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Impacts of capital and land constraints on the economics of new livestock technology in western Kenya

Fanny B. Nyaribo

Small Ruminants Collaborative Research Support Program, Winrock International Institute for Agricultural Development, SR-CRSP, P.O. Box 252, Maseno, Kenya

and Douglas L. Young

Department of Agricultural Economics, Washington State University, Pullman, WA 99164, USA

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ABSTRACT

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The introduction of new forages and milk marketing improvements was projected to permit even the smallest modeled farms in a western Kenya region to adopt dual-purpose goats and thereby improve family income and nutrition. Expanded credit permitted modeled medium and large farms, especially, to vigorously exploit these innovations; credit also expanded income more than did goat management improvements. Because credit, extension assistance, marketing improvements, and new forages will leave projected incomes of small farmers below those of medium and large farmers in the study region, development of off-farm jobs may still be necessary to supplement the incomes of this fast growing group. The marginal value of capital for medium and large farmers with new livestock technology was high. This suggests that government-subsidized credit might be unnecessary. With proper infrastructural and legal support, private capital markets might develop as new livestock technology and marketing improvements expand the demand for borrowing.

Correspondence to: Douglas L. Young, Department of Agricultural Economics, Washington State University, Pullman, WA 99164-6210, USA. FAX (509) 335–1173.

INTRODUCTION

High rates of population growth and lagging agricultural production have put severe pressure on living standards in much of sub-Saharan Africa over the past two decades. In Kenya, for example, annual agricultural output growth fell from 4.9% during 1965–80 to 2.8% during 1980–86 (World Bank, 1988). Kenya's population growth rate, on the other hand, climbed from 3.6% over 1965–80 to 4.1% in the late 1980's. Rural families on semi-subsistence small farms have borne the brunt of the poverty and malnutrition which have accompanied these trends. Smallholder agriculture provides up to 80% of total employment in Kenya (World Bank, 1988), but the amount of available land per family is inadequate and shrinking in many areas. Recent farm survey results from Hamisi Division in western Kenya, the site of this study, illustrate the growing land pressures (SR-CRSP, 1987). The average surveyed farm contained 1.19 arable hectares and had access to another 0.60 ha grazing land. Average farm household size was eight persons yielding only 0.15 ha arable land per person. The rural population density in this area of East Africa rivals that in south Asia.

Problems of extreme poverty and malnutrition in smallholder agriculture, plus the failure of other sectors to generate sufficient employment to absorb surplus labor, recently have prompted the Kenya government to promote employment, production, and nutritional status in the smallholder sector (Gov. Kenya, 1983). This represents a departure from earlier policies which favored large farms and plantation/export agriculture in the allocation of extension assistance, research support, and credit (Heyer and Waweru, 1976; Leo, 1978).

One component of Kenya's effort to assist smallholders has been the development and support of new livestock technologies suitable for semi-subsistence farmers. Hamisi Division in western Kenya has been one of the principal study sites for this work, under a Small Ruminant Collaborative Research Support Project (SR-CRSP, 1987). The project has the dual objectives of improving both nutrition and income of smallholders. Dual-purpose goats are attractive diversification alternatives because they can provide high protein milk and meat for household diets and use some crop byproducts as feed. Goats might fill a niche in farms too small to accommodate cattle. Recent research has shown a growing market potential for sheep and goats elsewhere in Africa (Francis, 1990).

Early baseline studies in Hamisi identified a lack of forage production and storage technology, inadequate livestock marketing infrastructure, limited land holdings, and capital shortages as major constraints to improving small-holder welfare via livestock. In response to this concern, SR-CRSP agronomists have developed new forage and feed storage technologies

(Hart et al., 1984; Onim et al., 1985). In consideration of the tight competition from food crops for arable land, systems were developed for successfully intercropping sudan grass and pigeon pea forages with maize and beans. Simple hand-powered hay baling techniques are used to help smooth out the seasonal feed supply function. In order to support an expanded livestock industry based on the new forages in areas like Hamisi, at least two institutional reforms are needed. First, agricultural credit would be necessary to finance increased production costs for the intensive food/forage intercrop enterprises. No farmers in the Hamisi survey sample reported receiving credit currently (SR-CRSP, 1987). Lack of credit has been a common barrier to technology adoption and welfare gains by small farmers elsewhere in Kenya (Wolgin, 1975). The second necessary institutional reform is strengthening the marketing infrastructure for milk. Currently, there is no organized milk collection route in Kakamega District where Hamisi is located. This has slowed the development of a commercial dairy industry despite an estimated large potential demand for dairy products in nearby market centers (Oyugi et al., 1986).

