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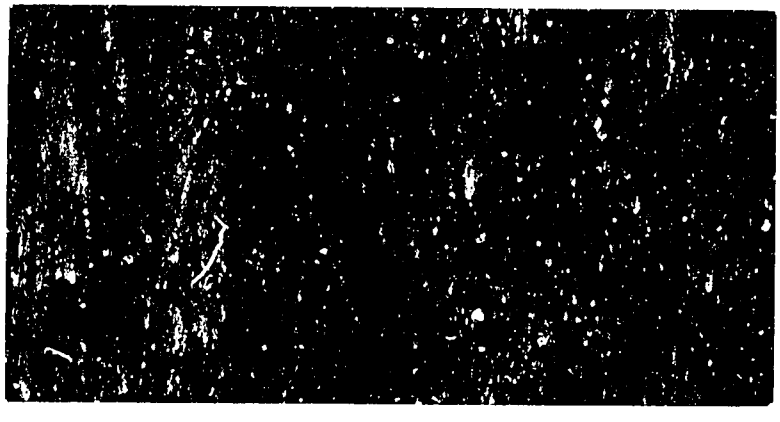

NUMBER 89

Development of Dual Purpose Goat Production For Smallholders in Western Kenya Using Computer Simulation and Systems Analysis

by

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ABSTRACT

Information from forage, breeding and management components of the Small Ruminant CRSP was integrated by using the Texas A&M Goat Simulation Model to evaluate dual purpose goat production practices in western Kenya. Over 100 simulations were performed in an effort to find optimal combinations of genotype, management and nutrition. Simulated results indicate that the near optimal genotype for a dual purpose goat (DPG) is a potential mature size of 40 kg and peak daily milk production of 4.0 kg. Basal forage resources are not sufficient to support a 6-doe flock of DPGs. The simulations performed indicate that supplementation with sudangrass, pigeon pea, sesbania and stored forage satisfactorily alleviate this problem. Dairy milk extraction procedures were tested and it was found that providing either 1/2 of the doe's milk or .5 kg milk/day for the kid is a desirable biological and economic combination. Flocks of 2, 4 and 6 does were simulated and compared for production characters. An important character was the number of days per year that milk was available to the smallholder. For 2, 4 and 6 doe flocks it was found that milk production fell to zero 92, 46 and 17% of the time. This result would indicate that the 6-doe flock could have a significant impact on reducing the nutritional deficit of the smallholder. The simulation data presented are being fed-forward to socio-economic components for their evaluation of questions which have arisen. The next phase of simulations will be to synthesize optimal production packages for targeted smallholders.

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INTRODUCTION

The western Kenya work-site of the SR CRSP provides a production environment which typifies many areas of the tropics. First, there is a high population density and population growth rate; second, these populations have limited physical and financial resources; and third, their diets often do not meet minimal nutrient requirements. The major goal of the SR CRSP in Kenya is to collaborate with Ministry of Agriculture and Livestock Development (MALD) to conduct the research that will result in information needed to develop programs that will improve both the nutritional status and the financial resources of small land holders. The SR CRSP has proposed that the most feasible method of accomplishing this goal is by introducing the dual purpose goat (DPG). For the DPG to be a viable alternative for the smallholder, it must produce a useable quantity of milk on a regular and consistent basis in order to alleviate deficiencies in nutrition (a target of 200 g/person/day of milk is considered minimal). The excess kids produced by the DPG flock can contribute to the financial resources of these people by providing a product to sell for cash income.

For researchers and extension personnel to make knowledgeable recommendations for effective use of DPG, the inputs and outputs of the total production system must be understood. Understanding the net effects of inputs and outputs on DPG production, results in the ability to manipulate management, nutrition and breeding into various production packages to meet the needs of smallholders in different ecozones or with varying resources.

To evaluate DPG production in various physical environments and impose over that a layer of different management and nutritional tactics would extend real world experiments past financial, physical and time constraints of the SR CRSP. An alternative approach is to examine the proposed production options using the goat simulation model developed by Texas A&M as part of the SR CRSP. Management, nutrition and breeding practices can be evaluated as a basis for developing recommendations concerning the direction for research and formulating sets of practices (packages) that are optiomal for given production resources; i.e., most likely to succeed under practical conditions.

The goat model used has been described by Blackburn et al. (1984) and Blackburn et al. (1986) and only a brief description is presented in this text. The model simulates the biology of the individual goat of any age or sex. Individuals may be aggregated into flocks of various sizes and age structures. Input information provided to the model, by the user, includes three sets of parameters.

Forage: availability kg/head/day, digestibility and crude protein of the diet.

Genotype: in terms of mature size, milk production level and ovulation rate.

Management: breeding policies, milk extraction, weaning, supplementation and parasite control.

By altering these input parameters, it is possible to simulate the effects of different environmental conditions or management practices, thereby making the model sufficiently flexible to answer a wide array

of questions concerning animal performance. Output from the model includes total feed consumed by the flock, weight and type of goats sold, reproductive rates, mortality and milk production. This information can then be used by other component projects of the SR CRSP to devise technology packages.

The systems analyses reported in this publication are the steps involved in the choice of a genotype for the DPG, the examination of potential productivity of DPG flocks on smallholder farms, the limitations of nutrition and interventions required to meet production goals, and considerations of management practices. These results provide the frame work for designing DPG technology packages that address general goals of the SR CRSP projects. General goals of the Systems Analysis project, in collaboration with other SR CRSP projects, may be stated as research objectives or questions:

1. Is it feasible for smallholder family DPG flocks to produce a minimal supply of 200 gm of milk per day for each family member throughout the year in Western Kenya?

2. Will practices such as intercropping, introduction of new forages, storing forages, etc. be required to supply the nutrients required?

3. What management practices are optimal for DPG production?

4. Is DPG production sociologically and economically feasible in terms of generating income from the sale of excess kids and milk, and the consumption of milk and meat by the family.

GENOTYPE EVALUATION

The limitations of using East African (EA) and Galla (G) breeds were documented by the early work of the SR CRSP breeding project (Ruvuna et al., 1983). Indigenous breeds were shown to be lower in

milk production (200 g/day) than Toggenburg crosses (670 g/day) at peak lactation. However, indigenous breeds had higher levels of kid survival. If the Systems Analysis stated goal for the SR CRSP of 200 g/day for each family member is to be met, goats with the higher levels of milk yield must be used. Cartwright (1984) stated that there are 3 basic functions which must be incorporated into breeding and selecting a DPG for smallholders. These are: growth, reproduction and lactation, and survival. The breeding project decided that the most effective way to combine these 3 functions was to develop a synthetic breed comprised of 2 exotic dairy breeds and 2 indigenous breeds. This procedure would take advantage of the milk and growth potential of the dairy breeds, and the disease resistance and survival characteristics of the indigenous population while retaining a high level of heterosis. However, the genetic potential to select an optimal combination in the new breed for western Kenya was unknown and there was no research information available on which to base an opinion. Therefore simulations were performed to determine the near optimal genetic potentials for size/age (or growth rate), maturing rate and milk production. These simulations were performed to provide the breeding project with information upon which to base breed choice and combination as well as intensity of selection.

Initial simulations were performed for a western Kenya production situation, using different genetic potentials for mature size (GSIZE) and peak milk production (GMILK) of a mature doe. Genetic potentials, expressed as GSIZE/GMILK, for the breeds were: East African 30/2.5,

Galla 35/3.0 and Toggenburg 55/6.0. The crossbreds would be expected to average above the mid-point of these parental potentials. Genotypes chosen for testing were: 35/3.0, 35/4.5, 45/3.0 and 45/4.5. These simulations indicated that the environment is capable of sustaining genotypes other than the indigenous type of goat and the 35/4.5, 45/3.0 and 45/4.5 could produce more milk and wean heavier kids than the 35/3.0 (figures 1 and 2).

