

Dairy Performance and Intensification under Traditional and Economic Efficiency Farm Plans in Uganda

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Abstract: This study was motivated by the realisation that although public and civil society projects interventions emphasize dairy intensification, dairy producers adopt systems that exhibit a continuum of intensification stretching from extensive to intensive levels. De-intensification of zero grazing, downgrading of herds in other grazing systems and adoption of extensive or intensive systems on farmers' own accord have been observed. The purpose of this study was to examine enterprise choices and resource allocation in different dairy systems under traditional (observed) and optimum (profit driven) scenarios. Longitudinal data used was obtained from 14 representative farms for zero grazed, tethered, herded, semi-intensive and fenced dairy systems in Masaka, Mbarara and Jinja districts. Observed and profit driven farm plans were assessed by whole-farm modeling using Linear Programming net farm benefit maximization. Results obtained show that net farm benefits were significantly higher for profit driven plans compared to observed farm plans for all dairy systems; milk cost of production was highest (168 Uganda shillings) in zero grazed systems and lowest in fenced systems (114 Uganda shillings). As expected milk density, milk/TLU and market orientation matched with the trend of dairy intensification. Only returns per land unit matches with degree of intensification. Returns to TLU and labour are not necessarily highest in most intensive farms. Shadow prices on crop residues and land indicate that extra feeding of crop residues would lead to significantly higher net benefits in zero grazed, tethered and semi-intensive systems. Increasing available land produces significantly higher net farm benefits for all systems except tethered systems. In all dairy systems, quantities of manure applied are lower than those deposited on farms. Sensitivity analysis on labour price shows that potential increase in wage rates more adversely affects long term sustainability fenced and zero grazed systems compared to other systems. The following recommendations were made. Promotion of dairy intensification implemented by Government (DDA, MAAIF, NAADS, NARO and PMA), civil society organizations and other actors in the dairy industry should strategically consider labour and feed resource availability. Targeted identification of superior cattle of indigenous breeds should be done by MAAIF, NARO and NAGRC and DB for improved management of herded dairy and preservation of indigenous breeds in the national herd. Dairy research and development by Government (MAAIF, NARO, NAADS and DDA), civil society organizations and other actors in the dairy industry should systematically identify and promote crop residues and manure technologies to improve exploitation of crop-livestock synergies. Further research is being proposed in the following areas. Optimum packages and domains for zero grazing and dairy upgrading where benefits justify associated higher input costs; Characterization and selection of indigenous breeds of desired attributes to benefit from their multipurpose uses and prevention of genetic erosion of indigenous breeds; Systematic selection, processing and application of crop residues and manures for development of appropriate management practices for sustained dairy yield stabilization.

Key words: Dairy • Farm benefits • Intensification • Linear programming • Maximization • Observed plans
profit motivation • Long term viability

INTRODUCTION

Uganda's dairy sub-sector liberalization, economic and ecological sustainability development objectives focus on widening the sections of society consuming milk and raise its per capita consumption from the current level of about 40 litres, using dairy as a route out of poverty and increasing milk production through increased animal productivity rather than numbers [1, 2]. Domestic farm resources particularly land, labour and feeds; market access; and location factors such as population density and weather vary within and between dairy sheds. Nevertheless, the effects of development policies and influence by fellow farmers, Government and civil society development projects have resulted into tendency towards promotion of high input-high output intensively managed dairy systems. Pingali, [3] and Smith *et al.* [4] argue that dairy intensification would ideally be motivated by population density, pressure on land and market access factors.

EXPERIENCES AND TRENDS OF DAIRY INTENSIFICATION IN UGANDA

Intensive management methods practiced and sometimes promoted by development agents may not necessarily be consistent with dairy product markets and farm resource endowments to which producers are exposed. This is exhibited by de-intensification of zero grazed systems to less intensive farms with small fenced paddocks for limited grazing. The less labour intensive and semi-intensive systems are deemed more appropriate following farmers' experiences with household land and labour resource endowment, farming objectives, farm support services, dairy product demand and market access conditions available resources [5]. In addition, trends of downgrading of recently upgraded herds are also common in semi-intensive, fenced and herding dairy systems especially where milk prices received by farmers are low.

