Categorisation of dairy production systems: A strategy for targeting meaningful development of the systems in Uganda

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Abstract

Dairy production is a major contributor towards national economies and household food security and incomes in sub-Saharan Africa (SSA). Milk production in the region is estimated at 1.27 million metric tonnes year^{-1}. However, this level of milk production is inadequate for the existing human population who would require 103 million metric tonnes year^{-1}. In Uganda, milk production only meets approximately 20% of the population's nutritional requirements. As such, methods need to be sought to increase milk production in the region.

Research efforts have made strides in identifying the causes of the production-demand gap in the SSA region and a spectrum of interventions to bolster the productivity. Unfortunately, these efforts have by far yielded insignificant results. First and foremost, for exploiting the full potential of the dairy cattle population in the region, among the critical elements often overlooked in research and development processes is the recognition of systematic parametric variations within the sector, which if considered could provide entry-points for targeting intervention efforts. One such high potential entry-point is the recognition of the existence of a dairy intensification "vector" across a country or region, along which exist sections with sequentially marked nuclei of fairly uniform socio-economic and biophysical dairy sub-systems features. To enhance the process of targeting research and development in the Ugandan dairy sector, dairy production systems in the country were categorised on basis of level of intensification of production.

Data were collected from 300 households in Mbarara, Masaka and Jinja districts in Uganda. The major variables derived from the data for the categorisation process were those related with milk production, expenditure, income, land area and cattle herds. The data was subjected to a cluster analysis which although produced 16 groups only five had prominent membership (above 5% of the farms). The five major clusters were selected as representative of the dairy production systems. A ranking system was used to develop an intensification continuum for the 5 systems. Herding-on own and communal land (cluster 9) was the least intensive, this was followed by Herding-mainly on own land (cluster 12) and Fenced (cluster 8) respectively. Semi-Zero Grazing (cluster 15) and Zero Grazing (cluster 13) were the most intensive dairy production systems with the latter being at the highest end of the continuum.

Key words: Categorisation, Clusters, Dairy Production Systems, Intensification

Introduction

The dairy sector is a major pillar in the socio-economic standing of sub-Saharan Africa (SSA); functioning both food security and income generation roles, particularly at small household level. In general, dairy cattle remain the key player among the livestock groups in the sector, accounting for 80% in the milk industry (De Leeuw et al 1999). Recent statistics show an average of 0.17 animal units (AU of 400 kg live weight) household^{-1}in the region (Winrock International 1992), with an estimated milk yield TLU^{-1}(TLU of 250 kg liveweight) of 70 kg year^{-1}(Staal et al 1997). The overall production for the region is estimated at 1.27 million tonnes annually, against the annual demand of 103 million tonnes, basing on the FAO requirement of 200 litres person^{-1}year^{-1}and the estimated population of SSA of 519 million (Sere and Steinfeld 1996). Moreover, statistics present very low milk yield dairy cow^{-1}year^{-1}of 340 kg in SSA compared to 5100 in developed countries (De Leeuw et al 1999). These statistics are evidently chilling in light of the rapidly growing human population in most parts of the region.

In Uganda, the dairy sector contributes 40-50% of the livestock GDP (DDA 2001/2002), which in turn contributes 17-19% of the agricultural GDP. Dairy plays a crucial role in the nutrition of most households with *per capita* milk consumption of about 40 litres (DDA 2001/2002). Recent statistics for the country present a desperate scenario, of annual milk yield of 900 thousand tonnes, against a requirement of 4.8 million tonnes (based on FAO annual *per capita* requirement and current national population). Research efforts have made strides in identifying the causes of the production-demand gap in the SSA region and a spectrum of interventions to bolster the productivity. Unfortunately, these efforts have by far yielded insignificant results.