These initial simulations led to a more extensive evaluation of genotypes for doe life time productivity (table 1). Genotypes tested were 50/6.0, 45/4.5, 40/4.0, 35/3.0, 30/2.0. These genotypes represent expectations of the size and milk production of indigenous goats selected out of the Kenya population, imported and crossbred goats. Simulated does were placed into test conditions at weaning and remained there. Four criteria examined were: number of kids born, average weaning weight, average dairy milk production per lactation and minimum doe body condition. The 30/2.0 genotype was not suitable for use as a DPG since the 30/2.0 doe was not able to produce milk, grow and reproduce in the western Kenya environment, therefore, it registered zero for all characters examined. The 50/6.0, 45/4.5 and 35/3.0 proved not to be a suitable potential DPG due to the low level of body condition of does which dipped to critical levels at certain times of the year. Low body condition was an indicator that these does were producing at a level which stressed their biological system. These stressed does were more susceptible to debilitating effects of disease and parasite infestation and could not reproduce regularly. Does of

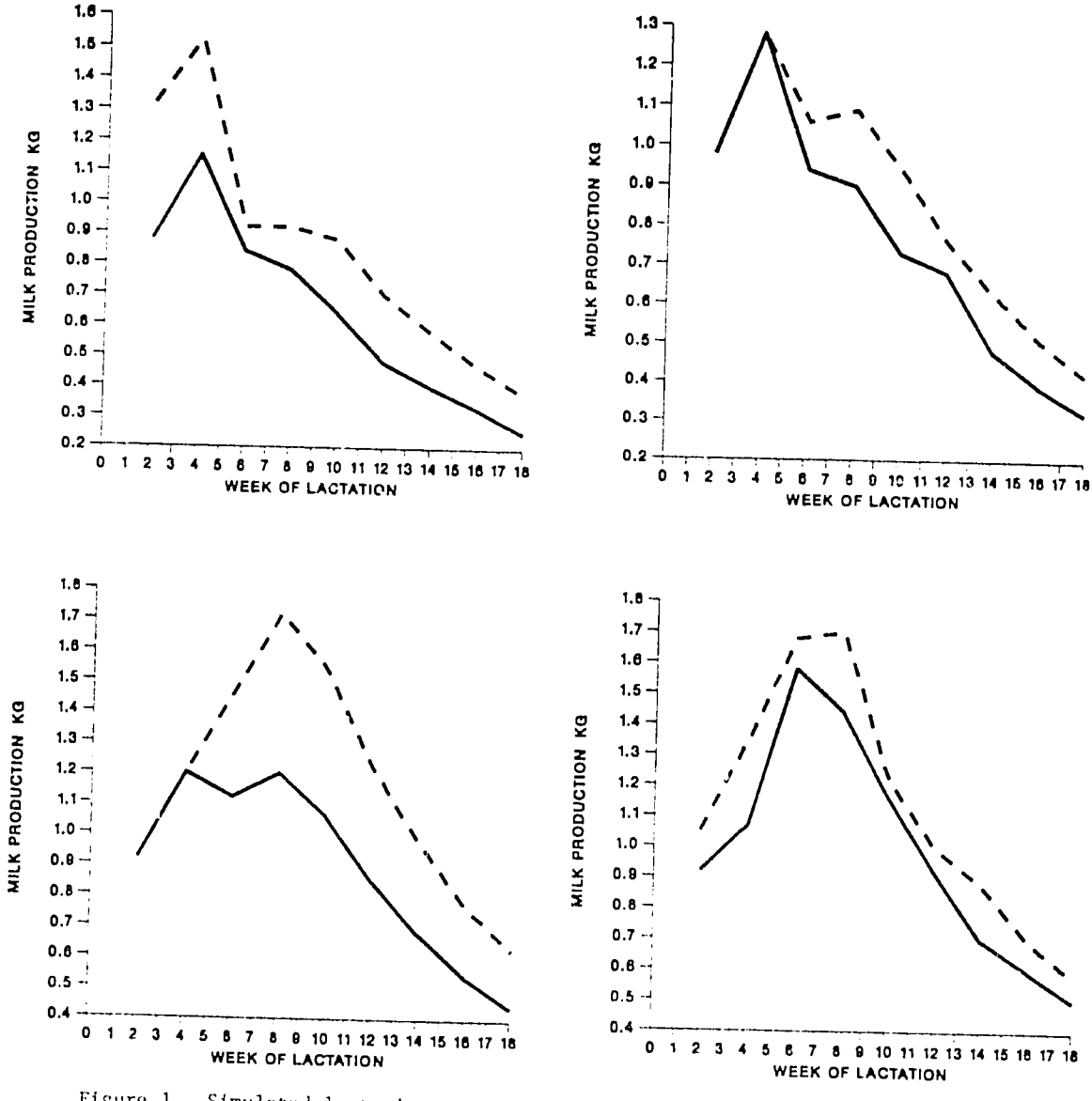


Figure 1. Simulated lactation curves of mature does each taken from a flock of 6 does for different genetic potentials for mature size (35 kg, left side vs 45 kg, right side) and milk production (3.0 kg, solid line vs 4.5 kg, dashed line); each doe may have lactated at different times of the year.

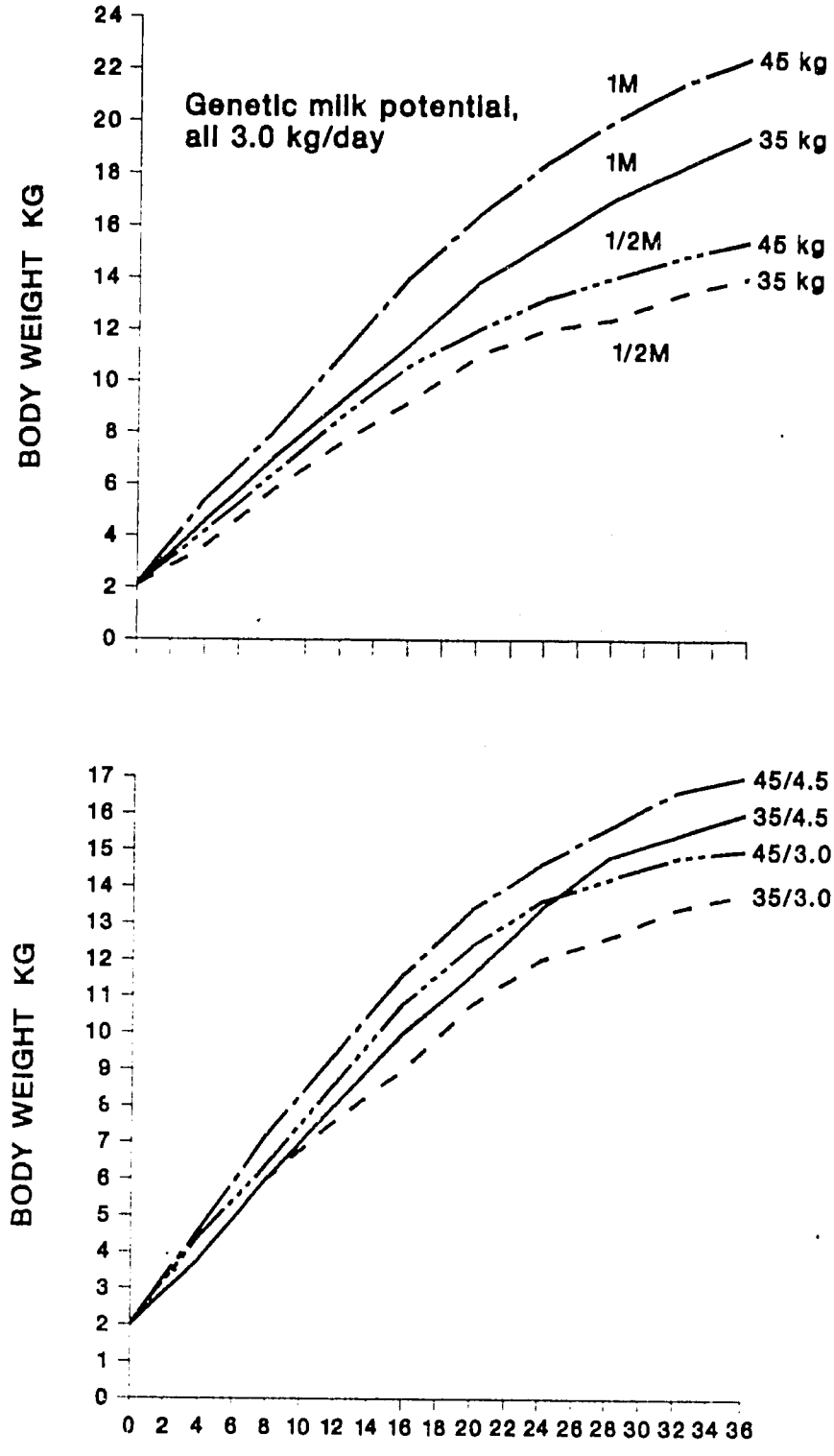


Figure 2. Simulated growth curves of kids with different genetic potentials for mature size (45 and 35 kg) and potential peak milk production (4.5 and 3.0 kg). Presentation of the effects of extracting all vs 1/2 milk production on kid growth is given in the top graph.

