staple food, as well as milk production. Small farmers keeping 1-3 cows produce most of the milk, demand for which is expected to increase, due to growing population and rising incomes (Omore et al., 1999). Hence, Market-Oriented Small-holder Dairy Research is a main thrust of national institutions (Ministry of Agriculture; Kenya Agricultural Research Institute, KARI) as well as the International Livestock Research Institute (ILRI). Livestock are part of an integrated crop-livestock system and are used to achieve multiple objectives. Smallholder farmers face many problems, including shortage of land. Many farmers grow Napier; other feeds are road side grass, weeds, maize (thinnings and stover), and concentrates. Shortage of feed and under-nutrition of animals are common. This contributes to low milk yields and long calving intervals. This study was conducted to examine the balance of feed supply and animal production in Kiambu district, one of the main milk suppliers for Nairobi city. Also the effect of manure on the estimated profitability of the system and the effect of livestock on N flows was examined.

Methods

Data on land use from Staal et al. (1997) were combined with estimated yields and quality of forages (R. Kaitho, B. Lukuyu, D. Mwangi and J. Methu, pers. comm.) to arrive at seasonal amounts and quality of feed, where the year (set at 360 days) was divided into 8 periods of 45 days. These data were used as inputs for the "Java" programme (Zemmelink et al., 1992). "Java" was designed to estimate potential animal production for situations where feeds of different quality are available. The programme operates by first ranking the feeds according to their potential intake of metabolisable energy (IME) when fed *ad libitum*. IME is calculated from intake of organic matter (IOM) according to the equation of Ketelaars and Tolkamp (1991) for sheep:

$$IOM = -42.78 + 2.3039*OMD - 0.0175*OMD^2 - 1.8872*N^2 + 0.2242*OMD*N,$$

where IOM is in g $kg^{-0.75}d^{-1}$ and both OMD (digestibility of organic matter) and N (nitrogen concentration in organic matter) in % (g/100g). IOM for sheep was multiplied with 1.333 to account for the higher average metabolism of cattle as compared to sheep and then with 1.1 because of the higher intake of lactating animals. After ranking the feeds, the programme enters a step-wise procedure to calculate the effect of varying degrees of inclusion of feeds on: (1) ration quality and voluntary feed intake; and: (2)

corresponding values for (a) the number of animals that can be fed and their production, (b) production of manure and (c) excretion of N in faeces and urine. For the "Java" programme, all animals are converted to standard animal units (AU) with the same type of production (milk or increase of body mass). The programme also distributes feeds equally amongst all animals. In Kiambu, 55% of the livestock units are dairy cows and farmers generally give lactating animals a flat rate of 2 kg concentrates d^{-1} (Staal et al., 1997). To estimate expected yields of milk and manure, and faecal and urinary N from animals fed fodder only or fodder with concentrates, output data of "Java" were further processed using spreadsheets. It was assumed that cows eat 2 kg concentrates without decreasing intake of forage. One AU was defined as an animal weighing 350 kg (approximate mean live weight of cows in the study area). Further assumptions were as in Table 1. When estimating revenue from livestock, a simple sensitivity analysis was carried out where different values were attached to milk (9, 12, 15 or 18 KSh kg^{-1}), manure (0, 2, 5 or 8 KSh kg^{-1} DM) and concentrates (7, 10 or 13 KSh kg^{-1}). For calculations of revenue, separate data were calculated per period and then summed; for calculation of N-flows, feeds were pooled for the whole year.

Table 1. Assumptions (parameter values) used in calculations

* g digestible organic matter = 15.8 MJ ME;
* concentrates: 88% DM (digestibility 0.75); 10 MJ ME and 140 g CP per kg DM;
* N content of milk: 6 g N kg^{-1} ; of live weight: 22 g kg^{-1};
* % DCP (digestible crude protein) in feed DM= 0.9*CP(%)-3.2; (used to calculate apparent digestibility of N)
* Urine N = N intake – manure N – milk N – N deposited in body
* ME requirements: 0.512 MJ $kg^{-0.75}$ for maintenance; 5 MJ kg^{-1} milk; 38.1 MJ kg^{-1} liveweight gain;