Among the critical elements often overlooked in research and development processes is the recognition of systematic parametric variations within a sector, which if considered could provide entry-points for targeting intervention efforts. One such high potential entry-point is the recognition of the existence of a dairy intensification "vector" across a country or region, along which exist sections with sequentially marked nuclei of fairly uniform socio-economic and biophysical dairy sub-systems features. In this case, intensification is defined as an increase in agricultural production per unit of inputs (which may be labour, land, time, fertiliser, seed, feed or cash). If the dairy intensification "vector" is properly mapped out as groups or "categories", the product would provide a guide for targeting interventions with fair precision. To achieve this definitely requires systematic and detailed understanding of the structure of this perceived vector, including all instrumental socio-economic and biophysical phenomena, particularly those related to resources and managerial capacity of the dairy systems.

Categorisation of dairy production systems in Uganda has been done variously. Okwenye (1994) classifies dairy production systems into three groups, namely pastoral, small-scale crop and livestock farms and specialised dairy farms. This classification is based on number of stock, feeding and grazing management and breeds reared. The Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) jointly with the International Livestock Research Institute (ILRI) (MAAIF/ILRI 1996) indicated that cattle production systems in Uganda form a continuum with semi-nomadic pastoralism at one end and zero grazing on the other. The study, which used non-detailed and overly qualitative information, categorised dairying in the country into intensive, semi-intensive and extensive systems. A critical consideration in the process was the level of capital investment and dairy cattle management (MAAIF/ILRI 1996), but excluded the inherent pressure exerted on the available resources such as livestock herd populations relative to available land, and its extended effect on plant nutrient stocks and their sustainable supply. Kasirye (2003) later categorised dairy production in the country based on size of holding, as communal grazing, free range grazing, fenced grazing and zero grazing. On the other hand, Fonteh et al (1998) conducted a fairly more detailed characterisation within smallholder dairy systems in Uganda and ended up with three categories, namely, urban, peri-urban and rural. Furthermore, each of the categories was further sub-divided into 4-10 sub-categories based on grazing and feeding management, major limiting resource, sources of cash income and wealth assessment.

Admittedly, the diversity of dairy categories generated by previous efforts reflects not only on the diversity of the foundation criteria used, but also on the objectives of each research effort. Hence, intervention efforts must take cognisance of the original aims and criteria for each categorisation process, as well as their (categories) strengths and limitations in representing the presumed categories. The more obvious inference is that the range of categories generated based on non-uniform criteria is a good recipe for category overlaps; a factor that renders intervention targeting fairly erratic and less objective. As such, efforts are required to harmonise the categorisation process and attain more robust categories particularly based on intensification. This is only achievable through a systematic and detailed process involving largely quantitative data.

The objective this study was to categorise the dairy production systems in Uganda based on level of intensification, with a view to permitting targeted research and sustainable development.

Materials and methods

The study was conducted in Uganda, as a cross-sectional survey during 2002. It involved three districts, namely, Mbarara (western), Masaka (central) and Jinja (eastern). The districts are sequentially separated by distances of 120, 320 and 200 km, respectively. They are known to have a diversity of dairy cattle management systems, ranging from pastoralism to purely zero-grazing (MAAIF/ILRI 1996) As such, the study focused on the level of dairy intensification and their perceived categories rather than differences among the otherwise administratively delineated units (districts). Additionally, these districts possess both extremes of rural and urban settings.

The survey involved three and six sub-counties and villages, respectively from each district. From each sub-county, 37 households were randomly but purposively selected based on involvement in dairying. Specifically, household selection was done along two transects laid out on sketch village maps developed jointly with key informants from the sub-counties. A pair of key sites was selected randomly to mark the beginning and the end of each transect. Subsequently, household selection was done along the most direct route, and this was alternated on either side of the route at specific intervals to ensure that most of the transect was covered. The procedure also ensured selection of equal number of households on either side of the route. The sampling interval along the route depended on household density. However, 2 and 4 households were skipped on either side of the route in low and high household concentration areas, respectively.