The objectives of the study were; to examine dairy profitability, productivity and returns to land, labour and animal units in observed and profit driven farm plans; and to make policy recommendations consistent with farmers' resource, location and market access conditions.

DATA SOURCES

Site Selection and Sampling Methods: The study was conducted in Mbarara and Kampala-Jinja dairy sheds and covered Mbarara; Jinja and Masaka districts. Longitudinal

surveys conducted in 12 months (August 15, 2003 to August 15, 2004) extracted data from 14 representative dairy systems of increasing levels of intensification namely; herding, tethering, fenced, semi-intensive and zero grazing. Intensification stratifying factors were milk/TLU, milk/hectare, veterinary input and service expenditure/TLU, percentage of exotic dairy breeds in the herd and grazing management. Data were recorded for two cropping seasons with the 1st season running from August 15, 2003 to February 15, 2004; and 2nd one from February 16, 2004 to August 15, 2004 on an interval of once every two weeks. Data collected comprised of; allocation of land for food, commercial and fodder crops, grazing and fallow; participation of household and hired labour in crop farming and livestock keeping; crop and livestock production and consumption activities.

Crop and livestock revenue generation; livestock feeding regimes, crop residue and manure utilisation; selling and buying activities of farm outputs and inputs; and household expenditure on farm inputs and services, food, fuels, tools, health, social services and needs.

MATERIALS AND METHODS

Conceptual Framework and Empirical Models: A whole farm approach that was used in the study, considered crop, pastures, household labour and food, cattle, other livestock as major activity categories (Appendix 1). Data were analysed to determine optimality in resource use by Linear Programming (LP) models. Similar to La Rovere *et al.* [6] market value of total production including subsistence, cultural, social capital, asset growth, cash income aspects of farm output of crop-livestock mixed systems were considered. The empirical general objective function form was specified as:

$$\text{Maximise } Z = \sum_{j=1}^m c_{ij} x_{ij} + \sum_{k=1}^n c_{ik} x_{ik}; \text{ for seasons } i = 1$$

and 2 in one year

For crop activities $j = 1$ to m ; livestock activities $k = 1$ to n

Where:

Z = Annual farm net benefits from crop and livestock activities

c_{ij} = Net benefits per unit of the j^{th} crop activity in the i^{th} season

c_{ik} = Net benefits per unit of the k^{th} livestock activity in the i^{th} season,

x_{ij} = Level of j^{th} crop activity in the i^{th} season.

x_{ik} = Level of the k^{th} livestock activity in the i^{th} season

Appendix: A lay out of crop-livestock whole farm Linear Programming model

Activities		Crop	Pasture	Livestock	Hh food	Hh labour	LHS	Rel	RHS
Constraint	Units	Ha	Ha	TLU	PEF	PEL			
Level season 1	Ha/TLU	0	0	0	0	0			
Level season 2	Ha/TLU	0	0	0	0	0			
Objective function s1	Shs/Ha/TLU	1	1	1	1	1			
Objective function s2	Shs/Ha/TLU	1	1	1	1	1		max	
Land	Ha	1	1					<	Ha HH land
Stock flow cash	Shs			+/-				<	'000/- Shs
HHPEL	PEL in s1					-		=	HHPEL PEL s1
HHPEF	PEF in s1				-			=	HHPEF PEF s1
Hired labour s1	Hours	+	+	+		-		<	Hours Hired labour
HH labour s1	Hours	+	+	+		-		<	Hours HH labour
Livestock inventory	TLU			+/-				=	Starting TLUs Start stock inventory
Balances s1									
Crop yields	Kg	+			+		-	<	Kg MKT
Milk	Litres			-	+		-	<	Kg MKT
Manure dry matter	Kg	+		-				<	Liters TLU
Crop residues dry matter	Kg	+		-				<	Kg TLU
Grazed feed dry matter	Kg		+	-				<	Kg TLU
								<	Kg TLU
SEASON 2									
PEL	PEL in s2					-		=	HHPEL PEL s1
PEF	PEF in s2				-			=	HHPEF PEF s1
Hired labour s2	Hours	+	+	+		-		<	Hours Hired labour
HH labour s2	Hours	+	+	+		-		<	Hours HH labour
Livestock inventory	TLU			+/-				=	Ending TLUs Ending stock inventory
Balances s2									
Crop yields	Kg	+			+		-	<	Kg MKT
Milk	Liters			-	+	+	-	<	Liters MKT
Manure dry matter	Kg	+		-				<	Kg TLU
Crop residues dry matter	Kg	+		-				<	Kg TLU
Grazed feed dry matter	Kg		+	-				<	Kg TLU
								<	Kg TLU