TABLE 1. SIMULATED AVERAGE LIFETIME PRODUCTION OF 5-YEAR-OLD DOES OF 5 GENOTYPES RAISED ON MASENO AREA FORAGE

Item	Mature Size/Milk Potential				
	50/6.0	45/4.5	40/4.0	35/3.0	30/2.0
No Kids	6	6	7	6.5	0
Av. Wean Wt., kg	17.2	17.1	13.8	12.0	0
Av. Milk Per Lactation, kg	157	149	115	98	0
Doe Condition Minimum %	67	68	77	63	0

genotype 40/4.0 maintained a relatively high minimum body condition and had more kids over 5 years than the other genotypes tested. The higher number of kiddings implies that there would be a more continous supply of milk per doe during her lifetime. However, in terms of quantity of milk yield and kilograms of kids weaned, the 40/4.0 was not maximum. The 50/6.0 and 45/4.5 were more productive in these respects. Nevertheless, the combination of performance characters make the 40/4.0 the most appealing choice since it has an acceptable production level and retains robustness. The extra body reserves indicate that, if the production conditions of the smallholder periodically deteriorate the 40/4.0 DPG will have some resiliency with which it can continue producing, while the 45/4.5 and 50/6.0 would not have as much buffering capacity. As farmers become more familiar with management of a DPG production system the possibility of increasing the genetic potential past 40/4.0 should be re-examined.

These data suggest, the 40/4.0 should be the SR CRSP Breeding project target DPG. An additional question arises. That is: Can an up-graded intermediary substitute for the 40/4.0 without undue compromise until the farmers goats can be bred and selected towards this goal?

Ruvuna et al. (1984) have shown that a doe with a mature size 40 kg is feasible and not difficult to breed. Therefore the Systems Analysis project was interested in evaluating the performance of a DPG with gentoype 40/3.0. This would represent a goat with 1/4 to 3/8

TABLE 2. SIMULATED PRODUCTIVITY OF 40/4.0 AND 40/3.0 GOATS IN A 4 DOE FLOCK.

Item	40/4.0	40/3.0
Total No. of Goats[a]	7.0	8.0
Av No. Lactating Does/Period/Yr	1.9	2.1
Flock Dairy Yield kg/Yr	332	319
Dairy Yield kg/Day	.92	.89
Dairy Yield kg/Lact Doe/Yr	175	152
No. Yearlings Sold/Lact Doe/Yr	1.5	1.6
Av Yearling Weight, kg	24	19
No. Culls Sold/ Lact Doe/Yr	.4	.4
Av Cull Wt, kg	30	30
Total Weight Sold/ Lact Doe/Yr	48	42
Total Feed Consumed, kg	2175	2376

[a] Does, suckling kids, weaned kids for sale and for doe replacement up to 1 year of age.

dairy breeding vs the 1/2 dairy breeding of the synthetic breed being developed by the Breeding project.

Simulations were performed with a 4 doe flock of the 40/3.0 genotype to compare with a 4 doe flock of 40/4.0 (table 2). For most characters studied, the 40/4.0 produced more milk and saleable kids. However, the 40/3.0 was similar to the 40/4.0 in many respects. The most undesirable characteristic of the 40/3.0 genotype was that the total number of goats in the flock had to be increased to remain stable in number (i.e., more kids had to be kept to assure enough replacement does). This may appear a minor difference, but the problem manifests itself by increasing the forage consumed (9%) and labor required and space needed by the flock. If the increased dry matter consumption, labor requirement and space requirements are acceptable then it can be concluded that the 40/3.0 would be an effective intermediary genotype in Western Kenya; therefore, does of this combination, which are more readily produced, may be useful in initiating smallholder involvement with the DPG.

NUTRITIONAL INTERVENTIONS

Dual purpose goat production in Kenya is dependent on forage which varies in quantity and quality throughout the year cycling parallel to, but a short time span later than, the rainfall cycle. Flocks may be managed so that fluctuating nutrient demands that vary with the growth, pregnancy and lactation status of each individual, tend to best coincide with the seasonal forage variation. However, the degree to which this can be done and meet the needs of the smallholder

families is limited. One objective of the SR CRSP is to smooth out the production cycle so that there is a more continuous supply of milk. As the simulations in tables 5, 6 and 7, show, this stability will require the storing of feedstuffs to be used at critical times of the year. Also development of additional feed resources is necessary.

Understanding the varying nutritional requirements of DPG does is essential for successfully adjusting the feed resource. The base nutrition which DPG's would have access to is presented in table 3; these values were obtained from the forage project (Hart et al., 1984). A simulation was performed to determine how a DPG of 40/4.0 would respond to this nutritional environment. During the nonlactating phases, the protein and energy requirements of the doe were met. However, during lactation the base diet did not yield sufficient protein and energy to meet lactation requirements plus maintenance requirements. As table 4 shows, energy was the most limiting nutrient. Simulations were designed and conducted to provide an objective, quantitative basis for examining management practices that would eliminate or minimize the nutritional deficit.

Two other diets, sudangrass plus pigeon pea and the improved diet in table 3, were tested to determine if the nutritional deficits could be over-come. These simulations indicated that when sudangrass and pigeon pea are incorporated into the diet the energy deficit is reduced by approximately 20%, however, there is still a nutritional impediment to production especially during early lactation (table 4).

TABLE 3. FORAGE QUALITY PARAMETERS FOR HAMISI

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Base (B)												
Crude Protein	.10	.10	.10	.10	.10	.10	.07	.10	.10	.10	.10	.08
Digestibility	.47	.47	.47	.47	.47	.47	.52	.47	.47	.47	.47	.51
Sudangrass and Pigeon Pea (SPP)												
Crude Protein	.10	.14	.14	.13	.15	.16	.09	.13	.10	.10	.10	.10
Digestibility	.49	.53	.54	.52	.53	.53	.52	.53	.50	.50	.50	.52
Improved Diet (ID)												
Crude Protein	.10	.10	.10	.10	.10/ .15[a]	.15	.15	.15	.15	.15	.10	.10/ .08[a]
Digestibility	.47	.47	.47	.47	.47/ .68[a]	.68	.68	.68	.68	.68	.47	.47/ .51[a]

[a] Denotes a split in parameters fed in the same month.

TABLE 4. PERCENTAGES OF PROTEIN AND ENERGY REQUIREMENTS FOR LACTATION WHICH WERE MET FOR DPG DOES

Period of Lactation[a]	Base		SSP		ID	
	Energy	Protein	Energy	Protein	Energy	Protein
1	55.5	63.2	61.6	61.6	85.6	91.2
2	41.6	42.3	55.5	54.8	93.1	100.0
3	47.6	52.6	61.6	66.4	100.0	100.0
4	53.3	61.6	62.4	70.6	100.0	100.0
5	58.5	74.8	69.7	85.6	100.0	100.0
6	64.8	100.0	77.4	100.0	100.0	100.0
7	64.0	100.0	80.1	100.0	100.0	100.0
8	65.6	100.0	83.7	100.0	100.0	100.0
9	65.6	100.0	87.4	100.0	86.5	91.2
10	100.0	100.0	100.0	100.0	92.2	100.0

[a] Period = 15 days.

These led to the construction of an "improved diet" which would reduce the nutritional limitations to milk production to a more acceptable level. The improved diet was based on limited use of sesbania which has produced promising results from initial forage research (Sidahmed et al., 1984) and appears to be a practical alternative.

The first series of simulations related to nutrition were reported by Cartwright et al. (1983). For the Maseno area it was shown that for the DPG to be viable and continuously supply milk to smallholders, storage or conservation practices would be necessary in order to make sufficient quantities of feed available throughout the year for reasonable production (figure 3). By shifting feed from one month where quantity was unlimited to the next month, for three different cases, the problem of forage availability could be solved (figure 3), however as previously shown this simple shifting does not solve the diet quality problem.