A semi-structured questionnaire was developed for this purpose and pre-tested in non-targeted sub-counties but with similar dairy systems in each of the three districts. The questionnaire was accordingly adjusted to respond to unforeseen features and issues encountered during the pre-testing. The questionnaire comprised of a spectrum of parameter questions, but the centre of gravity was on farm activities and labour, land size, farming objectives, cattle pests and disease management, cattle management systems including feeding and grazing strategies; cattle herd structure, level of milk production, access to extension services and credit, and farm and non-farm income/expenditure. More specifically parameters included proximity to the main road, long term hired labour, monthly household income, monthly off farm income and total farm land. Proportion of cattle herd comprising of improved breeds, total farm land, annual expenditure on artificial insemination (AI) and veterinary services per cattle Total Livestock Unit (TLU), cattle TLU ha^{-1} and feeding and grazing management score were derived from the collected data. The TLU scale was in the order of adult male = 1, adult female = 0.7, weaner = 0.5 and pre-weaner = 0.2 (Bebe et al 2003).to obtain the feeding and grazing management score, a scale of 0-10 was applied (Table 1), with 0 being the least intensive (typically the free range grazing systems utilizing even communal grazing lands), and 10 being the most intensive (represented by exclusively zero grazing management system).

Table 1. Feeding and grazing management scores in the dairy systems of Uganda

Score	Cattle feeding and grazing management
0	Communal grazing with no additional feeds
1	Herding on own land with no additional feeds
2	Grazing on fenced paddocks on own land with no additional feeds
3	Grazing on fenced paddocks on own land with additional fodder and crop residues
4	Tethering with irregular use of additional fodder and crop residues
5	Tethering with regular use of additional fodder and crop residues
6	Zero grazing with regular grazing
7	Zero grazing with irregular grazing
8	Zero grazing with no use of concentrates
9	Exclusively zero grazing with use of concentrates and grazing
10	Exclusively zero grazing with use of concentrates

In order to focus the subsequent analytical procedure, the milliard of parameters was logically screened for direct relevance to the categorisation process. This reduced the variables to ten. Specifically, the candidate variables included "proportion of cattle herd comprising of improved breeds", "annual expenditure on artificial insemination (AI) and veterinary services per cattle TLU","milk production per TLU day" "feeding and grazing management score", "proximity to the main road", "cattle TLU ha^{-1}", "total farm land", "long term hired labour", "monthly off-farm income", and "monthly household income".

This study lasted three months; as such it was found prudent to map out the exact location of each household for purposes of repeated measures and subsequent provision of a feedback to the interviewed households. The candidate parametric data were keyed into Excel spread sheets before transfer into MINITAB for Windows version 12.21 (1998) and GENSTAT software, Release 4.2, Discovery Edition 2 (2005) for cluster analysis. Cluster analysis is a valuable statistical tool for grouping items with similar tendencies based on a set of variables (Steel et al 1997). MINITAB was used to obtain the group means by subjecting the data to Cluster K-means analysis. Mapping out relationships between farms, was done in GENSTAT using hierarchical cluster analysis. Relationships were displayed on minimum spanning tree (MST), whose axes represented principle components developed from the 10 major variables deemed to have inference on dairy intensification. Clearly marked clusters on the map then became the "Dairy Intensification Categories".

In order to develop an intensification continuum for the major clusters obtained from the cluster analysis, a ranking exercise was done. Ranking was based on variables that had marked differences in values between clusters. The variables selected for ranking were subjected to a scoring system. Scores were allocated to the value ranges basing on their inference on intensification. The scoring system was different for variables which increase with increasing intensification and those which decrease. In the case of variables which increase with increasing intensification, the scoring scale corresponded with the factor values. As such, high values for the variable were allocated high scores while the inverse was true for the low values. In contrast, for variables which tended to decrease with increasing intensification, the score scale was increasing with decreasing values of the variable. This type of scoring system was used to maintain increasing overall scores with increasing dairy intensification and decreasing overall scores when intensification was decreasing. The clusters were then named according to their dominant management system observed among the farms therein.

Results and discussion

Dairy cluster analysis and cluster components in Uganda

The hierarchical cluster analysis which also included a Principal Component Analysis resulted first and foremost in a minimum spanning tree (MST in Figure 1) comprised of two principal component axes.