S1 and S2 refer to seasons 1 and 2; HHPEL and HHPEF signify household person equivalent for labour and food; MKT refer to market and household balances

Subject to land, labour, capital, subsistence, crop and livestock enterprise constraints.

For each dairy system, two types of farm plans were examined – that is observed and profit farm plans. Under observed plans constraints and enterprise levels were fixed to simulate current farm management. For the profit plans these constraints and levels were relaxed so the model can allocate resources based on economic efficiency (profit maximizing) criteria subject to provision of minimum subsistence requirements.

RESULTS AND DISCUSSION

Farm Characteristics and Dairy Intensification: Descriptive statistics of longitudinal farms in terms of land sizes, herd structures and breed categories is presented

with decreasing levels of intensification of zero grazed, semi-intensive, fenced, tethered and herded systems (Table 1).

The area of the study represented diversity in land sizes, feed resource endowment and breed categories. Herded (14 hectares) and fenced (13 hectares) systems were more land resourced. All systems had own pasture resources except the zero grazed system. Improved pastures, however, only existed on semi-intensive and fenced farms. Dairy herd sizes matched with land sizes with zero grazed, tethered and semi-intensive systems keeping on average 0.7, 2.4 and 3.5 cattle TLUs, respectively. Corresponding herd sizes for herded and fenced farms were 8 and 11 TLUs. Breed categories were specified as local, crosses and high grade depending on the degree of exotic dairy breeds in the herd. More

Table 1: Longitudinal farmers' land characteristics and cattle herd structure

Characteristic N	Dairy systems				
	Zero grazed 1	Semi-intensive 5	Fenced 4	Tethered 2	Herded 2
Land size (Ha) Crops	0.40	1.10	2.12	1.07	1.35
Pastures	0.00	1.63	10.44	1.06	12.76
Herd structure (TLUs)	Season 1(season 2)				
Bulls	0.00 (0.00)	0.00 (0.00)	0.50 (1.00)	0.00 (0.50)	1.00 (1.50)
Castrates/young stock	0.00 (0.00)	0.50 (0.50)	1.40 (1.75)	0.00 (0.50)	1.75 (2.50)
Cows	0.70 (0.70)	1.68 (1.82)	5.30 (6.50)	1.75 (1.40)	2.80 (4.90)
Heifers	0.00 (0.00)	1.00 (1.30)	1.75 (2.00)	0.50 (0.50)	1.25 (2.75)
Female calves	0.00 (0.00)	0.04 (0.12)	0.40 (0.30)	0.00 (0.00)	0.50 (0.50)
Male calves	0.00 (0.00)	0.00 (0.00)	0.40 (0.40)	0.10 (0.10)	0.20 (0.40)
Herd size	0.70 (0.70)	3.22 (3.74)	9.70 (11.90)	2.35 (3.00)	7.50(12.60)
Breed categories	Percentages				
Exotic	0.00	50.00	17.00	15.00	0.00
Crosses	100.00	35.00	83.00	0.00	0.00
Local	0.00	15.00	0.00	85.00	100.00