The SR CRSP identified two different eco-zones, Kakamega and Siaya, in which to work. In Kakamega, farms are higher in elevation and are approximately 1 ha in size. In Siaya average farm size is 1.5 ha and the elevation is lower. Therefore, it was of interest to evaluate how the DPG would produce in both of these environments. The two production environments were characterized by differences in forage quality and quantity (figures 4 and 5). These estimates were based on the work of Sands (1983) and input from the forage project (Hart, personnel communication). The figures clearly show that forage

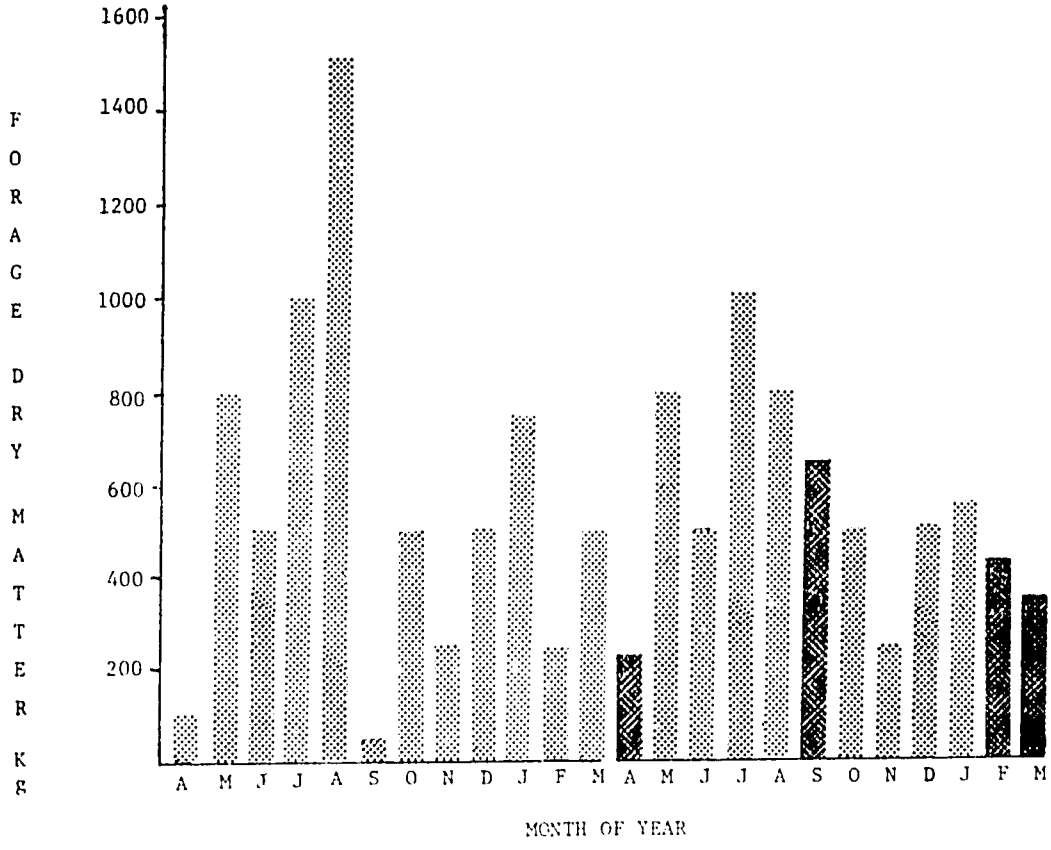


Figure 3. Dry matter available for dual purpose goat production proposed as an approximation of the production from 1 hectare by the Production Systems project. The left half depicts the amounts harvested each month and the right half the same except for the months of April, September and February in which some of the excess forage was carried over from the previous month with an appropriate loss in quality and amount.

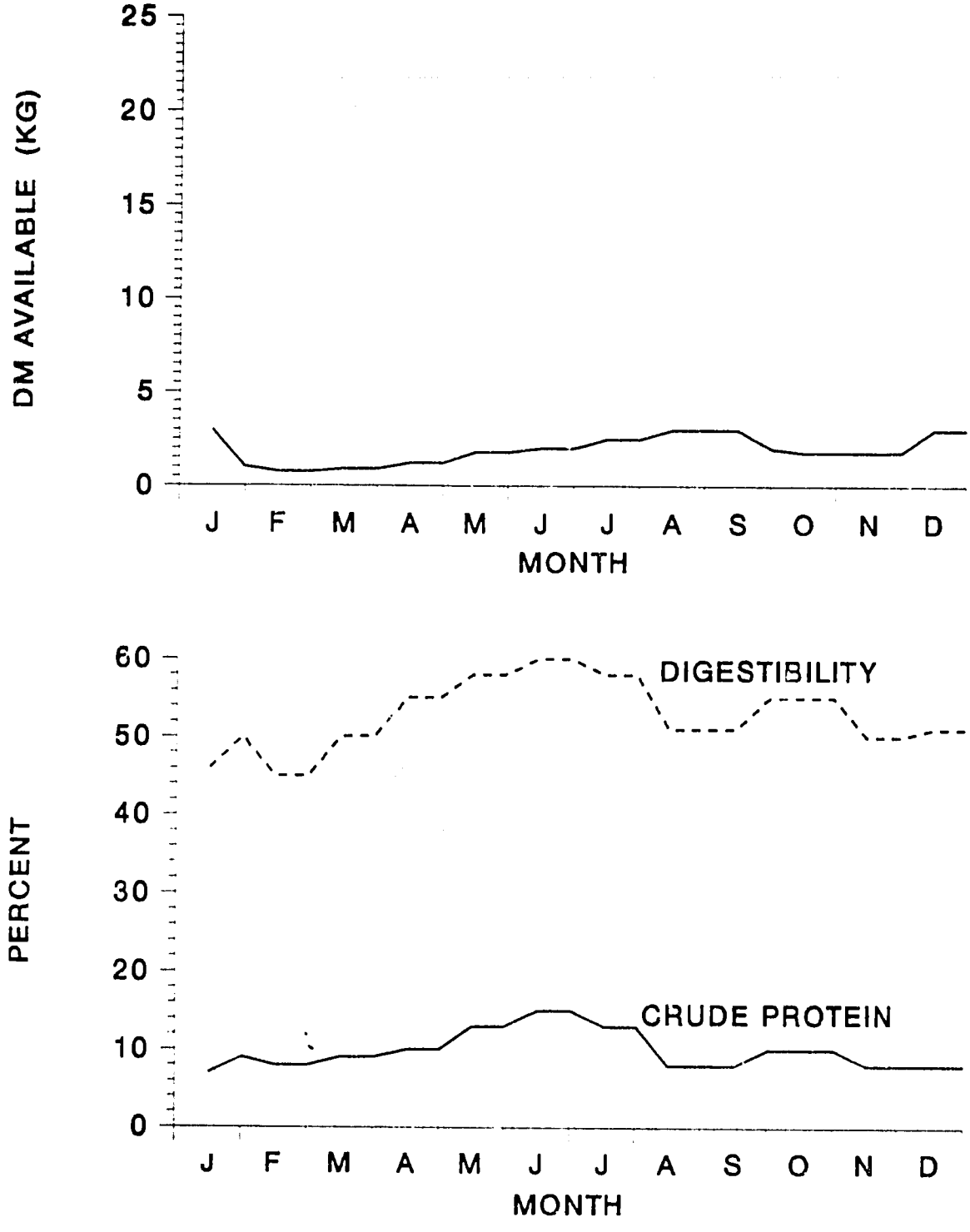


Figure 4. Dry matter available per doe based on seasonal forage patterns, corn stover yields and bean aftermath. Average crude protein and digestibility of the available forage.