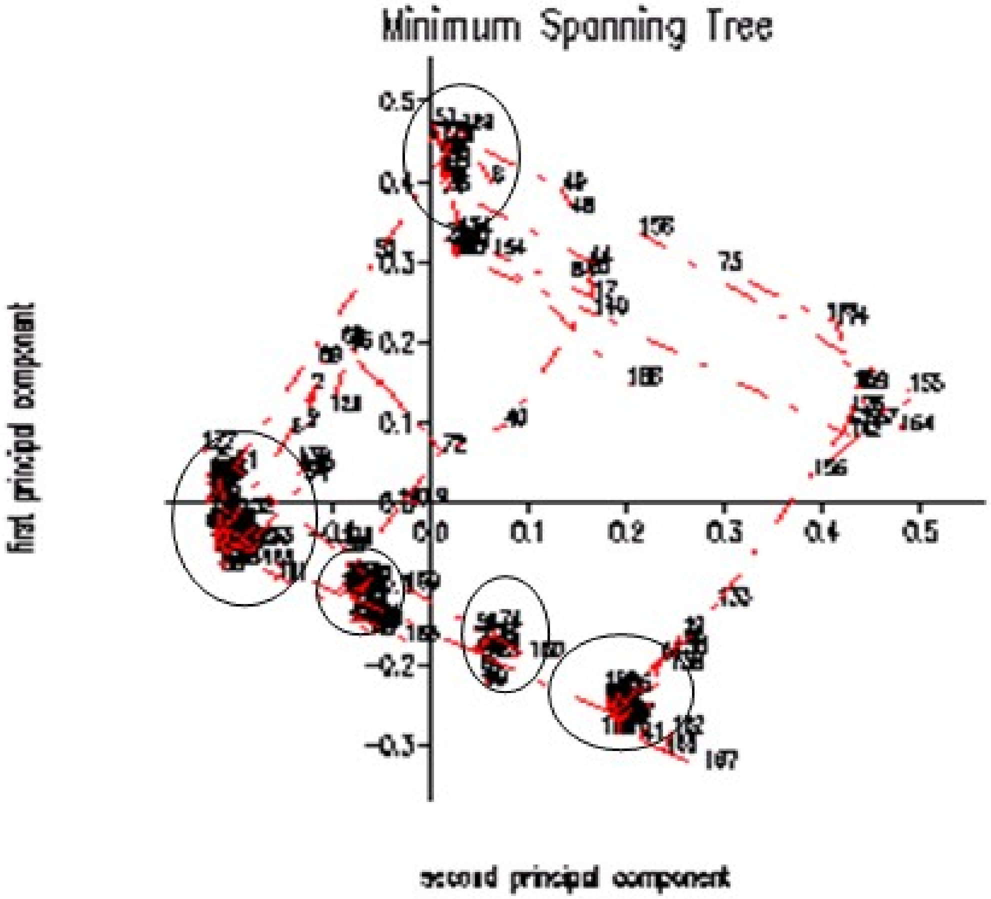

Figure 1. Minimum spanning tree showing the five distinct clusters

In general, the cluster analysis gave rise to 16 clearly discernible groups (Table 2). Of these, five clusters emerged prominently, namely clusters 8, 9, 12, 13 and 15, (Figure 1) each with 5, 19, 17, 12 and 9% of the overall farm cases involved in the survey (Table 2), respectively.

Table 2. Uganda's dairy clusters with means of the cluster analysis components

Cluster	Proportion of improved breeds in cattle herd	Expenditure on AI and veterinary services, Ushs TLU^{-1} $year^{-1}$	Milk production, Litres TLU^{-1} day^{-1}	Feeding & grazing management score	Proximity to the main road, Km	Cattle TLU ha^{-1}	Total farm land, ha	Long term hired labour, persons	Off-farm income, Ushs $month^{-1}$	Household income class	% of farms
1	0.17 (0.37)	26530 (5459)	0.58 (0.77)	1.9 (2.2)	3.2 (4.1)	1.5 (0.7)	2.3 (2.1)	0.9(1.1)	25714 (5345)	3.3 (1.4)	4
2	0.14 (0.33)	14556 (3218)	0.97 (2.17)	4.2 (2.0)	1.0 (1.1)	2.4 (2.2)	1.7 (1.6)	1.8 (1.2)	46666 (4330)	3 (1.6)	5

