Effect of intensification on feed management of dairy cows in the Central Highlands of Kenya

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Abstract:

As population density increases, crops and livestock become increasingly integrated as farming systems intensify. In order to increase output per unit of land farmers are forced to alter feeding practices as availability of feed resources change. In order to make appropriate recommendations to farmers it is important to understand these changes. The present paper describes a study in two areas in the Central highlands of Kenya representing areas of low and high population density and consequently low (LI) and high (HI) levels of intensification. Quantity and source (on or off-farm) of feed DM offered by type and milk production were monitored regularly for one year. Seasonal effects were considered by comparing parameters measured in months above and below average rainfall recorded in each area. Numbers of animals owned were higher in LI compared to HI, and milk production per animal similar. However production expressed per unit of land, an indicator of intensification was significantly higher ($p<0.05$) in HI. Results showed that in the more intensive systems planted fodder tended to replace grazing while crop residues represented a similar proportion of total feed DM offered. On average, farmers in intensive systems offered around 5 times the amount of concentrate in the more extensive areas, probably influenced by the good market access in the HI area. Similar amounts of feed were sourced from off-farm sources, however HI farms purchased on average 20% of the fodder offered whereas in LI purchased material accounted for only 10% of fodder. In the dry months all farmers increased the amount of DM offered to the animals. In HI this change was achieved by increasing amount of purchased feed, while in LI the amount of feed from on-farm sources increased. Amount of concentrate in HI increased by 50% in dry months while quantities in LI remained the same. The study showed that in even in areas of very high population density farmers choose to maintain a mixed system and purchase fodder from off-farm rather than abandoning staple crops in order to specialise in livestock. Recommendations of further increase in planted fodder should be considered carefully for intensive smallholder farmers in market oriented systems where there is the opportunity to purchase fodders off-farm.

Introduction.

In sub-Saharan Africa mixed crop-livestock systems predominate in the semi-arid, sub-humid and cool highland zones. In these areas, systems intensify and crops and livestock become increasingly integrated as the human population increases and land becomes a more important constraint than labour (Boserup, 1965; Mcintire *et al.* 1992). As intensification progresses, use of crop residues moves from open access to crop fields following harvest, to labour intensive management of grain as a dual purpose crop. In some cases, farmers harvest thinnings and green stover during the growing period as well as harvesting and storing the residues to feed to confined animals (Lukuyu 2000). Manure becomes a vital source of crop nutrients as scarcity of land precludes the use of fallow. Together with the stimulus of increasing demand for livestock products (Delgado *et al*. 1999), the trend is for systems to intensify, with output per unit of land increasing (Staal *et al*. 2000a). In the Central Highlands of Kenya, smallholder dairy systems provide livelihoods for more than 50% of agricultural households (Staal *et al.* 2002a). Farming systems are continually evolving in response to changes in available resources and access to market. In order to develop appropriate technologies and target extension advice it is important to understand how intensification influences the management strategies that farmers adopt. The present paper describes a study of feeding strategies in two areas of Kenya where population densities varied and farming systems were considered to represent different levels of intensification. A longitudinal study was carried out where a total of 42 farms were visited regularly during a period of 14 months in order to capture seasonal effects in feed management, production and markets.

Materials and methods.

Study site and farm selection: Farms were selected from Central and Rift Valley provinces (see Figure 1) to represent areas of high (HI) and low (LI) levels of intensification. Selection of the 21 farmers in each area was stratified to represent important systems observed during earlier characterisation surveys in the region (Staal *et* *al*. 2002). In Central province (HI), in Kiambu district to the North West of Nairobi, farms were selected where coffee (n=11) or horticulture (kale, cabbage and green maize (n=10) were the main cash crops. In Rift Valley province (LI) farmers were selected in Nakuru (n=11) and Nyandarua (n=10) districts where population density was lower compared to Kiambu and farm sizes generally larger. Main cash crops were horticultural (cabbages and kales) in Nakuru, with pyrethrum important in Nyandarua as well as cabbages and potatoes. Market access was poorest in Nyandarua where there were problems of marketing milk, particularly in the rainy season, this was reflected by lower average milk prices (17.6, 15.2 and 14.3 in Kiambu, Nakuru and Nyandarua respectively at the time of surveys).

