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Risk attitudes, resource rationalization and dairy intensification in Uganda: Stochastic dominance with observed and optimal net farm benefits

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ABSTRACT
Objective: Despite policy and development focus promoting dairy intensification, dairy management in Uganda still exhibits a continuum stretching from intensive to extensive systems. The purpose of this study was to examine farmers' risk attitudes and its effects on enterprise choices and resource use under different dairy intensification systems.
Methodology and results: Longitudinal data were obtained from 14 cattle farms drawn from Masaka, Mbarara and Jinja districts. Farms were sampled to represent increasing levels of intensification i.e. zero grazing, semi-intensive fenced, tethered, and herded dairy systems. Observed and profit driven farm plans were established by net farm benefit maximization using linear programming whole-farm modeling. Risk attitudes were examined by stochastic dominance techniques. Results of net farm benefit maximization show that all dairy systems are profitable under observed plans and that profit plans would lead to higher farm net benefits in all dairy systems. All systems, except tethered ones, have second order degree stochastic dominance (SSD). Tethered systems show first order stochastic dominance (FSD). Producers in zero grazed, semi-intensive, fenced and herded systems are risk averse whereas tethered farms extravagantly utilized farm resources beyond optimal levels. Farmers' risk averting behavior resulted into raising multiple crop enterprises in dairy systems. Optimal cattle herd sizes were in fenced and herded systems, slightly larger than optimal herds were kept in the semi-intensive and tethered systems while slightly lower than optimal herd sizes were raised in the zero grazing system.
Conclusion and application of findings: In order to successfully shift to more profitable systems, alternative management practices proposed are (1) adopting fewer but bigger crop enterprises; (2) maintaining traditional staple foods to cater for subsistence needs and preferences and to ensure gradual adjustment; (3) reclaiming fallow lands into production in zero-grazed, semi-intensive, fenced and herded systems; (4) releasing some land out of production in the tethered system; and (5) using more hired labour. Land released from the tethered system could be rented out to other land constrained systems. The proposed plans would lead to more stable dairy livelihood dynamics that are necessary for household subsistence needs, at the same time catering for traditional food preferences and nutritional diversity and also ensuring shifts towards the desired sustainable commercialisation of dairy systems under the Government's Plan for Modernisation of Agriculture (PMA) development policy framework.

Key words: Dairy, intensification, livelihood dynamics, sustainable commercialization

INTRODUCTION

In Uganda dairy development policy focuses on increasing per capita consumption of milk from the present low levels of about 40 litres and exploiting dairy production as an avenue for addressing the national development objective of 'prosperity for all' through improved cattle productivity rather than increasing herd sizes (MAAIF, 1992; DDA, 2004). These factors have led to concerted government and civil society efforts to promote intensification of production especially through stall feeding and upgrading of open grazing systems. Experiences encountered particularly in labour, feed and management costs and farm gate milk prices have in some cases resulted into de-intensification of dairy production (Atokple *et al*., 1995). Presently, dairy management in Uganda exhibits a continuum with farmers willingly adopting extensive (tethered and herded) and intensive (stall feeding, semi-intensive and fenced) dairy management systems. In addition, traditional sole cropping and livestock production systems are being transformed into crop-livestock integrated systems.

Farmers face a variety of risks in price, yield and resources. The risks are influenced by changes in demand and government policies, weather and environmental conditions, animal diseases, pests, parasites and accidents, feed and water shortages, and uncertain procurement of the required quantities and quality of various inputs (Hazell & Norton, 1986; Bezabih & Storck, 1992; Lien & Hardaker, 2001). Farmers' traditional or observed economic behavior therefore tends to focus on household livelihood strategies for food as well as income generation. Selected enterprise types, sizes and combinations are hence a result of a balance between labour markets, milk demand factors and risk attitudes.

If profit motivation were the major driver of farmers' decisions on resource allocation and enterprise choices, more economically efficient (profitable) alternative farm plans would be implemented. Producers' risk attitude, however, leads to significant differences between farmers' observed and profit driven enterprise types and sizes causing huge trade-offs in farm benefits. Yield and price fluctuations are the major sources of risk.

According to Derbetin (1993), if probabilities of occurrence of risky outcomes are known, risk can be dealt with. Robison *et al*. (1984) stated that farmers express their risk attitudes through forward pricing, production practices, insurance, holding liquid cash reserves, diversification, and liability management, among others. In Uganda, livestock production is partially commercialized (Ashley & Nanyeenya, 2005) and risk attitudes are mostly manifested through risk averting production practices. The objective of this study was to (1) examine enterprise choices and resource use, (2) study risk attitudes under observed and profit driven farm plans.