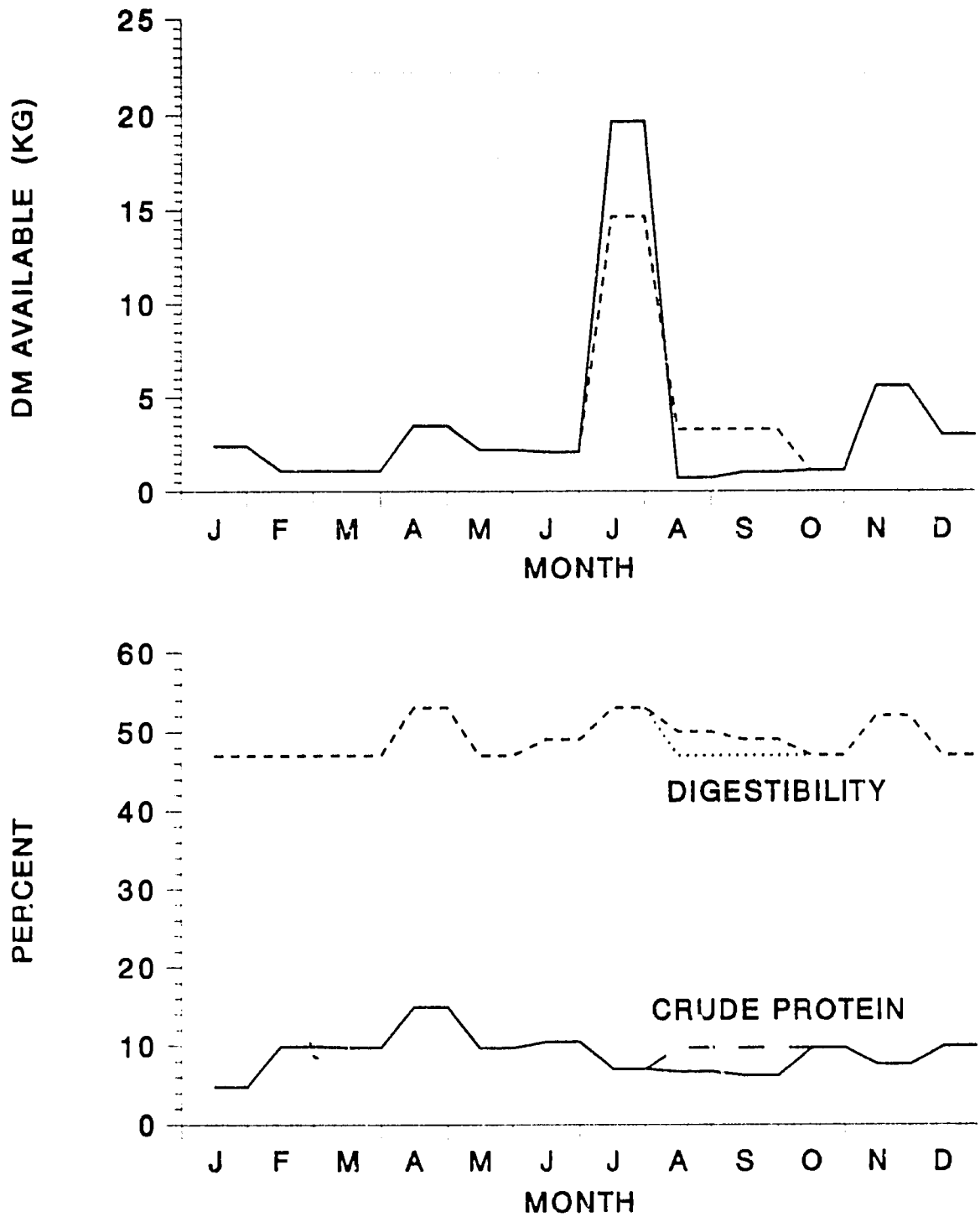


Figure 5. Dry matter availability per doe for a Siaya farm utilizing standing forage (solid line) or stored forage (dashed line). Average crude protein and digestibility of available forage, where storage represents an increase in crude protein but a decrease in digestibility.

biomass is limiting for the Kakamega site. The objectives of the simulations were to compare DPG productivity in the existing environment with the same resource plus the feeding of stored forage when a shortfall of the existing forage base occurred. Stored forage was assumed to be composed of maize stover and other crop residues readily available, stored in a manner similar to stacking hay. This approach would require little input from farmers. The stored forage was fed in August and September in Siaya, and September through November in Kakamega. In addition to the stored forage concept, the forage project was interested in selectively feeding small amounts of sudangrass obtained from inter-cropping with maize. Simulations were performed to examine how goats would respond in growth, lactation and reproduction to sudangrass fed as a supplement (.25 kg/day) during months when crude protein of feed was below 7%.

The forage availability (kg/hd/day) was the determining factor in the number of does that a farm could support. In Kakamega, with no intervention, only 3 does/farm could be supported. In terms of the SR CRSP goals of providing a continuous year-round supply of milk (200 g/day) for each family member, three does were not satisfactory. However, with stored forage six does can be supported. In Siaya both standing and stored treatments could support 6 DPG does. The average lifetime productivity of a DPG doe in both locations and nutritional treatments is provided in table 5. For the Siaya environment utilizing stored feed increased the number of kids born. However, due to the does higher reproductive performance weaning weight and average

TABLE 5. AVERAGE LIFETIME PRODUCTION OF A 5-YEAR OLD DOE WITH A MATURE SIZE POTENTIAL OF 40 KG AND A MATURE MILK POTENTIAL OF 4.0 KG PER DAY.

Item	Kakmega	Siaya	
	Stored	Standing	Stored
Number of Kids	6	5	
Av. Weaning Weight, kg	13.9	15.4	13.6
Av. Milk Yield Per Lactation, kg	117	142	115
Doe Condition, Minimum Score, %	64	61	64

TABLE 6. SIMULATED TEN YEAR FARM FLOCK AVERAGES WITH A MATURE SIZE POTENTIAL OF 40 KG AND A MATURE MILK POTENTIAL OF 4.0 KG PER DAY.

	SIAYA			KAKAMEGA	
Item	S[a]	ST[b]	SS[c]	ST	SS
Dry Matter Consumed Per Year Per Flock, kg	2592	2819	2766	2420	3180
Average Number of Does	5.0	5.2	4.4	4.9	5.6
Live Births Per Year	6.3	6.5	5.8	5.0	6.6
Kids Weaned Per Total Kids Born Per Year, %	62.5	60.0	58.0	51.0	57.0
Kids Sold Per Year:					
Number	5.0	5.0	4.4	3.7	4.9
Total Weight, kg	71	80	89	56	105
Total Weight Sold Per Year, kg (Kids and Cull Does)	101	108	107	87	118
Milk Production Per Year:					
Total Production, kg	1466	1665	1857	1983	2009
Dairy Production, kg	544	620	756	610	777

[a] S: Standing Forage (This practice not viable for Kakamega)
[b] ST: Stored Forage
[c] SS: Stored Forage plus sudangrass supplementation

milk produciton were decreased. For the lifetime of the doe, stored feed did enable her to wean more kilograms of kid but the total quantity of milk produced was not increased.

Flock model simulations were performed to evaluate standing forage (S), stored forage (ST), and stored forage plus sudangrass supplementation (SS). Table 6 gives flock performance data for the three practices. By improving the DPG's diet, in Siaya, reproductive rate increased from 126% for S to 132% for SS. Average sale weight increased from 14.2 kg for S to 16.0 kg for ST, and 20.2 kg for SS. Dairy milk yield increased by 14% and 39%. For Kakamega, supplying sudangrass supplement in addition to stored forage increased reproductive performance (102 vs 118% weaned kids/doe), weaning weights (15.1 vs 21.4 kg) and dairy milk yield by 27%. These results indicate that both the practice of storing feed for one month and providing sudangrass supplementation in moderate amounts, has a significant impact upon the biological output from the DPG goats. In addition, milk production is more consistent throughout the year (figures 6 and 7). Provided with this type of information, questions which need to be answered by the economics component of SR CRSP relate to the economics of storing feed and the effects of interplanting sudangrass on maize or pigeon pea production.

Work by Hart et al. (1984) indicated that forage quantity is not the limiting factor for the Hamisi area. The forage quality values given in this report are lower than those reported by Sands (1983) and given by Morrison (1946). The forage consisted of dried corn stover,