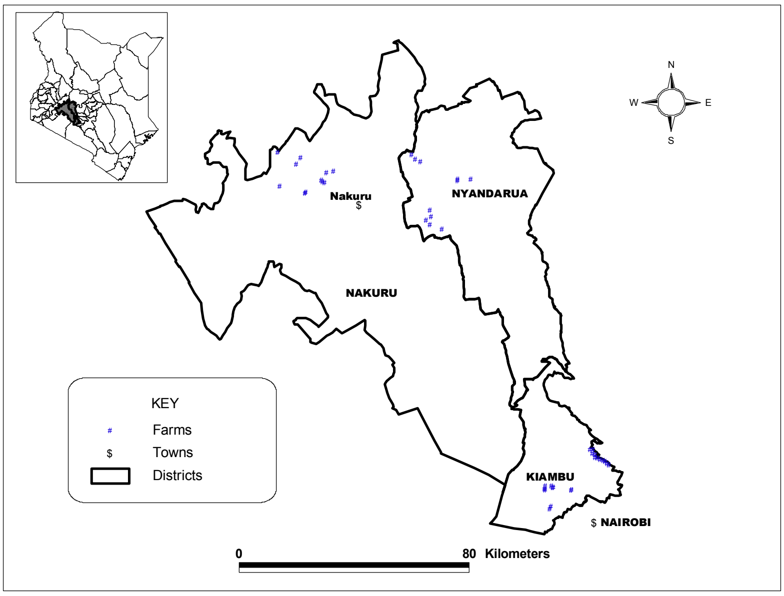

Figure 1: Location of selected farms in Nakuru, Nyandarua and Kiambu. Nakuru and Nairobi towns are also marked.

Data collection: In order to characterise the different systems, household parameters were collected including land size and cattle owned. All farms were geo-referenced and GIS layers used to estimate population density in a 5 km radius of each farm and market access as the total time to drive to the nearest market centre, taking account of different road types (Staal et al., 2002b). All farmers were visited twice weekly over a period of 14 months to collect data on feeding strategies and milk yield. Data collection took place from November 1997 to December 1998 in Central province and from January 1999 to February 2000 in Rift Valley province. Once a fortnight enumerators spent a full day on each farm recording quantity, type and source (on or off-farm) of feed offered to cattle during the day, whether or not feed coming from off-farm was purchased and milk yield. Annual supply of offered DM from concentrate, crop residues, planted fodder, grazed pasture and other cut and carry fodders was estimated relative to the TLUs (Tropical Livestock Unit = 250 kg) present on the farm across the year.

Data analysis: Characteristics related to individual households with no seasonal effects including local population density, market access, land size and cattle numbers were analysed using a mixed model (PROC MIX in SAS) where Intensification Group (IG) and System within group were considered as fixed effects with farm being the random effect. Milk production parameters were also analysed in this way, with production per hectare representing an indicator of level of intensification. Since unusual rainfall patterns occurred during the monitoring period, seasonal effect on feeding patterns was examined by estimating amounts of feed offered during months where rainfall was above (wet) or below the overall average according to rainfall measurements from metereological stations in Kiambu, Nakuru and Nyandarua. In HI and in Nakuru and Nyandaurua districts in LI, 7, 2 and 5 months out of 12 were above average respectively. These data were analysed using a mixed model (PROC MIX in SAS) where intensification group (IG), season (S), system within IG and IG by S interaction were fitted as fixed effects, with the random effect being farm within systems nested within groups. The first 2 months data were not used in the analysis since they were taken as lead-in periods when enumerators were learning the data collection procedures.