METHODS AND METHODS

Study sites and sampling plan: The study covered Mbarara, Jinja and Masaka districts. Longitudinal surveys were conducted covering 12 months so as to capture year-round profiles and streams of farm costs, benefits and activities. Data were recorded once every two weeks for two cropping seasons with the 1st season running from August 15, 2003 to February 15, 2004, and 2nd season from February 16, 2004 to August 15, 2004. Data were extracted from 14 representative farms drawn from five dairy systems of increasing levels of intensification. These included herding, tethering, fenced, semi-intensive and zero grazing systems. Intensification was defined on the basis of the following factors; milk per tropical livestock unit (TLU), milk per hectare, cattle TLU per hectare, veterinary input and service expenditure per TLU and percentage of exotic dairy breeds in the herd. Zero grazing, semi-intensive and fenced systems were classified as intensive while herding and tethered farms were extensive. 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-livestock integration through crop residue and manure utilization; selling and buying activities of farm outputs, and inputs; household expenditure on farm inputs and services.

Conceptual framework and empirical models: A whole farm approach was used in the study. This considered crop, pastures, household labour and food, cattle and other livestock as major activity categories. Data were analysed to determine optimality in resource by Linear Programming (LP) models. The market value of total production including subsistence, cultural, social capital, cattle asset growth in TLUs and cash income from farm output of crop-livestock mixed systems was considered, as done by La Rovere *et al.* (2005). 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.

Subject to land, labour, capital, subsistence, crop and livestock enterprise constraints, two types of farm plans were examined for each dairy system, i.e. observed and profit plans. Under observed plans, constraints and enterprise levels were fixed to simulate current farm management as observed. For the profit plans, the constraints and levels were relaxed so that the model can allocate resources based on economic efficiency (profit maximizing) criteria subject to provision of household minimum subsistence requirements. Farmers risk attitude was assessed using cumulative probability distribution functions of net farm benefits for observed and profit driven farm plans for each dairy system. Graphs of the two cumulative functions may conform to either first order or second order stochastic dominance depending on the weight assigned to risk in the farmer's utility function. This measure of satisfaction guides the decision maker to choose activities and levels maximising expected utility of farm benefits or income from uncertain outcomes that are consistent with their degree of risk aversion.

Farmers' past experiences on yield and price fluctuations was used to generate the deviations around the mean (Maleka, 1993). Standard deviations on each crop price and yield, and milk output and price enterprise were used to develop expectations of 100 potential net benefits values for both observed and profit plans using a MINITAB random number generator. For the dairy enterprise, additional revenue risks stem from further milk loss distinct from weather or price changes. This necessitated inclusion of additional probabilities of infertility or delayed conception (non-fatal) and death (fatal) circumstances. Such milk loss risks were estimated by multiplying probabilities associated with fatal and non-fatal milk losses with the lowest value of cumulative milk net benefit and deducted from the cumulative milk net benefit function for the range of probability over which that particular event occurs.

In the cumulative profit plan, dairy system net benefits were hence adjusted for weather, price and breeding (non-fatal) and death (fatal) related dairy revenue loss risks. By plotting 100 expectations of both the observed and profit models on the same plane, the degree of producers' risk aversion was deduced using the location of the graphs on the plane. Risk efficiency criteria that integrate information about a decision maker's preference and expectations to identify choices under uncertainty (King & Robinson, 1984) was employed. Graphs come out either First Order Degree Stochastic Dominance (FSD) or Second Order Degree Stochastic Dominance (SSD) condition. In FSD criterion, decision makers prefer less to more for all possible outcomes and are therefore inappropriate in resource use or irrational in decision-making. Under SSD situation, individuals are risk averse, avoid worst possible outcome and forego best possible gains (King & Robinson, 1984), and they therefore trade risk for extra benefits.

RESULTS AND DISCUSSION

Farmers' land characteristics and cattle herd structure: The areas covered in this study represented diversity in land sizes, feed availability, cattle herd sizes and breed categories (Table 1). 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, existed on only semi-intensive and fenced farms. The sizes of dairy herds had a positive relationship with the size household landholdings 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 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 herds therefore increased with dairy intensification.

Table 1: Dairy farmers' land characteristics and cattle herd structure in Uganda.

Characteristic		Dairy systems				
		Zero grazed n = 1	Semi-intensive n = 5	Fenced n= 4	Tethered n =2	Herded n =2
Land size (Ha)	Crops	0.40	1.10	2.12	1.07	1.35
	Pastures	0	1.63	10.44	1.06	12.76
Herd structure (TLUs)		Season 1(season 2)				
Herd size		0.70(0.70)	3.22(3.74)	9.70(11.90)	2.35(3.0)	7.5(12.60)
Breed categories		Percentages				
Exotic		0	50	17	15	0
Crosses		100	35	83	0	0
Local		0	15	0	85	100

Zero grazed dairy systems: Results of enterprise and resource levels in zero grazing systems in seasons 1 and 2 for the observed and profit driven plans are shown in table 2. In the profit maximization plan, land under cultivation would increase by 54 and 50 percent in seasons one and two, respectively, and a fourfold and threefold increase in hired labour for seasons one and two respectively, hence the increase in net benefits of 58%. Correcting shortages in family labour using hired labour (Mengistu, 1997) is necessary for expanding crop and dairy enterprises and would be justified by the significant change in net benefits. In the profit plan, all slack land resources are used for production. In the profit plan, cattle herd sizes would be raised by 49% and 80% in seasons one and two, respectively. In the observed plan, calves and yearling are sold quickly yet by maintaining them as in the profit plan optimum herd size, they would contribute more in terms of milk revenues and TLU market off take. This arrangement concurs with Bezabih and Stork (1992) who noted increased herd size and more market integration in the improved model compared to the actual model. Fewer and bigger crop enterprises were selected, the yams enterprise was dropped and the size of the coffee-banana plot was retained but it was heavily intercropped with maize in the second season and expanded by 141%. Household food security would be safeguarded since the adjustments would lead to a significant increase in net benefits of at least 51% (table 1).