3	0.6 (0.49)	23954 (5103)	1.76 (1.37)	5.8 (3.0)	0.1 (0.2)	2.1 (0.7)	1.6 (1.3)	1 (1.4)	50000 (0)	3.5 (1.2)	2.19
4	0.43 (0.54)	47861 (9207)	1.13 (2.3)	4 (3.7)	0.4 (0.6)	0.8 (0.3)	5.7 (10.8)	1 (1.4)	48286 (3729)	3.57 (0.8)	3.83
5	0.83 (0.41)	92259 (9367)	0	4.3 (2.9)	0.8 (1.3)	0.7 (0.6)	1.3 (0.8)	0.2 (0.4)	1083 (1201)	2.5 (1.2)	3.28
6	0.56 (0.51)	25399 (7354)	2.95 (5.2)	5.3 (2.9)	0.9 (0.9)	2.4 (1.9)	1.3 (1.3)	0.8 (1.5)	85000 (10000)	4.25 (0.5)	2.19
7	0.12 (0.24)	7933 (3665)	0.48 (0.5)	3.1 (2.2)	1.1 (2.1)	4.9 (5.9)	4.7 (7.8)	1.8 (1.4)	34063 (6120)	3.13 (1.4)	4.37
8	0.38 (0.50)	16732 (16024)	2.09 (1.61)	1.9 (2.6)	1.4 (2.5)	1.2 (1)	16.5(26.5)	1.8 (1.1)	221000 (23781)	5.7 (0.5)	5.46
9	0.29 (0.41)	2501 (2608)	0.86 (1.12)	1.7 (2.8)	2.4 (3.8)	1.6 (1.6)	6.7 (9.2)	1.1 (1.3)	2826 (4487)	2.23 (1.2)	19.1
10	0.15 (0.35)	7763 (5518)	1.61 (1.25)	1 (1.9)	3.4 (4.2)	1.2 (1)	6.0 (3.3)	1.4 (1.2)	94125 (8887)	4.88 (0.8)	4.37
11	0.02 (0.05)	6569 (4507)	0.82 (1.51)	3.9 (2.7)	3.1 (4.1)	4.2 (7.1)	1.7 (1.0)	1 (1.4)	63429 (5224)	4.14 (0.7)	3.83
12	0.16 (0.34)	12702 (2934)	1.03 (1.32)	3.1 (2.3)	1.3 (1.8)	2.3 (2.1)	5.2 (7.7)	1.1 (1.2)	4406 (5073)	2.16 (1.1)	17.5
13	0.42 (0.48)	52974 (8356)	2.9 (4.05)	5.2 (3.0)	1.2 (1.3)	0.9 (0.7)	2(1.7)	0.5 (1)	5386 (7400)	2.82 (1.6)	12.0
14	0.34 (0.48)	14796 (16141)	1.17 (1.1)	1.6 (2.5)	0.8 (1.4)	2.2 (1.7)	2.1 (2.2)	1.2 (1.6)	160000 (15811)	4.8 (1.3)	2.73
15	0.24 (0.40)	27099 (5114)	2.05 (2.98)	3.7 (2.9)	1.1 (1.5)	1 (0.7)	2.5 (1.8)	0.9 (1.3)	1765 (2507)	3.18 (2)	9.29
16	0	35063 (7992)	0	1.5 (2.1)	0.5 (0.7)	1 (0.8)	2.3 (1.7)	1.5 (0.7)	68500 (2121)	5 (0)	1.09
$LSD_{0.05}$	0.16	2681	0.86	1.1	1.02	0.902	3.41	0.48	3138	0.52	