Results and Discussion

Household characteristics and intensification indicators: Table 1 shows that population density in HI was more than six times higher than that in LI, reflected by smaller farm sizes ($p<0.05$). Numbers of cattle owned were lower in HI compared to LI ($p=0.060$) as expected, however because of differences in land sizes, stocking density in Nakuru district was similar to those in the intensive sites. Market access was greater in HI ($p<0.001$) with no difference between the sub-groups. Within LI market access was significantly poorer ($p<0.001$) in Nyandarua. The indicator of time taken to nearest market centre generally reflects the difficulty with which farmers sell milk, since it describes the remoteness of the farm and the difficulty with which milk can be collected or taken to market. Market access was expected to have a significant effect on management choices at the farm level. For example in Nyandarua, although some processors collect milk this tends to be in times of scarcity when they cannot source milk from more accessible farms, local markets. A number of farmers report throwing away milk during the season when milk production elsewhere in the country is at a peak because they were unable to sell it or consume it at home. Poor market access was reflected by a lower proportion of milk produced being sold in Nyandarua (57% compared to 70 and 71% in Kiambu and Nakuru respectively) (SDP unpublished reports). Milk production per farm or TLU is similar in all sytems ($p>0.05$). However the intensification indicator, output per unit of land (l/ha), increases as farm size decreases and farmers intensify dairy production. These changes reflect use of on and on-farm feed resources, as discussed in the following sections.

Table 1: Household parameters in areas of high (HI) or low (LI) intensification. Least square means are represented and means with different superscripts differ significantly

Intensification group (IG)	HI		LI		sed		Sig	
AEZ defined as accompanying cash crop	Hortic.	Coffee	Nakuru Hortic./ coffee	Nyandarua Coffee/ wheat/ sheep	IG	System within Group	IG	System within Group
Population density (persons /km)	763a	617b	101	96	24.3	34.3	***	***
Market access (minutes to market centre)	14.4	13.7	21.0a	45.4b	1.94	2.75	***	***
Land size (ha)	0.8a	1.7ab	2.9ab	4.8b	1.18	1.66	*	NS
Cattle owned (TLU)*	3.3	3.7	6.2	5.3	1.19	1.68	0.060	NS
Stocking rate (TLU/ha)	4.8a	3.5ab	4.5a	1.7b	0.90	1.23	NS	0.076
Milk Production (l/TLU)	2.3	2.2	1.8	2.4	0.39	0.55	NS	NS
Milk Production (l/farm/day)	7.2	8.9	13.1	11.3	3.47	4.90	NS	NS
Milk production (l/ha)	12.3a	9.2ab	7.1ab	4.0b	2.27	3.21	*	NS

TLU = Tropical Livestock Unit = 250 kg M

Effect of intensification*:* Analysis of differences between systems within group indicated no significant differences, reflecting the non-significant difference within group for intensification indicators such as milk production/ha (Table 1). Therefore, only main effects of intensification and season are reported (Table 2). Total amount of DM offered per animal was slightly higher in the more intensive area (HI), although the difference did not quite reach significance ($p=0.67$). Significant differences were observed in the type and source of feed dependant on the level of intensification. In LI, where farming was more extensive, the main source of feed was from grazed pastures on farmers' own land and from communal grazing sources off-farm. In the more intensive systems in HI grazing was almost non-existent with almost all animals being kept under zero-grazing systems and receiving much higher amounts of the planted fodder Napier grass (*Penniseteum purpureum*) ($p<0.001$) and concentrate ($p<0.001$). In intensive systems some concentrate was produced on-farm in the form of poultry litter, while in extensive systems the little concentrate offered was all purchased. Crop residues were offered in similar amounts ($p>0.05$) and contributed a similar proportion of total feed (26 and 27% respectively for HI and LI respectively). However, in LI, with an average of 1.8 ha under maize, crop residues were mainly from maize with some vegetable and vegetable waste, mainly potatoes and cabbage. In HI where the area under maize is much smaller (0.19 ha) proportion of maize residues tended to be lower ($p=0.07$) with one quarter of residues coming from banana, sweet potatoes and other vegetables on average and proportions of as high as 0.60 being observed.

Table 2 Total quantity of feed DM offered and the amount offered from off-farm sources and the proportion of the off-farm feed that was bought. Values are adjusted means for the wet and dry months in areas of high (HI) and low (LI) intensification. Effect of intensification group (IG), season (S) and the interaction between the two are presented.