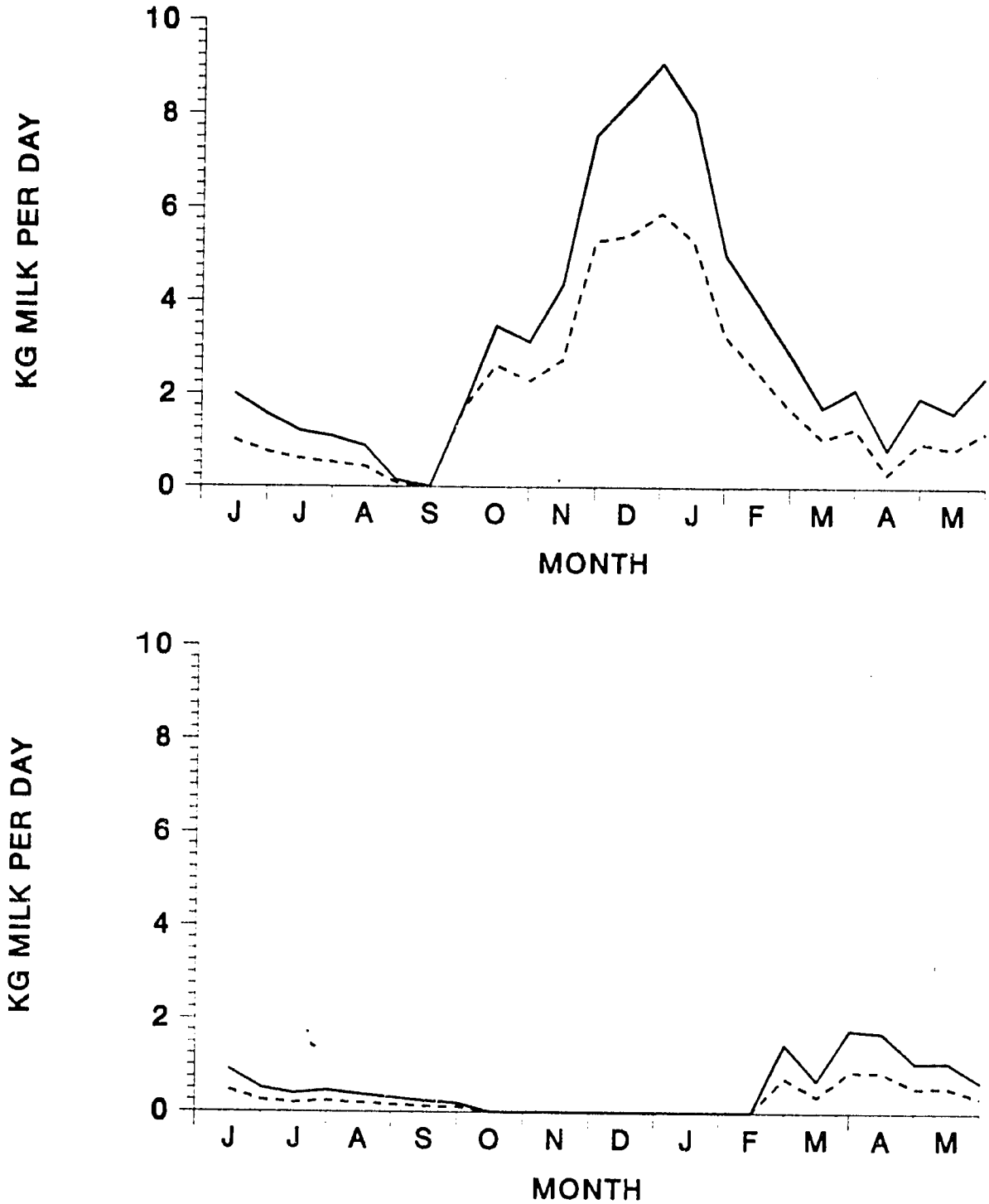
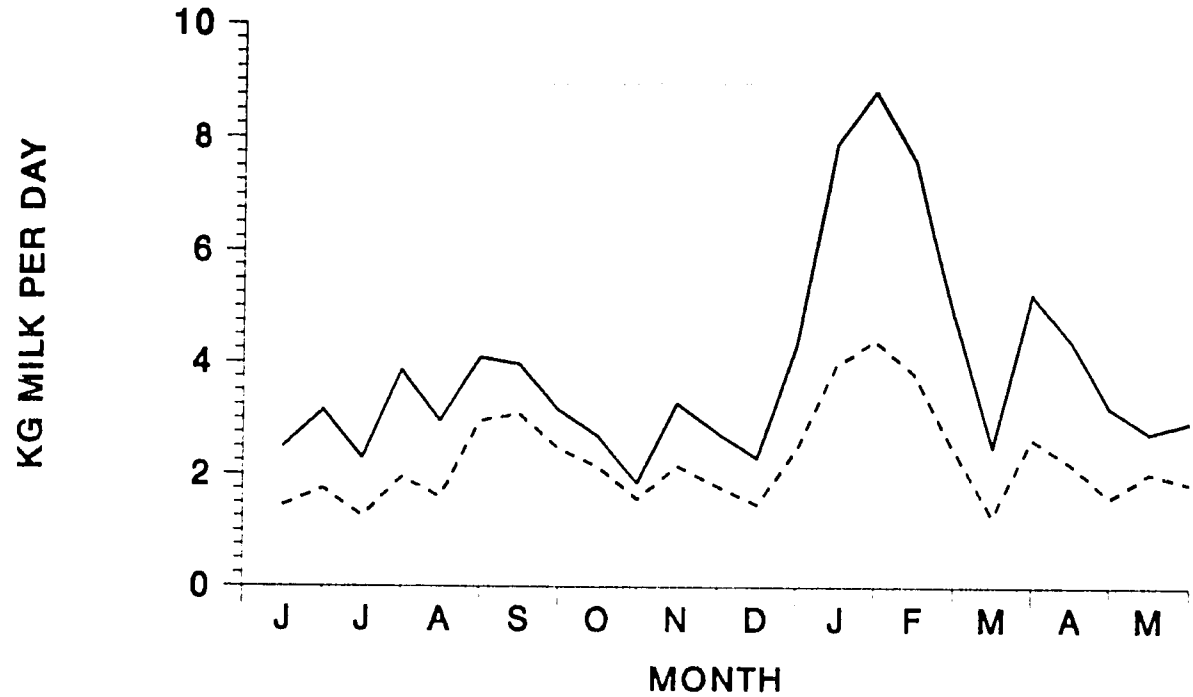


Figure 6. Total (solid line) and dairy (dashed line) milk production for a Kakamega farm utilizing stored forage in year 5 (top) and year 10 (bottom) of a simulation.



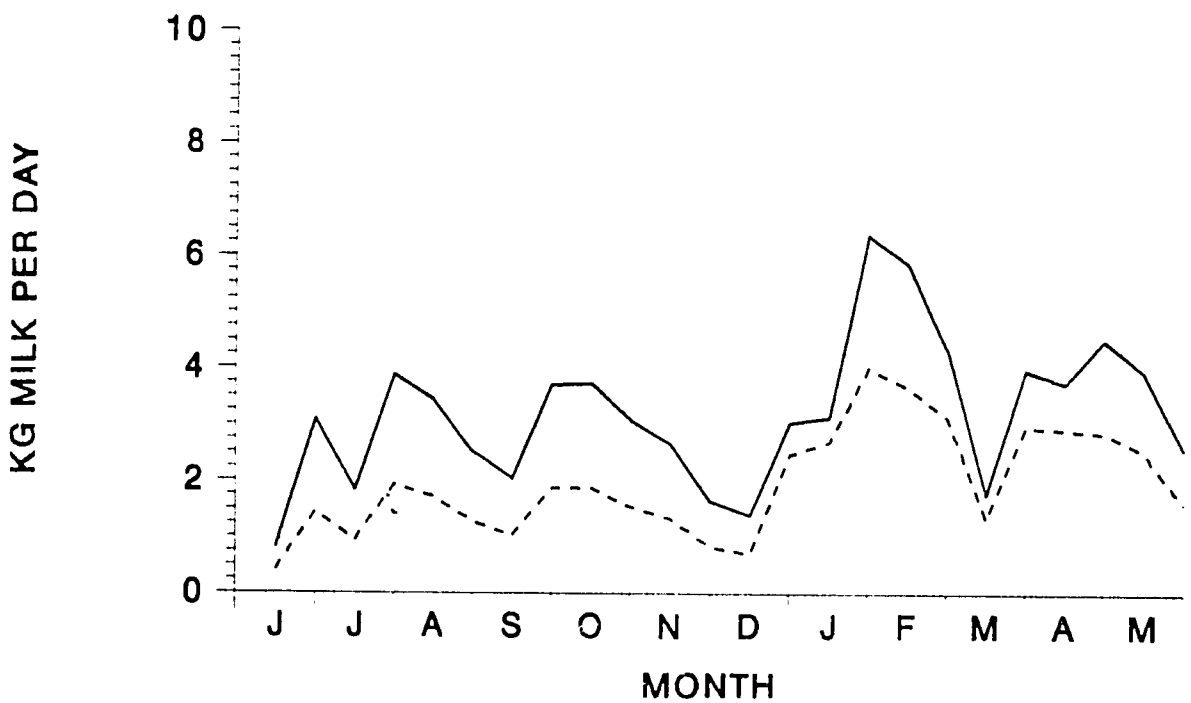


Figure 7. Total (solid line) and dairy (dashed line) milk production for a Kakamega farm utilizing stored forage plus supplementation in year 5 (top) and year 10 (bottom) of a simulation.