Results

Livestock population, land use and forage production

Kiambu covers 1448 km^2 with a population of 480 persons per km^2 (1989 census). Combining this with the average of 6.2 persons per household and other data of Staal et al. (1997) leads to a an estimated 112,100 households of which 104,425 (93%) are agricultural households, holding a total of 211,044 AU ruminant livestock and donkeys. Of these, 55% are cows, 28 % other cattle (mainly young stock), 10% sheep, 4% goats and 3% donkeys. Extrapolation of survey data (Staal et al. , 1997) leads to the following estimates for land use (km^2): cash crops (205), napier (191), vegetables (331), maize (181), compounds (217), roads and paths (161) and roadsides (161). Estimates of forage yields depend on many assumptions and even within Kiambu, there is considerable variation due to differences in climate and cropping patterns. Table 2 shows estimated totals for the whole district. Seasonal variation in availability of feeds is high. Maize thinnings are mainly available during the growing seasons (April-June and October-December). During the dry seasons, large amounts of maize stover are available. This is of much lower nutritional quality than the thinnings, especially the stems, which comprise 2/3 of the total. Also yields and quality of Napier, as well as the amounts of weeds (harvested from vegetable land) and roadside grass vary seasonally.

Table 2. Amount of different feeds available per period of 45 days (10^6kg) and weighted mean of crude protein concentration (% CP in dry matter), and digestibility of organic matter (OMD).

Period	Napier	Maize Thinnings	Maize Stover	Weeds	Roadside Grass	Total DM	% CP	OMD (%)
1. April/May	25.8	12.8	-	7.4	5.8	52.0	10.9	66.4
2. May/June	22.3	25.7	-	7.5	5.8	61.3	9.4	63.7
3. July/Aug	21.3	-	18.9	7.4	5.8	53.4	6.5	58.0
4. Aug/Sept	18.8	-	56.7	-	2.9	78.4	4.3	54.1
5. Oct/Nov	14.8	12.8	-	7.5	2.9	38.0	10.9	65.5
6. Nov/Dec	26.9	25.7	-	7.4	5.8	65.8	9.7	64.7
7. Jan/Feb	12.1	-	18.9	-	2.9	34.0	4.4	55.0
8. Feb/March	12.1	-	56.7	-	2.9	71.7	3.7	52.3

Potential livestock production from forage

When seasonal distribution was ignored and all feeds were pooled for the whole year, 197,000 AU could be fed *ad libitum* at 1.26 times maintenance. This corresponds to 2.11 kg milk per AU per day. Due to the seasonal variation in feed supply, the number of AU that could be fed *ad libitum*, varied from 106,000 in Period 5 to 341,000 in Period 4. Due to the low quality of maize stems, the average quality of feeds in Periods 4, 7 and 8 was so low that animals could not even reach maintenance. The optimum herd size, giving the highest possible production varied from 69,000 in Period 7 to 194,000 in Period 6. The optimum constant herd size (constant throughout the year) would be 130,000 AU. This is much lower than the herd actually found in the area (211,000 AU). This comparison ignores that concentrates are also used, but is in agreement with field observations that farmers often have great problems in finding sufficient feed for their animals.

Revenue from milk and manure when feeding concentrates

When it was assumed that 55% of the AU were lactating and received concentrates, maximum milk production (187 million kg per year) was obtained with a total herd of 160,000 AU (88,000 cows, producing 5.9 kg AU^{-1} d^{-1}). The optimum herd size increased to 190,000 when a high value of manure (5 or 8 KSh kg^{-1} dry matter) was added to the revenue from milk and costs of concentrates were ignored. The optimum herd size decreased to 140,000 - 150,000 when costs of concentrates were taken into account and the gross margin (revenue from milk + manure – costs of concentrates) was maximised. This was so for all milk prices (9, 12, 15 or 18 KSh kg^{-1}) combined with prices of ≤ KSh 5 kg^{-1} dry manure and ≥ 10 KSh kg^{-1} concentrates. Optimum herd size only increased (to 180,000 – 190, 000 AU) when the intermediate price of dry manure (KSh 5 kg^{-1}) was combined with the lowest price of concentrates (7 KSh kg^{-1}) or when the highest value for dry manure (KSh 8 kg^{-1}) was used to compensate for a higher price of concentrates.