The objective of the current analysis will be to assess the impact of two key constraints, size of landholdings and credit availability, on the response to new forage technology and to improved milk marketing infrastructure by smallholders in the western Kenya study site.

MODELLING METHODOLOGY

A set of representative farm linear programming (LP) models, one for each of three farm sizes, is used to model responses of Hamisi farmers to the new forage technologies and milk marketing infrastructure. Linear programming has been a popular choice for modeling farmer decision making in response to technical or institutional innovations in LDC's (for example, see Low, 1975; Norman, 1977; Calkins, 1981). LP has an important limitation, however, in studies like the current one where optimal farm plans may incorporate relatively small numbers of livestock. The divisibility assumption of LP will permit cattle and/or goats to enter at any nonnegative value, which violates their intrinsically integer nature. Mixed integer programming (MIP), with integers used for the cattle and goat activities, was considered, but rejected because we wished to interpret the dual values or 'shadow prices' on constraining resources. Unfortunately, the usual interpretation of dual values does not hold for MIP (Williams, 1978, pp. 203–206). Also, LP was considered a satisfactory compromise for the positive objectives of this study of determining general responses of 'representative farms' (which reflect an average of many farms) to credit avail-

ability and technical/institutional innovations. If the objective were to prescribe specific optimal plans for individual farms, the need to restrict livestock numbers to integer values would be more critical.

Following Calkins (1981) and Job (1982), the farm household's objective function was specified as net returns over variable costs and subsistence food expenditures. Household subsistence requirements are imposed in the model and can be met by home grown food (at implicit farm gate prices) or purchased food (at retail prices). This implies a lexicographic utility function in which subsistence requirements are met prior to maximizing net returns. The objective function reflects the quasi-subsistence orientation of western Kenya smallholders who place great weight on meeting household food requirements when making production decisions. The lexicographic objective function captures one aspect of smallholder risk aversion.

Food crop activities in the model, which are sometimes intercropped, include maize, beans, sorghum, vegetables, and bananas. New forages include sudan grass and pigeon peas, which are always intercropped with maize and/or beans. Mixed grass hay, natural forage from fence rows, maize stover, and on and off-farm grazing also provide livestock feed as available. The model includes tea and coffee as cash crop alternatives. There are two cropping seasons in Hamisi, the 'long rains' in March–July and the 'short rains' in September–December. Some food and forage crops are grown in both seasons. Sudan grass provides six cuttings during the year. Three livestock activities were included in the model: Zebu cows, goats which kid in April, and goats which kid in November.

Production, sale, and consumption activities are specified as appropriate for each activity. Storable crops may be sold at seasonal prices in any of four quarters with storage losses deducted. Transfer activities transfer stored food crops or forages from quarter to quarter and track kids into older age groups. The model permits selling kids at varying ages. Requirements for replacement does and heifers are incorporated into the model's input requirements and offtake rates. Cull does and cows, net of death losses, are sold.

The model permits purchasing maize, beans, cow milk, beef, and vegetables at seasonal retail prices in each of the four quarters. Labor (up to seven person-days per quarter for all farm sizes) may be hired in quarters 2 and 3, when labor bottlenecks might occur. Cash borrowing is permitted up to the limits specified in the subsequent credit analysis.

The realism of a combined crop, livestock, and human subsistence model will be highly dependent upon capturing seasonal fluctuations in resource supplies and demands (Hazell and Norton, 1986). A previous modeling analysis of the same study area failed to disaggregate temporally beyond the annual level which undoubtedly influenced the results (Job, 1982).