Table 2: Milk productivity and market orientation by dairy system

Dairy systems	Litres per annum Per TLU	Per hectare	TLU values '000 Ug.shs	Milk annual production (litres)		
				Total	Sold	Sales (%)
Zero grazing	2,370	4,148	629	1,569	1,224	74
Semi-intensive	1,562	2,040	842	5,567	4,660	84
Fenced	790	687	699	8,634	5,631	65
Tethered	469	612	533	1,304	847	65
Herded	211	158	345	2,223	641	29

Table 3: Farm benefits, costs and returns to land, labour and livestock units

	Gross Benefits	Variable Costs	Net benefits (NB) Whole farm	Dairy net benefits per			
	Per annum			Ha	Hour	TLU	Wage rate
Dairy systems	('000 Uganda shillings)						
Zero grazing	1,455	341	1,114	1,291	0.571	738	0.126
Semi-intensive	4,992	906	4,086	926	0.666	785	0.126
Fenced	5,695	1,449	4,246	257	0.799	300	0.048
Tethering	2,167	322	1,845	171	0.130	214	0.126
Herding	3,436	716	2,720	52	0.391	187	0.074

than one breed categories were being raised except zero grazers who only kept crosses and herded systems with local cattle. The proportion of crosses and exotic breed categories in the herd therefore increased with dairy intensification.

Farm Benefits, Dairy Returns to Resources; and Milk Cost of Production: An assessment of relationship between dairy productivity, proportion of milk sales and intensification (Table 2) revealed that milk productivity per TLU and per unit of land; and market orientation in

terms of percentage of milk sold total milk production generally increased with dairy intensification (Table 2). This concurs with 6.Gass and Sumberg, 1993 who observed that in intensive livestock systems resources are concentrated to generate higher output per unit of animal, land, capital and time and 7.DDA, 2004 who noted that level of commercialization, reflected by market orientation, increases as dairy production becomes more intensive.

Farm performance assessment was done by maximisation of net farm benefits. Net benefits were

Table 4: Milk cost of production by dairy system

Dairy system	Variable and unit costs per litre (Uganda shillings)						Producer price
	Milk transport	Hired labour	Vet. services	Vet. inputs	Water	Total cost	
Zero grazing	0.0	35.3	7.5	74.4	50.6	168.0	535.3
Semi-intensive	45.5	32.2	33.4	10.3	8.3	129.7	402.1
Fenced	28.0	52.5	24.3	9.3	0.0	114.1	211.5
Tethering	0.0	110.4	15.5	9.2	0.0	135.1	469.3
Herding	0.0	40.9	69.9	16.8	0.5	127.8	303.1

Table 5: Farm benefits in observed and profit plans by dairy system

Dairy system	Net farm benefit per annum 'million Uganda shillings				Net farm benefit per hour Uganda shillings			
	Observed (1)	Profit (2)	2-1 (%)	t-test	Observed (1)	Profit (2)	2-1 (%)	t-test
Zero grazing	1,114	1,763.31	58.31	13.70***	320	350	9.38	3.10***
Semi-intensive	4,086	6,288.99	53.92	15.95***	610	931	52.62	15.71***
Fenced	4,246	5,447.28	28.30	6.54***	480	490	2.04	0.60
Tethered	1,845	3,854.99	108.99	20.56***	260	514	97.69	19.48***
Herded	2,720	4,219.14	55.13	15.14***	196	389	98.47	22.32***

***Denotes significant difference at 1%

calculated from market value of farm production and livestock herd growth changes minus variable costs. Hired labour was calculated on the basis of total hired labour hours and market wage rate. Livestock pasture, planted fodder and crop residue feeding were based on dry matter yields and dry matter livestock feed requirements. Returns to investment in labour were assessed by comparing net benefits per labour hour with wage rate per hour of hired labour. Results show positive annual net farm benefits ranging from 1,114, 000/= for zero grazed to 4,245, 000/= for fenced dairy. This means that all dairy systems, from herding (least intensive) to zero grazed (most intensive) are profitable. This is similar to findings of Ika, 1997 who showed that crop-livestock systems in Ethiopia were profitable. A comparison of dairy enterprise returns and market wage rates (Table 3) indicated that all dairy systems remunerated farmers' labour above its opportunity cost (what they could get if they were to sell their services on farm labour market outside their farms). It is also evident that the most intensive systems do not necessarily have higher returns to labour and per TLU. Semi-intensive and fenced farms had higher returns to labour and per TLU compared to zero grazed farms. Intensification was, however, positively associated with returns to land.