Nitrogen flows

For the construction of Table 3, it was assumed that forages are pooled for the whole year, that 55% of the AU's are lactating cows and that cows receive 2 kg concentrates $AU^{-1}d^{-1}$. When herd size increases, a larger amount of N in concentrates is added to N in forage. As a result, not only more milk is produced, but also more N is returned in animal excreta. With 210,000 AU, the amount of N in animal excreta exceeds that in forages.

Table 3. Effect of Herd Size (Animal Units) on N-flow in Kiambu (10^6 kg y^{-1}).

Herd size	50,000	100,000	150,000	210,000
Entering Animal Production System				
In forage	5.27	5.27	5.27	5.27
In concentrates	0.39	0.78	1.17	1.64
Distribution after passing through system				
Milk and animal body mass	0.71	1.23	1.49	1.39
Unused forage	2.63	1.11	0.25	-
Feces	1.14	2.08	2.82	3.39
Urine	1.18	1.63	1.88	2.13
Total in unused feed and excreta	4.95	4.82	4.95	5.52

Discussion and conclusions

Seasonal distribution and low quality of feeds are a major problem faced by smallholder farmers in central Kenya. Even when feeds are pooled for the whole year and the best forages are selected for a herd of only 50,000 AU, estimated intake of energy covers the requirements for only 5.9 kg milk $AU^{-1}d^{-1}$. When herd size is increased to 150,000 AU, this decreases to 3.5 kg $AU^{-1}d^{-1}$ and for 210,000 AU (approximate actual number) it becomes 1.5 kg $AU^{-1}d^{-1}$. Feeding 2 kg concentrates daily per cow increases these values by 3.5 kg $AU^{-1}d^{-1}$, but certainly the total for 210,000 AU (5 kg $AU^{-1}d^{-1}$) is far below the potential production of the animals. This is consistent with reported rapidly declining lactation curves, often poor condition of animals and long calving intervals.

Estimates of the optimum number of AU depend on the criteria used (maximum milk production or maximum revenue) and prices of milk, manure and concentrates. Most estimates are, however, in the range of 140,000 – 150,000 AU, much lower than the estimated actual number. The difference can partly be explained by the high value of manure (see also Lekasi et al, 1998). In addition, farm sizes are small and many households have only one cow and cannot reduce herd size unless they stop milking altogether. Meeting the needs of individual households may be more important than maximizing milk production in the district.

When comparing households with lower and households with higher total income, Staal et al. (1997) found that the latter group included relatively more households with dairy cattle This is consistent with the impression that keeping dairy cows is economically attractive. But households with dairy cattle (77% of all agricultural households) have on average also nearly twice as much land (0.98 ha) than households without dairy cattle (0.51 ha). The latter group has on average only slightly less maize (0.15 compared to 0.18 ha) and vegetables (0.26 and 0.34 ha, respectively). The major difference is in the area of cash crops (coffee, tea, fruit trees, pyrethrum) (0.05 and 0.24 ha, respectively) and Napier (and other forage crops) (0.06 and 0.22 ha) (D. Njubi, pers. comm.). Households holding the smaller farms apparently give priority to growing food crops and reduce the area of forage crops as well as cash crops. If farm size gets smaller it becomes increasingly important to increase the yield of forage per ha (e.g. maize thinnings), but that should not interfere with the production of food crops. When it becomes too difficult to feed one cow, smaller animals (e.g. dairy goats) may be an alternative

When significant amounts of purchased concentrates are fed, livestock can have a net positive effect on the N-balance at the farm level, even if no extra fertiliser is imported for forage production (Table 3). This is, however, only true if all N in animal excreta is returned to the land. Unfortunately, a large proportion of the N is in the form of urine and it must be assumed that much of that is lost under prevalent management systems (Lekasi et al., 1998). On many farms this may even be true for N in feces. Some farmers use not only concentrates but also forage from other farms. This adds to the N balance of their farms, but must be compensated by applying more fertilizer on farms who sell forage.

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