TABLE 7. SIMULATED MEAT AND MILK OFFTAKE BY FLOCK SIZE, GENOTYPE[a] AND FORAGE[b].

Item	2 Doe 40/4.0		4 Doe 40/4.0				4 Doe 40/3.0		6 Doe 40/4.0	
	B	I	B	I	B+S	I+S	B	I	B	I
Av No. Lactating Does/Period/Yr	1.0	1.2	1.9	2.2	2.1	2.3	2.1	2.3	2.8	3.4
Flock Dairy Yield kg/Yr	162	288	332	507	508	622	319	584	424	716
Diary Yield kg/Day	.45	.8	.92	1.4	1.4	1.7	.89	1.6	1.2	2.0
Dairy Yield kg/Lact Doe/Yr	162	240	175	230	242	270	152	254	151	211
No. Yearlings Sold/Lact Doe/Yr	1.5	1.8	1.5	1.9	1.6	1.6	1.6	1.5	2.0	1.9
Av Yearling Wt, kg	21	29	24	31	24	32	19	30	19	30
No. Culls Sold/Lact Doe/Yr	.2	.3	.4	.2	.3	.3	.4	.4	.3	.2
Av Cull Wt, kg	29	35	30	42	37	40	30	43	40	38
Total Wt Sold/Lact Doe/Yr	43	55	48	73	48	61	42	55	50	66

[a] Genotype refers to the mature doe body weight of the DPG as 40 KG and peak potential daily milk yield of 4.0 or 3.0 kg

[b] B = Base; I = Improved; B+S = Base plus Sesbania; I+S = Improved plus Sesbania

fence row growth, fallow growth, bean leaves and cassava leaves. Examined in addition to this forage base (B) were base forage plus sudangrass and pigeon peas (PP), and sesbania (Se) as a selective feed supplement which was fed at a rate of .5 kg/day to a doe or yearling when body condition drops to a critical level (72%). Examination of the effects of alterations in the nutrition were examined by simulating a 4 doe flock (table 7). Generally, providing DPG's with B and Se supplement increased productivity to a level similar to that of PP treatment. Providing DPG's with either PP or Se supplements improved dairy milk offtake but had little impact on total weight sold when compared to the PP diet. These simulations indicate three viable practices for smallholders to use when raising DPG's.

MANAGEMENT

A major management consideration for DPG production is determining the amount of milk to extract for dairy purposes, and what impact does this extraction have on kid performance. Work by Cartwright et al. (1983) documented the effects of extracting 1/2 the milk on kid weaning weight for indigenous and dairy genotypes. This led to experiments reported by the SR CRSP Breeding project (Ruvuna et al., 1984) where different types of milking strategies were tested. Further quantification of milk division strategies were presented by Blackburn et al. (1985) and are presented, in summary, here.

Milking Strategies:

Four milking procedures were tested using forage input parameters from Hamisi and Siaya and the DPG genotype (40/4.0). The four milking

procedures were: 1) unlimited access by the kid to its dam's milk and the remainder, if any, for dairy; 2) kid takes 1/2 of the milk and the remaining 1/2 for dairy throughout lactation; 3) kid consumes a maximum of .5 kg milk and the remainder, if any, for dairy; 4) kid consumes a maximum of .3 kg milk and the remainder, if any, for dairy. With each of these treatments the comparison of base forage to base forage plus supplement was made (the supplement consisted of sudangrass and pigeon pea), supplement was fed throughout the year. The term dairy is used to refer to milk taken for family use or sale. There were two concerns for treatments 3 and 4. One was that at some point in lactation the amount of dairy milk produced is not worth the labor required for milking, therefore the farmer leaves the total amount for the kid. Another was that there is a minimum amount of milk necessary for acceptable kid growth.

Simulated results indicated that treatment 1 weaned the heaviest kid while treatment 4 weaned the smallest (17.4 vs 10.0 kg). Intermediate weaning weights were obtained for treatment 2 and 3 (12.8 and 13.1 kg). Using base forage plus supplement increased weaning weights for treatments 1, 2 and 3 (10.3 to 11.7%) but had little effect on kid weaning weight in treatment 4 (10.0 vs 10.7 kg). This indicates that kids raised by the treatment 4 method were under stress resulting in stunting or growth is severely slowed (table 8). The treatment 4 doe raises a small kid because a larger fraction of her total milk production is used by the farmer (61% vs 10, 50 and 46% for treatments 4, 1, 2 and 3 respectively).

TABLE 8. EFFECTS OF MILK EXTRACTION PROCEDURE AND SUPPLEMENTATION ON DUAL PURPOSE GOAT PRODUCTION.

	Treatment							
	Unrestricted(1)		1/2 Milk (2)		.5 kg Milk/d(3)		.3 kg Milk/d(4)	
Item	Base	Base +SPP	Base	Base +SPP	Base	Base +SPP	Base	Base +SPP
Weaning weight, kg	17.4	19.2	12.8	14.3	13.1	14.6	10.0	10.7
Dairy milk, kg	10.2	18.5	51.6	64.4	48.0	66.0	63.5	84.9
Length of Lactation, days	15.0	30.0	150.0	150.0	75.0	75.0	90.0	120.0
Ave Milk/days, kg	.68	.62	.34	.43	.64	.88	.71	.71

Length of lactation (table 8) is a critical component of DPG production in satisfying the goal of providing smallholders a continuous supply of milk at a prespecified level of milk/day. Treatments ranked 2, 4, 3 and 1, for length of lactation with and without supplementation. However, when average dairy milk/day were compared the ranking changes to treatment 4, 3 and 2 without supplement and 3, 4 and 2 with supplement. This situation provides critical trade-offs between length of lactation and the amount extracted for human consumption. Input from both economic and sociological components in the project can make a valuable contribution to determine which strategy will benefit the smallholder most.

Biologically, treatments 2 and 3 provide an intermediate combination of weight of kids for sale and dairy milk yield. The major difference being the length of time milk can be extracted for dairy. The treatment a smallholder selects may be dependent upon the number of does he owns. Farmers with fewer does may opt for treatment 2 which would provide milk from a doe for a longer period of time. Conversely, the more does a farmer has, enables him to switch to a shorter lactation which yields more milk/day but for a shorter period of time, without going through a "dry" period.

Flock Size

Flock size and replacement policy are difficult areas to assess with real goats and limited resources. Use of the TAMU Goat Model makes it feasible to evaluate the potential productivity of flocks of

2, 4 or 6 does. Initially a flock of 6 does was evaluated which had evenly spaced parturitions and lactations (figure 9). These initial simulations demonstrated that the forage resource was capable of sustaining 6 does and that a 6 doe flock could supply sufficient milk to meet the Kenya SR CRSP goal 200 g/person/day (figure 10). These initial simulations did not account for the replacements necessary to make the flock selfsustaining. It, also assumed that does would continue to have evenly spaced parturitions. Examination of these problems was necessary to test the feasibility of the six doe flock. Further simulations were designed to examine 2, 4 and 6 doe flocks, where does were not forced to rebreed at a particular time, and young kids (up to 1 year of age) and replacement does were simulated as part of the flock.

Performance of 2, 4, and 6 doe flocks is given in table 9. Flocks of 6 does had a larger number of does lactating at any one time, however, kids raised in this flock had slightly lower average yearling weights than 2 and 4 doe flocks. This difference was due to stresses, of the 6 doe flock kids which were born throughout the year.