Livestock nutrient requirements for digestible crude protein and digestible energy were disaggregated by livestock type and by quarter (National Academy of Sciences, 1981; International Feedstuffs Institute, 1982; Hart et al., 1984). Nutrient requirements reflected weight, age, lactation, and gestation status. Human subsistence requirements, adjusted by the age-sex composition of the household, were specified by quarter for calories, protein, calcium, vitamin A, vitamin C, thiamin, niacin, riboflavin, and iron (Scrimshaw and Vernon, 1976; USDA, 1985). Nutritional constraints in the model were set at 80% of recommended levels in recognition of likely persistence of suboptimal nutrition in Hamisi despite the availability of new technology and institutional reforms. Previous studies have limited human nutritional requirements to calories and protein (Job, 1982). Incomplete nutritional modeling can generate diets that could lead to severe health problems and be inconsistent with the household labor output in model solutions (Pitt and Rosenweig, 1985).

Quarterly demands for human consumption, livestock feed, sale, or storage were constrained within quarterly supplies from current production, purchases, or storage. Similarly, quarterly demands for cultivable land, grazing land, operating capital, and labor were constrained within quarterly supplies. Crop yields, animal weight gains, and milk output reflected seasonal weather differences.

Surveys conducted during 1986 and 1987 by SR-CRSP researchers in Hamisi Division provided most of the information on resource levels, enterprise productivities and resource requirements, prices, and other data required by the farm-level LP models used in this analysis (SR-CRSP, 1987). Other data were drawn from the decade-long western Kenya SR-CRSP and secondary sources (Jaetzold and Schmidt, 1982; Job, 1982; Sands, 1983; Mukhebi et al., 1986; Reynolds, 1986; Conelly et al., 1987; Rep. Kenya, 1987). Sources for livestock and human nutrient requirements were cited previously. A large number of unpublished budgets were compiled for seasonally specific crop and livestock activities in the model. These budgets generated production cost requirements and summarized survey-based input–output and price data.

Table 1 lists the key resource constraints of the three farm sizes modeled. The small farm size represents the smallest 43% of the sampled Hamisi farms, while the large farm size represents the largest 17% of the sampled farms (SR-CRSP, 1987). The modeling of small and large representative farms was intended to examine policy and technology impacts on both the 'absolute poor' and a larger 'viable' farm size. All cultivable land was owned by the operators. No sharecropping or renting was found in Hamisi. Grazing land, except for relatively small fence row and farmstead areas, was the farm's computed 'share' of public communal grazing.

TABLE 1

Resource constraints by farm size, Hamisi model

Size	Land (ha)		Labor (AE days)	Own capital (KSh.)
	Cultivable	Grazing		
Small	0.49	0.60	1,461	3,051
Medium	1.19	0.60	1,461	3,151
Large	2.01	1.39	1,461	3,737

KSh., Kenya Shilling: KSh.17.00 = US$1.00 (1987).

Mean household size in Hamisi was eight persons. When adjusted for age composition and members working off the farm, 1,461 adult equivalent (AE) days were available for farm work annually. There was no statistically significant difference (0.05 level) in family labor availability across farm size so the same quantity was used for all sizes. These very high labor supplies reported in the Hamisi survey underlay the need for income and employment expanding development in the region. The primary source of 'own

TABLE 2

Selected economic results by farm size and credit availability, Hamisi Division, western Kenya

Farm size [a]	Credit availability (KSh.)	Income over subsistence (KSh.)	Output value (KSh.)	Percent output value			Hay production (kg)
				Crop sales	Livestock sales	Consumption	
Small	0	9,015	14,415	19	45	37	1,997
	812	9,090	17,132	16	36	47	1,324
	Unlimited	9,090	17,132	16	36	47	1,324
Medium	0	11,906	19,041	39	34	28	1,164
	1,637	20,131	28,973	43	39	18	2,977
	Unlimited	24,668	34,524	45	40	15	3,835
Large	0	14,821	22,571	52	25	23	1,391
	2,766	29,135	39,661	49	37	13	2,227
	Unlimited	48,037	60,773	47	44	9	7,341
Improved goat management							
Small	0	12,992	19,959	13	60	26	1,691
Medium	0	13,745	20,543	12	58	30	890
Large	0	17,982	25,020	14	65	21	–