Risk attitude (fig. 1) indicates that zero grazing systems have a Second order Degree Stochastic Dominance condition (SSD), suggesting that these farmers are risk-averse. The zero grazed farms kept exotic dairy breed categories mostly in peri-urban areas where demand for milk was reasonably high. The profit driven farm plan could be adopted provided sources of constraints, especially infertility and delayed conception that are commonly associated with cow-dominated herds are managed. This would possibly reduce the risks associated with production instability reflected in coefficient of variation of 26% in the profit plan net benefits compared to 10% in the observed plan.

Table 2: Resource use, net benefits and enterprises in zero grazed dairy systems in Uganda.

Characteristic	Observed plan		Profit plan	
	S1	S2	S1	S2
Banana-beans (ha)	0.162	0.162	0.162	0.162
Coffee-banana (ha)	0.099	0	0.239	0
Mainly maize (ha)	0	0.091	0	0.238
Yams (ha)	0	0.013	0	0
Cultivated area (ha)	0.261	0.266	0.401	0.400
Dairy TLUs	0.700	0.700	1.040	1.260
Hired labour hours	470	0	1,683	324
Family labour hours	1,494	1,470	1,434	1,470
Hired labour (%)	24	0	54	18
Net benefits ('000 Ug.shs)	356	758	538	1,226

S1 and S2 refer to seasons 1 and 2, respectively

Herded cattle grazing systems: The cultivated area for the profit plan for season 2 is significantly higher ($p \leq 0.01$) than the farm plan. This would, however, involve using up all available land resources. Dairy herd sizes would be kept at the same level for both plans. Crop enterprises selected for the profit plan placed emphasis on banana and maize-based intercrops so as to cater for subsistence needs, staple foods and preferences. The choices would still ensure household multiple objectives of food self provision, food security and cash generation. The amount of hired labour used was more or less the same in both plans. By maintaining the cattle herd size and raising cultivated area by at most 27%, net benefits would increase by at least 30% in the profit plan compared to the observed plan (table 3)

Herded farms (fig. 2) had Second order Degree Stochastic Dominance condition and were therefore risk averse. Herded farms largely kept local cattle with bulls easily accessible in the composite herds. The fatal and non-fatal disease-related, delayed conception and infertility risks are therefore low. Production risk exposure was more or less similar in both observed and profit plans with corresponding coefficients of variation at 18 and 21%. The profit plan could therefore be implemented with little or no fear of raising farm risk exposure.

Semi-intensive dairy systems: Results obtained showed no significant differences in terms of cultivated area but dairy herd size of the profit plan would be smaller ($p \leq 0.01$) compared to the observed plan (table 4). This would require selling off some animals so as to raise farm productivity and returns, and cut down on costs. Intercropped cassava and maize-based crop enterprises would be emphasised so as to provide the required food, feeds and cash for the households. The profit plan suggested less fodder cultivation to match with reduction in observed dairy herds to optimum levels of 3.18 dairy TLUs per season. By making these adjustments, there would be a marked increase of at least 53% in net benefits for the profit plan compared to the observed plan. The significant increase in net benefits for the optimum plan would suggest higher returns to labour, that are more or less the same quantities for both observed and profit plan (table 3).