AI = Artificial insemination; Ushs = Uganda shillings (Ushs 1850 = 1 US$); TLU = Total cattle units; Feeding & grazing management score range: 0 = Communal grazing with no additional feeds, up to 10 = Exclusively zero grazing with use of concentrates. Income class rating was based on classes which ranged from 1, to 6 (1 = < 10,000; 2 = 10,000 – 30,000; 3 = 30,000 – 60,000; 4 = 60,000 – 100,000; 5 = 100,000 – 200,000 and 6 = >*200,000 Ushs month^{-1}) Sample size = 183; values in parenthesis are standard deviations*

As such, the groups with insignificant farm cases were labelled non-substantial clusters in the context of strategic dairy management; hence were delisted at cluster level. Subsequently, the five main clusters, 8, 9, 12, 13 and 15, formed the platform for developing the desired dairy intensification farm categories. Overall, the level of cluster prominence was in the order of 9, 12, 13, 15 and 8.

Cluster 8 had features of large farm land (16 ha) and very high off-farm income (Ushs 221,000), while Cluster 13 prominently characterised by high expenditure on veterinary services (Ushs 52,974 TLU^{-1}year^{-1}) and high tendencies towards zero grazing management (feeding and grazing management score = 5.2). On the other hand, Cluster 12 was uniquely represented by least farm land (0.6 ha) and very low proportion of improved breed in their cattle herds (0.16). Cluster 9 had the lowest expenditure on veterinary services and cluster 15 the lowest off-farm income.

Cluster intensification levels and dairy categories

Three variables were identified from the original 10 for use in developing an intensification continuum. These were milk production, total land, and expenditure on veterinary services. The ranges of values within each score for the selected variables are shown in Table 3.

Table 3. Value ranges for ranking clusters

Milk production, Litres TLU^{-1}	Milk score	Total land, ha	Land score	Annual expenditure on veterinary services, Ushs TLU^{-1}	Veterinary services score
0	1	< 1.01	4	0 – 6667	1
0 – 0.5	2	1.01 – 2.08	3	6667 – 14458	2
0.5 – 1.78	3	2.08 – 3.84	2	14458 – 31234	3
1.78 - 1219	4	>3.84	1	31234 - 100000	4

Farms in cluster 13 had the overall highest level of intensification of production (Table 4), while those in cluster 9 had the lowest level. In between these two clusters, were clusters 15, 8 and 12 in decreasing order of intensification.

Table 4. Ranking of the major clusters on basis of the three major variables to obtain the intensification continuum

Cluster	Factors used in scoring			
	Milk production	Total land	Expenditure on veterinary services	Total score
8	3	2	2	7
9	2	2	0	4
12	2	2	1	5
13	3	4	3	10
15	3	3	2	8

On basis of the feeding and grazing management systems practised on the farms in the different clusters (Table 5), clusters 8, 9 and 12 had large proportions (60% and above) of exclusively grazing management.

Table 5. Proportions (%) of use of the various feeding and grazing management methods on dairy farms in the five clusters

Dairy management attributes	Clusters				
	8	**9**	**12**	**13**	**15**
Mainly grazing with some zero grazing	0	19	25	13	57
Mainly zero grazing with some grazing	0	6	0	13	14
Only grazing	75	63	75	38	14
Only zero grazing	25	13	0	38	14
Communal herded					
False	90	80	63	82	70

True	10	20	38	18	29
Own pasture herded					
False	50	54	63	73	82
True	50	46	38	27	18
Communal tethered					
False	100	94	94	74	71
True	0	6	6	27	29
Own pasture tethered					
False	80	89	97	82	76
True	20	11	3	18	24
Fenced pastures					
False	50	74	63	68	82
True	50	26	38	32	18

In contrast, proportion of the same in clusters 13 and 15 was below 40%. Exclusively zero grazing was highest in cluster 13, however, presenting an equal proportion with only grazing. In cluster 15, mainly grazing with some zero grazing was the most dominant management system with a proportion 4-folds those in the other systems.