	HI		LI		s.e.d			Significance		
	Wet	Dry	Wet	Dry	IG	S	IGXS[+]	IG	S	IGXS
Total feed kg DM / TLU / day										
All feed	7.8	8.3	6.0	7.1	0.82	0.33	0.44-0.92	0.067	*	NS
Concentrate	0.90	1.58	0.23	0.23	0.22	0.12	0.16-0.27	***	**	**
Crop residues	1.6	2.5	1.1	2.4	0.39	0.30	0.40-0.55	NS	***	NS
Other cut/carry fodder	0.6	0.7	1.1	1.0	0.28	0.10	0.13-0.30	NS	NS	NS
Grazing	0.0	0.1	2.8	2.5	0.25	0.07	0.09-0.27	***	*	*
Planted fodder	4.7	3.5	0.8	1.0	0.46	0.18	0.23-0.50	***	**	***
On-farm feed kg DM / TLU / day										
All feed	5.7	4.9	3.4	4.3	0.66	0.30	0.40-0.76	*	NS	**
Concentrate	0.08	0.08	0.00	0.00	0.03	0.01	0.02-0.04	*	NS	NS
Crop residues	1.3	1.5	0.7	1.6	0.28	0.24	0.31-0.41	NS	*	NS
Other cut/carry fodder	0.4	0.4	0.3	0.4	0.13	0.06	0.09-0.15	NS	NS	NS
Grazing	0.0	0.1	1.6	1.4	0.32	0.06	0.08-0.33	***	0.067	*
Planted fodder	3.8	2.9	0.7	1.0	0.38	0.18	0.24-0.44	***	*	***
Off-farm feed kg DM / TLU / day										
All feed	2.2	3.4	2.6	2.7	0.69	0.24	0.31-0.75	NS	**	*
Concentrate	0.82	1.50	0.23	0.23	0.23	0.12	0.16-0.27	***	**	**
Crop residues	0.27	1.01	0.38	0.80	0.27	0.18	0.24-0.35	NS	***	NS
Other cut/carry fodder	0.21	0.32	0.78	0.60	0.26	0.07	0.09-0.27	NS	NS	*
Grazing	0.00	0.02	1.16	1.07	0.24	0.05	0.06-0.25	***	NS	NS
Planted fodder	0.85	0.58	0.07	0.04	0.22	0.09	0.12-0.25	**	NS	NS
Purchased feed										
All feed (kg DM / TLU / day)	2.0	3.1	0.7	1.1	0.59	0.23	0.31-0.66	**	***	NS
All feed (proportion of off-farm)	0.90	0.88	0.42	0.40	0.08	0.02	0.03-0.08	***	NS	NS
Concentrate		All purchased								
Crop residues		All purchased								
Other cut/carry fodder (proportion of off-farm)	0.40	0.40	0.06	0.07	0.10	0.04	0.05-0.11	***	NS	NS
Grazing		None purchased								
Planted fodder		All purchased								

[+]A range is given for sed for the interaction. This is because differences in group size make it inappropriate to report mean sed.

Little difference in the total amount of feed DM from off-farm sources was observed between the two study sites ($p=0.07$). However, in the extensive system this represented grazing, crop residues and other cut and carry fodder (cut grass, hay, kitchen waste and vegetables). In intensive systems, although amount of crop residue was similar, there was almost no grazing and relatively large amounts of planted fodder and concentrates offered (0,71 and 1.16 kg DM TLU^{-1} day^{-1}). Concentrates, crop residues, and planted fodder from off-farm sources were always purchased, while pasture was always free. This resulted in a larger proportion of purchased feed in the intensive system ($p>0.001$) where almost all of the feed from off-farm was purchased.

Seasonal variation: In both intensification groups more feed was offered in the dry months ($p<0.05$), however the strategies used to achieve higher offer rates in the two areas was very different. In HI farmers compensated for a lower amount of feed being produced on farm, with decreases in total feed DM largely resulting from decreased amounts of planted fodder ($p<0.05$), by increasing the amount of both concentrates and crop residues purchased off-farm ($p<0.01$). In contrast, in LI there was an increase in amount of feed produced on-farm with increased quantities of crop residues offered (0.05). The total amount of feed in LI sourced off-farm did not change, but an increase in the amount of crop residues purchased and a small decrease in all other feeds was observed. The amount of concentrate offered in LI was low in both wet and dry months