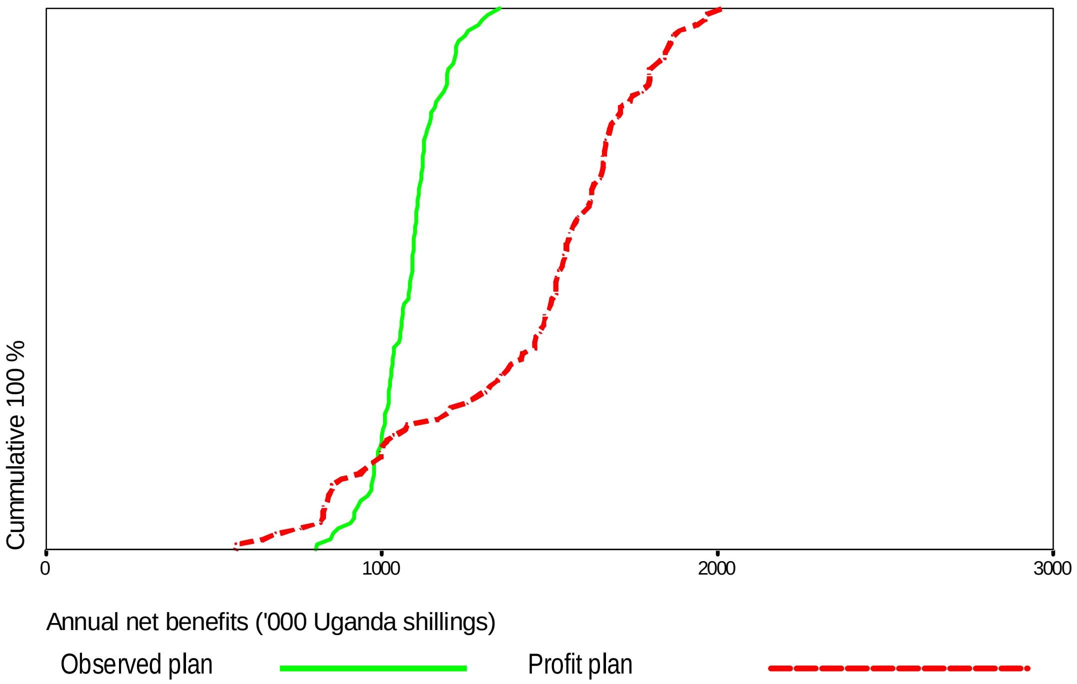

Figure 1: Observed and profit driven net benefits in zero grazed dairy systems in Uganda.

Profit and observed plan net benefit cumulative functions (fig. 3) indicate that farmers practicing semi-intensive grazing management had a second order degree stochastic dominance, and are therefore risk averse. Semi-intensive farms were being managed by farmers mostly constrained by land, commonly located in peri-urban areas, with small paddocks and heavily relying on feed supplementation. They kept a combination of local, crosses and exotic cattle breed categories. The net benefit coefficients of variation at 9% and 21 % for observed and profit plans would suggest that farmers should pay attention to higher risk exposure associated with higher production instability in the profit plan. Similarly high risk associated with profit maximization at coefficient of variation at 0.23 compared to 0.18 for the traditional plan were reported by Abenet *et al.* (1992).

Tethered cattle grazing system: Results obtained showed significant ($p \leq 0.01$) reductions in cultivated areas and dairy herd sizes in the profit plan compared to the observed plan. Crop enterprise sizes mostly dropped in season one (table 5). This result is similar to that of Staal and Davis (1992) who observed a fall in observed food crop plantings in the first and second seasons for highland farmers in Cameroon. The profit driven model concentrates on production of intercropped banana and cassava so as to cater for minimum subsistence needs and food preferences. Profit plan net benefits increased by at least 20% compared to observed farm benefits. This implies higher land use efficiency for the profit plan. Better husbandry practices are more easily adopted with reduced enterprise sizes.

Results of trends of profit and observed net benefit cumulative functions showed that tethered farms had a first order degree stochastic dominance condition (fig. 4). Farmers in this system are not risk averse, and they extravagantly utilized their resources beyond optimum levels. It was therefore more rational to reduce cultivated areas in the profit plan compared to the observed plan in both seasons. Tethered farms were dominated by local breeds, and were being managed in two types of farms. In type 1 commercially oriented farms simulate zero grazed dairy and in type 2 are subsistence farmers selling surplus milk for cash needs. They both operate at low cost systems by using a rope rather than a fence or herdsman to graze cattle. Profit plans have higher production instability with net benefit coefficient of variation at 25 compared to 7% for the farm plan. Extra land could be used as fallow to rejuvenate its potential or hired to other farms where land is a constraint.

Table 3: Resource use, net benefits and enterprises in herded dairy cattle systems in Uganda.

Characteristic	Observed plan		Profit plan	
	S1	S2	S1	S2
Banana-beans (ha)	0.598	0.622	0.437	0.661
Banana-fodder (ha)	0.039	0.166	0.028	0
Coffee-banana (ha)	0.665	0.099	0.840	0.661
Coffee-beans (ha)	0	0.121	0	0
Intercropped banana (ha)	0.031	0.031	0.083	0
Intercropped maize (ha)	0.029	0	0	0
Cultivated area (ha)	1.361	1.039	1.368	1.322
Dairy TLUs	7.50	13	7.5	13
Hired labour hours	1,204	2,377	1,068	2,349
Family labour hours	3,850	6,424	3,849	3,575
Hired labour (%)	24	27	22	40
Net benefits ('000 Ug.shs)	1,360	1,360	2,450	1769