Unit cost of production of milk is an important aspect of dairy management. In the short run period, fixed costs are not expected to change and were therefore not considered in the calculation of the cost of milk production. Besides, family labour, costs of assets and

opportunity cost of land are not considered in the calculation but home-consumed milk is included. Cost of milk production per litre is based on basic production variable costs. These include milk transport from farm to selling point, veterinary service costs on treatment, acaricide and antihelminthic applications, vaccinations and assistance in calving; dairy inputs like feeds, acaricides, dewormers and drugs; hired labour; and water purchases as shown in (Table 4).

The results show that the zero grazing system had the highest unit cost of milk at 168/= with the lowest for the fenced system at 114/= per litre of milk. A similar trend in milk unit cost of production was shown by ILRI-MAAIF [7]. The results are, however, contrary to Griffith and Zepeda [8] who indicated that extensive farms produced milk at the least cost. Intensive farms in Costa Rica heavily depend on expensive imported feeds yet in Uganda livestock feeding even for intensive farms heavily rely on home grown fodder and own pastures with high family labour inputs.

Relationships between observed and profit driven net benefits show that profit driven plan net farm benefits were higher ($p \leq 0.01$) than those obtained from observed farm plans for all dairy systems (Table 5). Net benefits from profit plans are greater by at least 28% in the fenced system. The biggest difference of 109%, was recorded in the tethered system. This agrees with Mengistu [9] and Okoruwa *et al.* [10] who noted a 15-22% difference in optimum gross margins compared to the farm plans and Bezabih and Storck [11] who observed

Table 6: Crop residues and farmland shadow prices and manure use levels

Dairy systems	Crop residues Farmland (Shadow prices '000 Ug. shs)		Manure use (Percent of total manure deposition)	
	Per Kg DM	Per hectare	Season 1	Season 2
Zero grazed	1.16	796.00	14.00	0.00
Semi-intensive	2.60	1,288.00	0.40	0.00
Fenced	0.36	836.00	1.40	3.30
Tethering	2.52	3.00	13.80	4.00
Herded	0.39	793.00	1.90	0.40

Table 7: Percentage reduction in net benefits due to increase in wage rates

Dairy systems	Increase in wage rates (per cent)			
	50	100	150	200
Zero grazing	7.17	14.34	21.51	28.63
Semi-intensive	1.45	2.90	4.36	5.81
Fenced	6.02	12.03	18.05	24.07
Tethered	2.36	4.72	7.08	9.47
Herded	1.94	3.89	5.83	7.77

37% difference in cash income of oil crops in the farm compared to the profit plans. Net farm benefits per unit of labour invested were significantly higher in the profit plans compared to farm plans in the semi-intensive, tethered and herded systems. This implies that returns to labour would be significantly higher in the profit plans compared to observed plans for all systems except fenced farms. This implies that fenced farms were utilizing labour at more or less the optimum level.

Crop-livestock Interactions and Labour Sensitivity:

Crop-livestock interactions considered were feeding own crop residues to own cattle and application of own cattle manure herd to own crop fields. Benefits of these interactions were assessed by shadow prices of 'cut and carry' crop residues and extent of manure use (Table 6). Kitchen wastes like crop peelings, sheaths and haulms were the common own crop residues fed to cattle. Others included stems and leaves of cereals and bananas left after harvests and crop thinnings of mostly cereals like maize. Shadow prices on crop residue show that additional units of crop residue per TLU leads to higher farm net benefits compared to the input cost (111/=per Kg). The response is, however, higher for zero grazing (1,160/=), semi-intensive (2,600/=) and tethered systems (2,520/=) where feed supplementation is most intense compared to herded and fenced systems.