[a] Cultivable and grazing land areas, respectively, by farm size are: small, 0.49 and 0.60 ha; medium, 1.19 and 0.60 ha; and large, 2.01 and 1.39 ha.

capital' was seasonal remittances from family members working off the farm.

RESULTS

Model solutions were obtained for three credit availability levels for each farm size; zero credit, a size-based credit ceiling imposed by the Kenya Government Agricultural Finance Corporation (AFC), and unlimited credit. The AFC limits credit to KSh. 1,376 per ha of cultivable land, which implies limits of KSh. 812, 1,637, and 2,766 for the three farm sizes in this study. A subsidized interest rate of 5% was used throughout to reflect the common use of interest subsidies by the government and by external funders of agricultural development projects in Kenya.

Table 2 summarizes model solutions for nine farm size-credit scenarios plus three farm size and 'improved dual-purpose goat management' scenarios. These results report gross output value and its percentage composition among crop sales, livestock product (animals and milk) sales, and human consumption for each scenario. Intermediate products, specifically livestock

Credit used (KSh./ha)	Dual values				Livestock (whole units)	
	Cultivable land		Grazing land Hi Qtr. KSh./ha)	Own capital (KSh./KSh.)	DPG	Cattle
	I (KSh./ha)	II (KSh./ha)				
0	15,028	9,294	676	0	2	2
55	15,028	9,294	676	0.05	9	1
55	15,313	8,934	2,159	0.05	9	1
0	469	0	217	5	0	2
1,637	486	0	248	5	0	4
2,575	13,851	7,530	4,602	0.05	0	5
0	3	0	161	5	0	2
2,766	521	0	248	5	0	6
6,839	13,297	8,618	2,875	0.05	0	8
0	17,820	8,596	5,447	0	12	0
0	0	0	565	6	12	0
0	0	0	565	6	18	0

feed, are omitted from this total. Dual values are reported for cultivable land in the two cropping seasons (I and II), for grazing land in the period with the highest dual value (Hi Qtr.), and for capital.

One of the most obvious results in Table 2 is that agricultural credit – even at highly subsidized rates – provides little help to the small 0.49 ha farm. Cultivable land, not capital, is the limiting resource on this farm. The dual value of land during the 'long rains' season I exceeds KSh. 15,000. Land is rarely sold in Hamisi, but this dual value was similar to surveyed farmers' subjective estimates of per ha *total* (not annual rental) land values in the Division (SR-CRSP, 1987). Cultivable land is needed primarily to grow forages for the profitable goat enterprise and to grow subsistence food crops; 37–47% of the small farm's gross output value is consumed by the household. Despite land constraints the small farm accommodates nine dual-purpose goats when credit is available. The goat enterprise is facilitated by the new intercropped forages and milk marketing infrastructure.

The medium size farm, in sharp contrast to the small farm, finds capital the most limiting resource. The dual value of capital for the zero and ceiling credit scenarios, at KSh.5, exceeds the subsidized price of capital (KSh.0.05) one hundred-fold. With unlimited credit, this dual value drops appropriately to the interest rate (see Table 2). Interestingly, cultivable land and grazing land also generate positive dual values for the medium farm, and these rise sharply as credit increases. This illustrates that the farm's land resources become more valuable when used in conjunction with more capital.

The medium farm has sufficient land to exploit the new livestock innovations even without credit. Livestock products rose from 34% to 40% of output value as credit rose from zero to unconstrained. Unlike the small farm where dual-purpose goats were preferred, the profit maximizing livestock choice on the medium farm was cattle. This is consistent with current livestock composition in Hamisi where cattle outnumber goats by a large margin (SR-CRSP, 1987). Absolute income over subsistence climbs markedly from KSh. 11,906 to 24,668 as credit availability increases. As expected, subsistence consumption represents a smaller proportion of total output for the medium farm; consumption demands only 15% to 28% of output versus 37–47% on the small farm. The joint availability of more land and capital plus the technical/institutional innovations to promote livestock integrate the medium farm more thoroughly into the market economy.