S1 and S2 refer to seasons 1 and 2, respectively

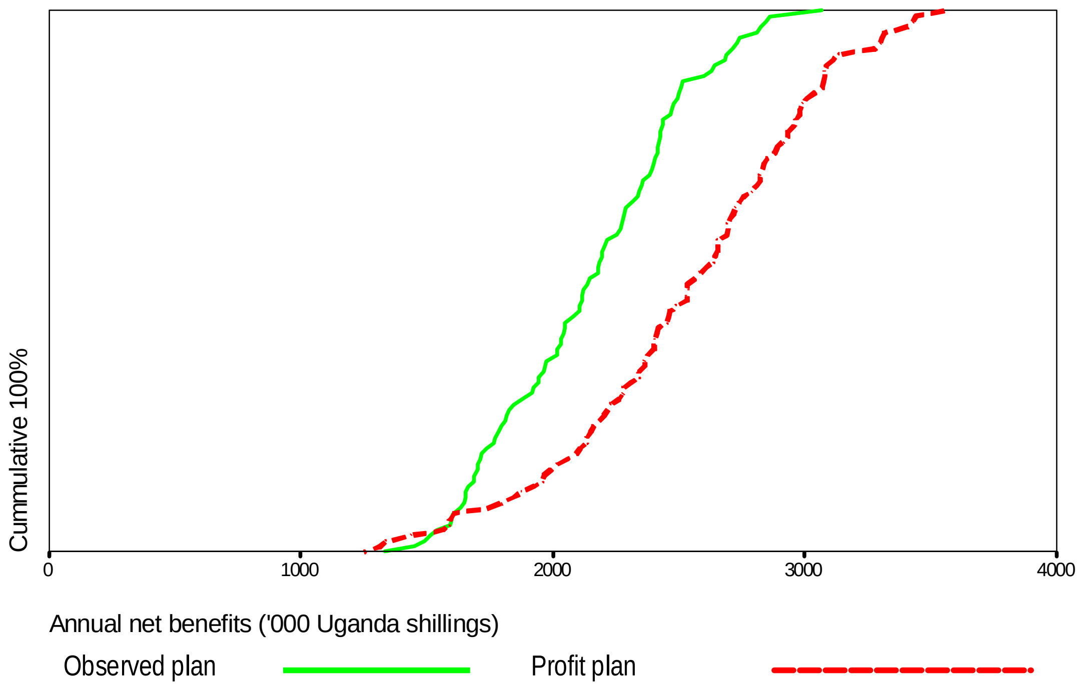

Figure 2: Observed and profit driven net benefits under herded dairy systems in Uganda.

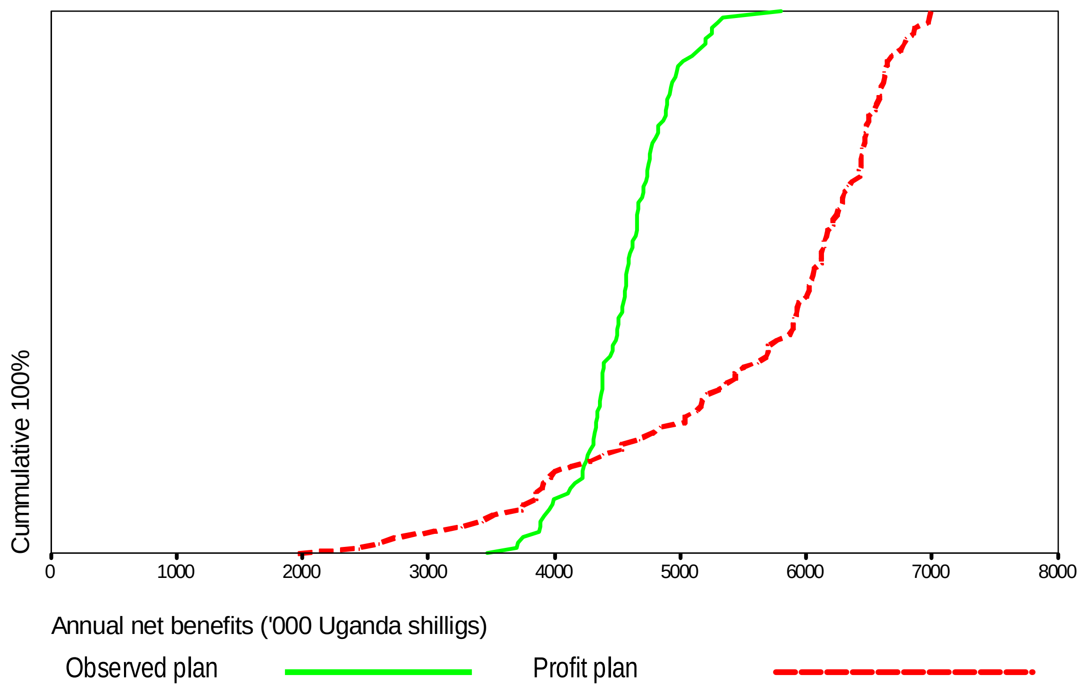

Figure 3: Observed and profit driven net benefits in semi-intensive dairy systems in Uganda.

Fenced dairy cattle systems: The profit plan would emphasise production of finger millet-sorghum and banana-fodder intercropping systems, and sugar canes; and maintains sweet potatoes, banana intercrops, groundnuts and pineapples. Risk aversion through food self provision and diversity in diets as well as feed and cash generation objectives were hence catered for. Cultivated areas are significantly higher ($p \leq 0.01$) for the profit plan compared to the observed plan although dairy TLUs remained the same. These adjustments would lead to increase in net benefits of 80 and 20% in seasons one and two, respectively (table 6). Expansion of net farm income through increasing land under cultivation and integration of high value crop management in combination with aquaculture was also observed by Engle (2001). Family labour hours were the same for observed and farm plans but hired labour levels were almost doubled for the profit plan in the first season.