Discussion McIntire et al. (1992) proposed that the effect of population density on crop-livestock interactions could be described by an inverted U shaped relationship. Where low population densities exist, farmers specialise in crop or livestock production with cattle under extensive management. Under these conditions feed scarcity is overcome by cattle mobility and crop farmers maintain soil fertility by the use of long-term fallows. As land becomes scarcer crop and livestock enterprises become integrated on the same farm, with nutrient recycling improving efficiency of nutrient capture (McIntire et al., 1992). In terms of feed resource use this relationship can be represented by a series of inverted U-shaped curves for different feed resources with crop residues increasing and then declining in importance as planted fodder and supplements replace grazing at high population densities (Figure 2, S.Fernandez-Rivera, personal communication). Increasing levels of planted fodder and concentrate use are also considered as intensification indicators (Baltenweck et al. 2003). Patterns observed in the present study can be considered to conform to this pattern, with crop residues contributing approximately 25% of feed DM offered in both systems, with grazing in LI (41% of feed DM) being replaced by planted fodder in HI (51% of feed DM). Planted fodders are usually rare as sources of feed even where there are well-adapted species are available (McIntire et al. 1992). These authors give three reasons for this; 1) the competition between land and labour 2) the seasonality of planted fodders which are abundant at the same time as alternative, cheaper sources and 3) the mobility of livestock allowing them to move to harvest cheaper resources on common access land. The Kenyan Highlands is, however, cited as an exception where good market access results in good returns to investment in these materials. At the same time limited common lands and almost universal confinement of cattle limit the alternatives.

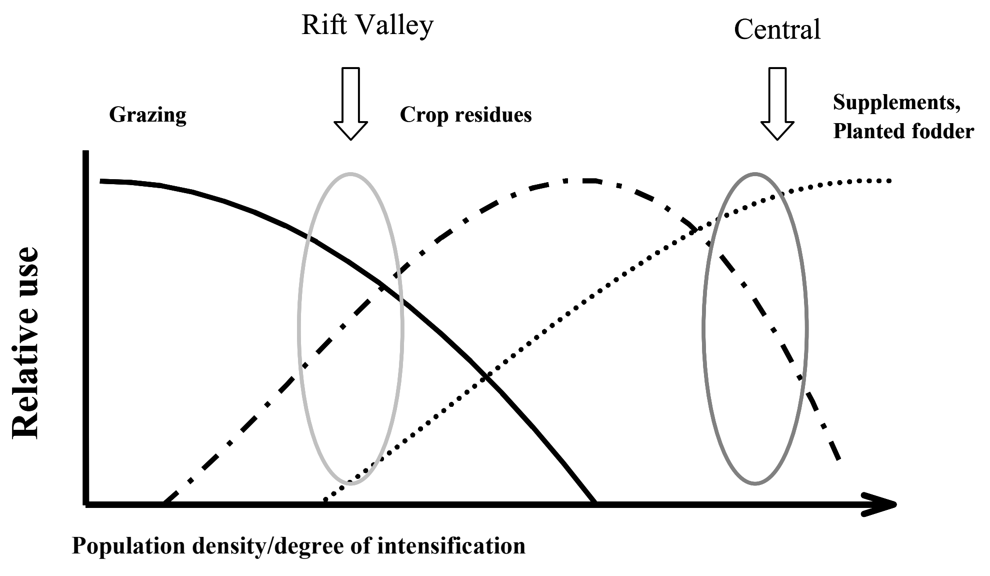

Figure 2: Effect of intensification on feeding strategies (*Personal communication: S Fernandez-Rivera, ILRI*)

Interactions between crop and livestock enterprises on different farms are considered mainly in extensive systems, for example, where crop farmers allow grazing of residues in order to obtain animal manure (Powell and Williams, 1995). However, in the present study 20% of total fodder offered is purchased from other farmers in HI, compared to only 10% in LI. This suggests that in the study area, despite very high population densities, farmers preferred to maintain a mixed enterprise rather than specialise. Thorne et al. (2002) suggest there may be cultural resistance to replacing a staple such as maize with Napier, which is effectively a cash crop.

Conclusions: It was clear from the present study that farmers use a wide variety of feeds to cover livestock requirements. At very high population densities farmers do not necessarily specialise but maintain a mixed enterprise by purchasing forages from other farmers as well as offering relatively high levels of concentrate feeds. Recommendations to specialise further by increasing the area under planted fodders in such situations may be resisted by farmers who are able to resource feed off-farm.

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