The large farm results reflect the same trends exhibited for the medium farm at higher levels (see Table 2). Greater cultivable land resources on the large farm permit somewhat greater reliance on crop enterprises. Credit again increases income, output, and the marginal value of land. With

unlimited borrowing, the large farm is able to profitably use more than twice as much credit as the medium farm, KSh. 6,839 versus 2,575.

The final three rows in Table 2 examine the potential impact of a focused extension education effort which hypothetically improves dual-purpose goat management across all farm sizes, but without accompanying credit. This scenario responds to arguments that national capital shortages might make credit allocation to smallholders infeasible, so that less expensive extension education efforts should be pursued. Improving dual purpose goat management, without increasing production cost levels, is assumed to increase kid weaning rates from 66% to 90%, increase weaning weights from 8 to 10 kg, decrease doe death losses from 15% to 10% per year, and increase annual milk yield in excess of kid requirements from 101 to 152 kg per doe. The lower productivity levels are based on average performance of Hamisi smallholders, while the 'improved management' levels reflect performance of the top 10–20% of the goat enterprises in the sample (SR-CRSP, 1987).

Improved dual purpose goat management increases income over subsistence by 44% from KSh.9,015 to 12,992 on the small farm. The small farm increases its goat herd to twelve and no longer keeps any cattle. While improved goat management makes it profitable for medium and large farms to switch to goats from cattle, capital shortages stunt the income increasing potential of improved goat management on these farms. Improved management without credit on the large Hamisi farm generates income over subsistence of KSh.17,982. This is only 37% of the KSh.48,037 generated by average management with unlimited credit.

Given the abundant labor supplies on Hamisi farms (see Table 1), labor was never constraining in any time period nor, appropriately, was any labor ever hired. The existence of labor surpluses throughout the year in these modelling results mirrors the prevailing high levels of underemployment among smallholder households in western Kenya.

Calcium and Vitamin A, rather than protein or calories, were the limiting nutrients for these western Kenya households. Dual values were relatively stable across scenarios and seasons for these nutrients. In the vicinity of the optimal solutions, increasing the household's subsistence requirements for calcium by 1 mg and of vitamin A by one international unit would reduce income over subsistence by KSh.32–56 and KSh.61–64, respectively. Modeled farm households generally purchased modest quantities of beef and up to 250 kg per quarter of vegetables to supplement farm grown food. Most milk and all market animals were sold.

Consistent with Blackburn et al.'s (1986) results for the same region, digestible energy (DE) was generally constraining in livestock diets. While digestible crude protein was occasionally limiting in the third period, DE

was usually constraining in three or all four periods.

CONCLUSIONS

The results of this study indicate that new livestock forage technology, development of milk markets, and extension education to improve livestock management within existing resources could lead to profitable adoption of dual purpose goats by small farmers in western Kenya. While adopting goats could yield much needed gains in incomes and nutrition of small farm families, their incomes are still projected to lag significantly behind those for larger farmers, especially when credit is available. This suggests that regional development aimed at creating off-farm jobs may still be necessary to supplement the incomes of this fast growing group.

This research indicated that increasing credit would strongly assist medium and large farmers in Hamisi Division to exploit new livestock forage and milk marketing innovations. Improving dual purpose goat productivity within existing resource levels, possibly by a concerted extension effort, was shown to boost smallholder incomes less than by expanding credit at current management levels.

Extremely high imputed marginal values of capital call into question the need to subsidize interest rates. With some infrastructural and legal support, efficient private capital markets might develop in Hamisi as new livestock technology and marketing channels expand the demand for borrowing. Even partial alleviation of the capital shortage through private or public sources could increase output and income on medium and large farms.

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