Results of observed and profit driven net benefit cumulative distribution functions showed that fenced farms had a second order degree stochastic dominance condition, and hence were risk averse (figure 5). The profit plan would be more attractive but has higher production instability with net benefit coefficients of variation at 32% for the profit plan compared to that of the observed plan at 13%. This concurs with Kaguongo *et al.* (1996) who observed that higher instability was associated with intensified dairying. Fenced farms were characterized by cattle herds of at least 9.7 TLUs comprising of crosses and exotic dairy breed categories. Confined herds of grade cattle results into production risks especially delayed conception and infertility hence adopting the profit plan must be accompanied with better breeding management to avoid related risks common with confined cattle herds with no bulls.

Table 4: Resources, net benefits and enterprises in semi-intensive dairy systems in Uganda.

Characteristic	Observed plan		Profit plan	
	S1	S2	S1	S2
Banana-beans (ha)	0.023	0	0	0
Banana-cassava (ha)	0.008	0.008	0.092	0
Banana-fodder (ha)	0	0.024	0	0
Beans-cassava (ha)	0.236	0.119	0	0
Beans-maize (ha)	0.434	0	0	0
Coffee-fodder (ha)	0.063	0.063	0	0.268
Fallow (ha)	0.025	0	0	0
Fodder (ha	0.121	0.822	0.075	0.083
Intercropped banana (ha)	0	0.016		0
Intercropped cassava (ha)	0.162	0.188	0.267	1.153
Intercropped maize (ha)	0.049	0.101	0	0
Mainly cassava (ha)	0.102	0.020	0	0
Mainly coffee (ha)	0	0.015	0	0
Mainly maize (ha)	0.219	0.161	1.115	0
Mixed intercrops (ha)	0.043	0.029	0	0
Sweet potatoes (ha)	0.109	0.050	0.075	0.039
Vegetables (ha)	0.028	0	0.006	0
Yams (ha)	0	0.014	0	0
Cultivated area (ha)	1.622	1.630	1.630	1.543
Dairy TLUs	3.220	3.770	3.180	3.180
Hired labour hours	891	532	981	467
Family labour hours	2,430	2,873	2,430	2,876
Hired labour (%)	27	16	29	14
Net benefits ('000 Ug.shs)	2,254	1,832	3,455	2,834

S1 and S2 refer to seasons 1 and 2, respectively.

Table 5: Resource use, net benefits and enterprises in tethered dairy systems in Uganda.

Characteristic	Observed plan		Profit plan	
	S1	S2	S1	S2
Banana-beans (ha)	0.341	0.341	0.210	0.210
Beans-maize (ha)	0.048	0.119	0.029	0
Beans-cassava (ha)	0.055	0	0	0
Fruit trees (ha)	0	0.008	0	0
Intercropped cassava (ha)	0.068	0.222	0	0
Intercropped maize (ha)	0.166	0.079	0	0
Mainly banana (ha)	0.013	0.013	0.025	0.025
Mainly coffee (ha)	0.057	0.057	0.057	0.057
Mainly cassava (ha)	0.057	0.012	0.110	0.673
Mainly maize (ha)	0.009	0.009	0.097	0
Sweet potatoes (ha)	0.166	0.221	0	0
Cultivated area (ha)	0.980	1.081	0.561	0.965
Dairy TLUs	2.350	3.000	2.330	1.920
Hired labour hours	1,143	0	1,447	0
Family labour hours	2,224	3,762	2,224	3,836
Hired labour (%)	34	0	39	0
Net benefits ('000 Ug.shs)	627	1,218	745	3,110

S1 and S2 refer to seasons 1 and 2, respectively.