Clearly, use of communal grazing lands is higher among the more intensive clusters namely 13 and 15. In contrast, within cluster 8 use of own pastures for grazing was rampant with the proportion amounting to approximately 2 times that in cluster 12 where it was the lowest. Similarly, proportion of farms with fenced pastures was highest in cluster 8. Unlike the widespread notion that grazing on communal lands is restricted to indigenous cattle (K2-Consult 2002; Kasirye 2003), it is evident here that even under intensive management with sufficient proportions of improved breeds, communal grazing is practiced. As such, the term "communal grazing" is not suitable for use to represent a single dairy production group. In addition, grazing on communal lands is therefore not limited to subsistence dairy production but is also practiced in the commercial systems.

Evidently, the largest proportion of exclusively zero grazing farms in cluster 13 is confirmation of the high level of intensification of dairy production within this group. Hence attributes associated with this cluster are typical of zero grazing farms. On the other hand, the least intensive systems in cluster 9 are associated with grazing and herding mainly on own pastures. Closely related to cluster 9, is 12 which also has prominence of herding but in this case with more farmers utilising communal land than those in cluster 9. Cluster 8 is dominated by use of own fenced pastures and would, therefore be representative of fenced farms. The large proportion of farms in cluster 15 within the "mainly grazing with some zero grazing" group presents a basically semi-intensive (semi-zero grazing) management system. Dairy systems depending purely on grazing, as observed by Staal and Kaguongo (2003), tended to be located where land resources were available. In this case this occurred with increasing distance from the main roads at approximately 2.4 and 1.4 km for clusters 9 and 8 respectively.

Mbarara is dominated by clusters 12 and 8 while Masaka is dominated by cluster 9. Clusters 15 and 13 have highest incidence in Jinja. This distribution of clusters among the districts provides inference on the types of production systems suited to the area climatic conditions and preferences of the people. Extension and development work, therefore, should take this into account and not overly focus on specific farm types as the only development pathway.

Clearly, the dairy farm categories established are critical in targeting research and development. As such, intensive feeding strategies should be targeted at farms in cluster 8 (fenced) and 13 (zero grazing). This is because they already have high potential dairy cattle compared to other categories. Similarly, areas dominated by these clusters; 8 and 13, with higher milk yields than the rest, should receive priority in research and development work on identification of profitable milk marketing channels and sources of market information. Interventions on controlling stocking rates should target cluster 12 (herding mainly on own land) where cattle TLU ha^{-1} is highest. Clusters 13 (zero grazing) and 15 (semi-zero grazing) should be targeted with strategies on maximum utilisation of land to reduce the effects of limited land sizes. On the other hand, strategies to reduce hired labour should be directed towards cluster 8 (fenced) where herding, fencing and general livestock management increase the need for hired labour.

Conclusions

- The dairy systems in Uganda express large variation in terms of land use, feeding strategies and herd structure, which are linked with costs and investments, milk yields and labour use and results in different degrees of intensification.
- Our study isolated five distinct categories along the farm intensification continuum based on their management centre of gravity into Herding-on own and communal land (cluster 9), Herding-mainly on own land (cluster 12), Fenced (cluster 8), Semi-Zero Grazing (cluster 15) and Zero Grazing (cluster 13).
- These categories are based on multiple pertinent criteria purposely selected and sequentially screened for relevance to the clustering and eventual categorisation processes.
- Most of the criteria especially those quantitative in nature have hitherto not been considered in earlier classification efforts.
- The ultimate critical criteria that formed the foundation for categorisation are (i) the milk production, (ii) total land and (iii) annual expenditure on artificial insemination and other veterinary services.
- The categories, together with their supporting conditions outlined in this study, provide a valuable decision support tool for targeting research and development interventions.
- Such interventions include those devised to address issues related with breeding, feeding and grazing, crop-livestock interactions, health management and product marketing strategies.

Acknowledgements

The authors are grateful to staff of the International Livestock Research Institute (ILRI), Makerere University and the Danish Institute of Agricultural Sciences (DIAS) for technical advice. The Danish Agency for International Development (DANIDA) funded this study. The National Agricultural Research Organisation (NARO) and the Government of Uganda provided logistical support.

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Received 17 April 2007; Accepted 13 May 2007; Published 6 July 2007

Go to top