Crop residues supplementation should target in intensively managed and/or confined tethered, zero grazed and semi-intensive dairy systems. These systems

cultivate substantial proportions of their total land and receive high milk prices. Crop residue feeding co-exists with high cropping densities and favourable market prices both of which stimulate dairy intensification. These findings concur with Mengistu [9] with shadow prices for own pasture justified higher investment in pasture given higher farm benefits compared to associated costs incurred.

The practice of manure application to own crop fields was uncommon. Manure was not a binding constraint. Application levels were less than amounts produced. Shadow prices of zero values for manure in all dairy systems, implies that the additional value of manure is less than the cost of applying it. Overall, a maximum of 15% of total manure produced was applied by farmers in all systems. Nevertheless, zero grazed and tethered systems had higher proportions of manure applied to crops compared to other systems. Zero grazers applied manure to banana-coffee intercrops at 590 Kg DM/ha/annum and tethered farms used 766 Kg DM/ha/annum of manure on banana-beans enterprises. In fenced dairy systems, the bulk of manure (5,400 Kg DM/ha/annum) was applied to pineapple fields and about 700 Kg DM/ha per annum was applied to banana fields. Cattle manure application rates of 4.2 tons per hectare are considered appropriate [12]. Manure application is mainly done in the season that coincides with mid and end of year school holidays probably to take advantage of increased family labour and on high value (pineapples) and commercial crops (bananas and coffee). There was hardly any manure related crop-livestock interaction in the semi-intensive system. Optimality in land use shows that for all dairy systems the marginal value product of land is positive. Except in the tethered system, marginal increase in land of one hectare would increase annual net farm benefit by more than 150,000 Uganda Shillings (the annual market rental price of land).

With respect to raising wages, in Uganda urbanisation and economic development are underway.

Such trends tend to rise with economic development which increases the opportunity cost of labour [3]. Results of hired labour sensitivity on profit plans are shown in Table 7.

Results show the worst scenario of 200% increase in wages, which causes highest reduction in net farm benefits for zero grazing systems (29%) and fenced farms (24%). These systems are hence more prone to raising wage rates. Promotion of labour saving technologies like herbicides, use of groups in crop husbandry and collective milk marketing instead of individually transporting milk to collection centres would be recommended. Similar to Griffith and Zepeda [8] recommended use of labour saving technologies to increase labour productivity rather than availability would in addition avoid environmental degradation linked to dairy intensification.

CONCLUSIONS AND RECOMMENDATIONS

All dairy systems are profitable and remunerated labour above its opportunity cost. In all dairy systems alternative profit driven plans offered higher farm benefits compared to observed farm plans. As expected milk density, milk/TLU and market orientation matched with the trend of dairy intensification. There was no direct relationship between returns to labour and TLU; and milk cost of production per litre with dairy intensification but returns to land was positively related to intensification.

The following recommendations were made: Promotion of dairy intensification implemented by Government (DDA, MAAIF, NAADS, NARO and PMA), civil society organizations and other actors in the dairy industry should strategically consider labour and feed resource availability. Targeted identification of superior cattle indigenous breeds should be done by MAAIF, NARO and NAGRC and DB for improved management of herded dairy and preservation of indigenous breeds in the national herd. Dairy research and development by Government (MAAIF, NARO, NAADS and DDA), civil society organizations and other actors in the dairy industry should identify and promote crop residues and manure technologies to improve crop-livestock synergies. Further research is being proposed in the following areas. Optimum packages and domains for zero grazing and dairy upgrading in situations where benefits justify associated higher input costs; Characterization and selection of indigenous breeds with desired attributes to benefit from their multipurpose uses and prevention of genetic erosion of indigenous breeds; Strategic selection,

processing and application of crop residues and manures and development of appropriate management practices for sustained dairy yield stabilization.

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