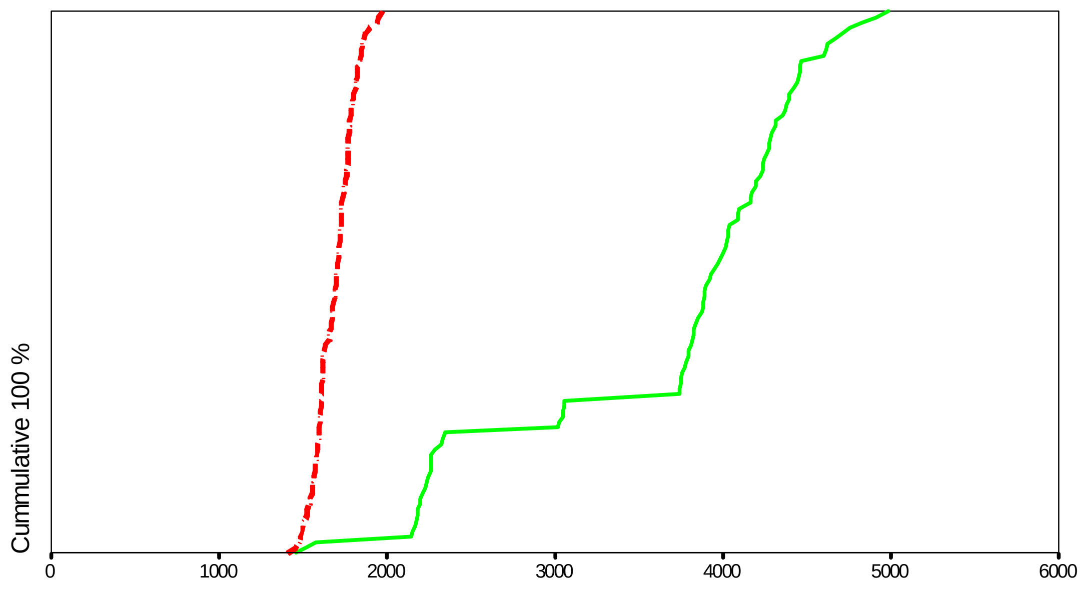

Figure 4: Observed and profit driven net benefits in tethered dairy systems in Uganda.

Table 6: Resource use, net benefits and enterprises in fenced dairy systems in Uganda.

Characteristic	Observed plan		Profit plan	
	S1	S2	S1	S2
Banana-beans (ha)	0.517	0.512	0.512	0.512
Banana-fodder (ha)	0.165	0	0.813	0
Banana-cassava (ha)	0.038	0	0	0
Beans-maize (ha)	0	0.054	0	0
Coffee-banana (ha)	0.057	0	0.057	0
Fallow (ha)	0.245	0	0	0
Finger millet-sorghum (ha)	0.056	0.059	0.860	0.105
Groundnuts (ha)	0	0.021	0	0.021
Intercropped banana (ha	0.013	0.027	0	0.709
Mainly banana (ha)	0.027	0.025	0	0.269
Pineapples (ha)	0.013	0.018	0.013	0.013
Sugar canes (ha)	0.249	0.245	0.083	0.356
Sweet potatoes (ha)	0	0.110	0	0.349
Cultivated area (ha)	1.380	1.071	2.338	2.334
Dairy TLUs	9.7	12	9.7	13.3
Hired labour hours	2,902	3,229	5,224	3,615
Family labour hours	1,212	1,352	1,212	1,353
Hired labour (%)	71	71	81	73
Net benefits ('000 Ug.shs)	1,593	2,653	2,275	3,173

S1 and S2 refer to seasons 1 and 2, respectively

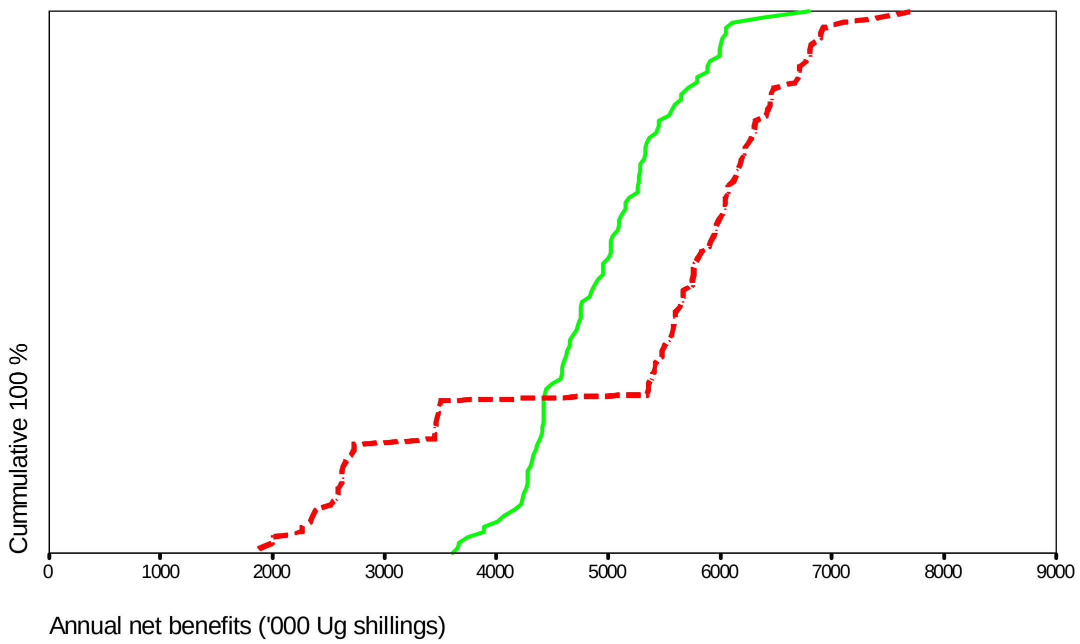

Figure 5: Observed and profit driven net benefits in fenced dairy systems in Uganda.

Conclusions and recommendations: In all dairy systems, observed farm plans had many small crop enterprises and unused land for farming. Profit plans generate more farm benefits than observed plans using fewer crop enterprises. Herd sizes are maintained in fenced and herded systems, reduced in the semi-intensive and increased in the zero grazing system. Slack land resources are utilised in the profit plans for all systems except tethered farms. Stall-fed, fenced and herded dairy systems show rationality in resource use. These farms obtain less than their potential if they were run more economically and efficiently. The findings show that profit alone is not the prime mover of farm production. Producers manage a range of multiple farm enterprises to meet subsistence food tastes, diversity and preferences, social capital and to counteract effects of potential crop failure. These farmers are therefore partially commercialised and risk averse. For most dairy systems net benefit curves showed second order degree stochastic dominance (SSD) indicating tendencies for risk aversion. Tethered systems have first order stochastic dominance (FSD), which suggests they use resources in excess of optimal levels. This is confirmed by the fact that the profit plan option for tethered farms allocates less land to farm enterprises for higher returns. Higher benefits are, however, still realised in the tethered system profit plan compared to observed plan. Profit driven plans, however, have higher production instability compared to observed plans. In order to successfully adopt the more profitable alternative plans, the recommended practices are (1) commit slack land into production by all dairy systems except tethered farms; (2) Focus on fewer crop enterprises that ensure household subsistence needs; (3) Allocate resources to high-return (high value) commercial crop enterprises to maximise profit generation; (4) Maintain the breed categories already selected and for which producers have experience in raising; (5) Improve breeding management in confined systems to reduce reproductive failure and infertility related milk loss risks; and (6) Improve feeding and health management to stabilise dairy yields. The tethered systems in particular would follow similar management adjustments with reduction in cultivated area. Land released from tethered systems could then be rented out to other systems.

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REFERENCES

Abenet Belete, Dillon JL, Anderson FM, 1992. Impact of Fertiliser Use on Production and Cash Income of Small – Scale Farmers in the Highland Areas of Ethiopia. Agricultural Systems 40: 333 - 343

Ashley S. and Nanyeenya W, 2005: More than Income: Pro-poor Livestock Development Policy in Uganda. In Ellis, F and Freeman, A. H. (Editors.). Rural Livelihoods and Poverty Reduction Policies: Routledge London UK: 235 – 255.

Atokple I, Byenkya S, Wameotsile M, Sebojtja I, Aart-Jan V, 1995. Towards revitalising the livestock industry in Mukono district, Uganda. ICRA - NARO Working Document series 45.

Bessler AD, 1984. Subjective probability. *Risk management in agriculture* In Barry, P.J (Ed.): 11 – 30. Iowa Iowa State university press, USA.

Bezabih E. and Storck H, 1992. Improvement Strategies for Farming Systems in the Eastern Highlands of Ethiopia. Agricultural Economics 8: 57 – 77.

Derbertin DL, 1993. *Agricultural Production Economics*. 2nd Edition, Grevden Press Publishing Company, University of Kentuky, USA.

Engle CR, 2001, Risk analysis of optimal resource allocation by fish farmers in Rwanda. Collaborative research program, Africa study 7: University of Arkansas, Pine Bluff, USA.

Hardaker JB, Pandey S, Pattern LH, 1991. Farm planning under uncertainity: A review of planning models The Australian economics society inc.: 9 -22

Hazell PBR. and Norton RD, 1986. *Mathematical Programming for Economic Analysis in Agriculture.* New York: Macmillan Publishing Company.

Ika Darnhofer, 1997. Tagasaste and Oats-Vetch Production for Crossbred Dairy Cows in the Ethiopian Highlands: Animal Feeding, Farmer Decision making and Economic Considerations. Unpublished PhD thesis, University of Agricultural Sciences, Vienna, Austria.

Kaguongo NW, Staal SJ, Ackello-Ogutu, 1994. Risk with intensification of Kenyan smallholder dairying. Paper presented at the XXIII conference of IAAE, Sacramento, California.

La Rovere R, Hiernaux P, Van Keulen H, Schiere JB, Szonyi JA, 2005. Co-evolutionary scenarios of intensification and privatization of resource use in rural communities of South-western Niger. *Agricultural Systems.* 83: 251 - 276

Lien G. and Hardaker JB, 2001. Whole-farm planning under uncertainity: impacts of subsidy scheme and utility function on potifolio choice in Norwegian agriculture *European review of agricultural economics*, 28, (1): 17 - 36

Maleka P, 1993. An application of Target MOTAD Model to Crop Production in Zambia: Gwembe Valley as a Case Study. Agricultural Economics 9: 15 – 35.

Mengistu B, 1997. Use of Crossbred Cows for Milk and Traction in the Highlands Ecoregion: A Whole – Farm Evaluation Unpublished MSc Thesis, submitted to Alemaya University of Agriculture, Ethiopia.

Robison LJ, Barry PJ, Kliebenstein JB, Patrick, GF, 1984. Risk attitudes: concepts and measurement approaches. In: Barry PJ (Ed.), *Risk management in agriculture* :11 - 30 Iowa Iowa State university press, USA

Staal SJ. and Davis CG, 1992. Effects of Resource Constraints on the Production Systems and Earnings Potential of Small Farm Households in the West Province of Cameroon. *Farm and Business 1(2)*: 38 – 67.