An important consideration in evaluating the size of flock to recommend to smallholders is the number of nonlacting goats present at any time. Although total milk production increases with flock size, a question which the sociology project must answer is:

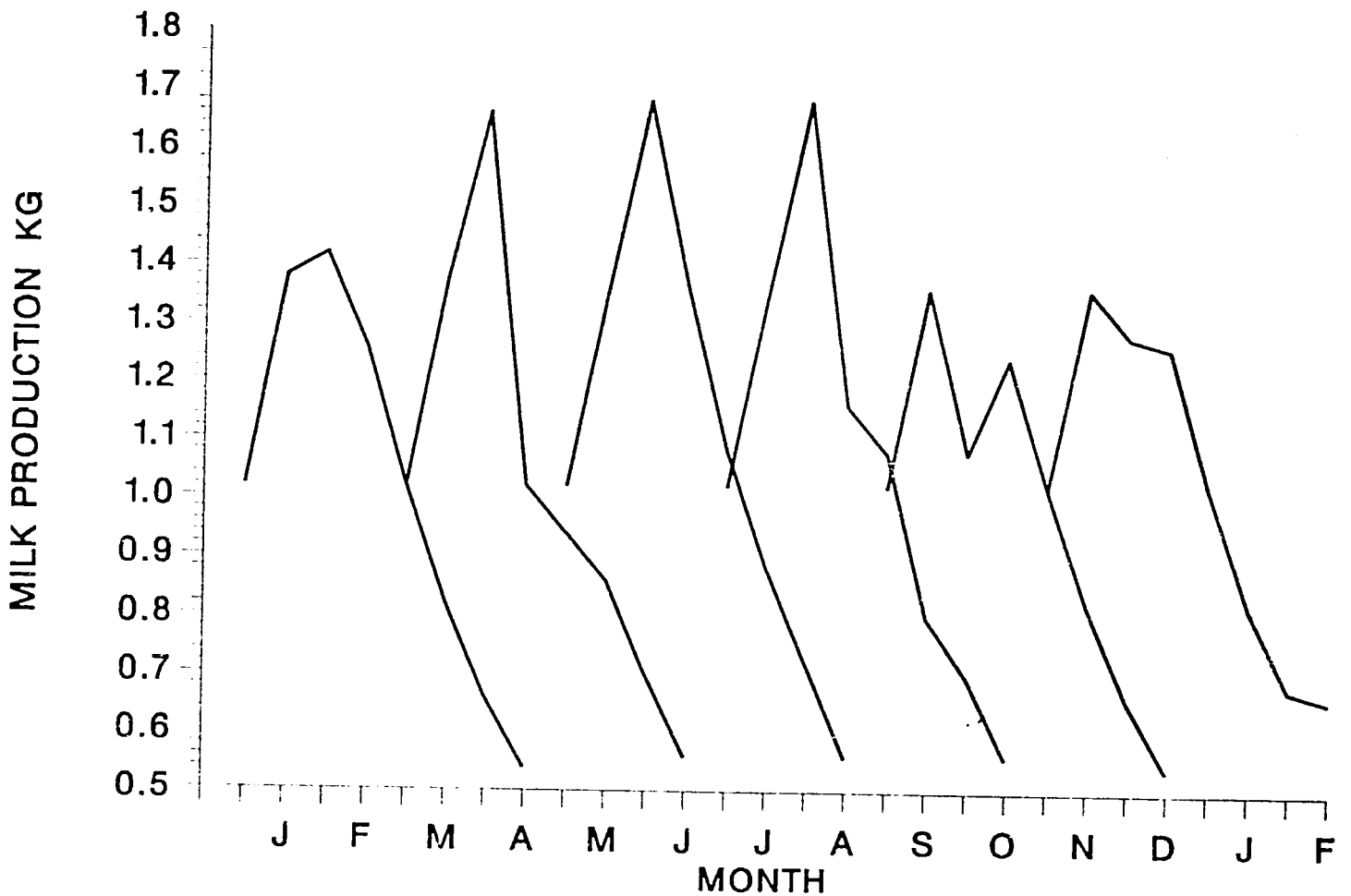


Figure 8. Simulated lactation curves of a flock of 6 mature does, forced to kid at two-month intervals.

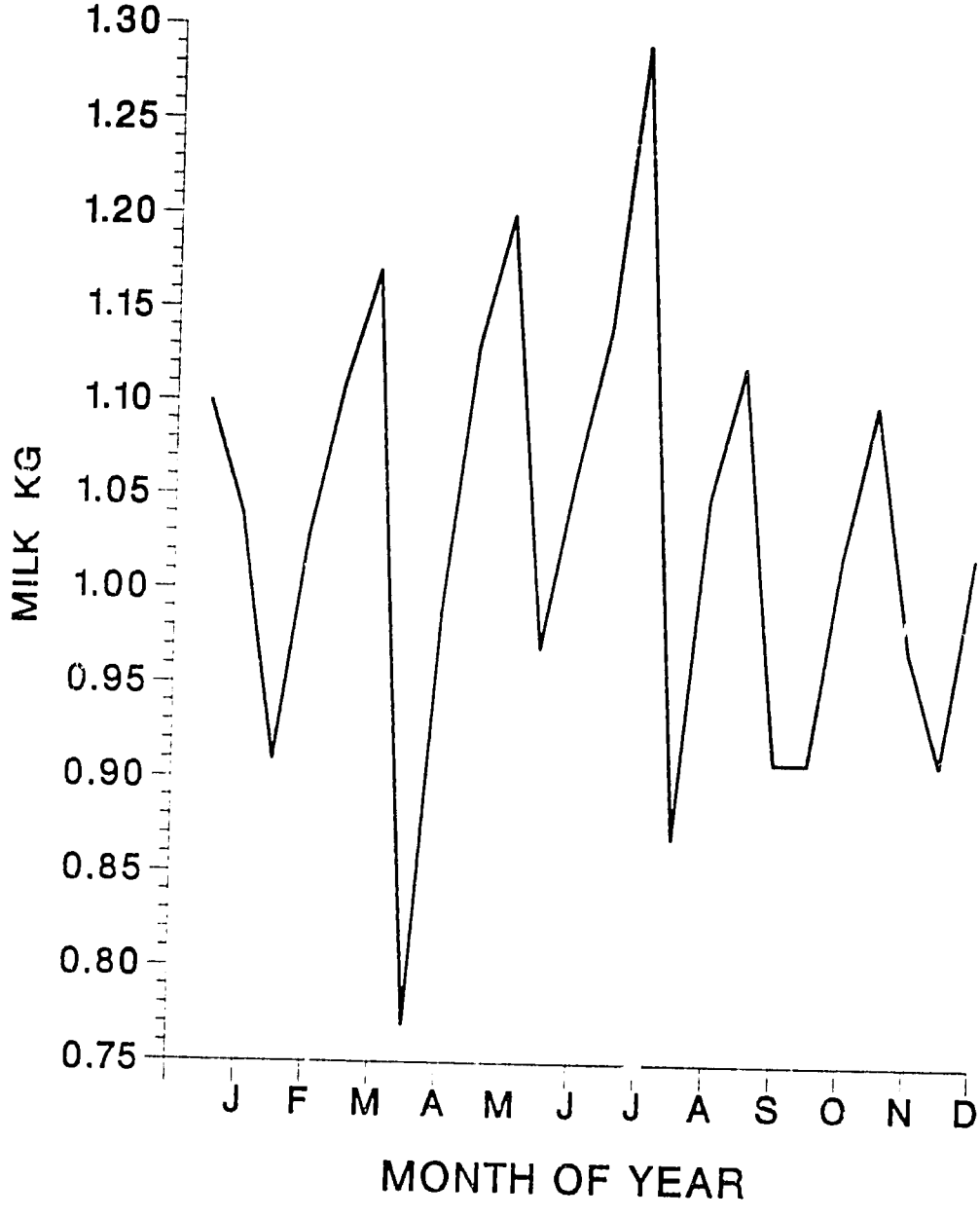


Figure 9. Simulated goat milk available for family use from a 6 doe flock, kidding a two-month intervals, with 1/2 the total milk production used for dairy purposes.

TABLE 9. ANNUAL AVERAGES FOR FLOCK SIZES OF 2, 4, OR 6, DPG[a] DOES ON BASE AND IMPROVED FORAGE.

FORAGE & FLOCK SIZE	TOTAL NO. GOATS	NO. LIVE BIRTHS	AV NO. LACT	DAIRY MILK, KG	AV WEAN WT, KG	AV YEARLING WT, KG	AV CULL WT, KG	TOTAL WT SOLD, KG	DRY MATTER CONSUMED, KG
BASE									
2 Does	4.8	3.2	1.01	162.9	13.4	20.7	29.0	43.0	1317.0
4 Does	7.0	5.4	1.88	332.4	13.7	23.6	30.0	90.4	2175.0
6 Does	10.4	7.8	2.84	424.4	13.0	19.3	40.0	140.2	3156.0
IMPROVED									
2 Does	4.6	3.2	1.15	288.4	16.2	29.0	34.5	66.2	1503.0
4 Does	7.8	6.4	2.23	507.0	15.9	30.5	42.0	160.4	2973.0
6 Does	12.6	9.4	3.43	716.1	15.9	30.2	38.0	223.6	4512.0

[a] DPG = Dual purpose goat breed assumed to have genetic potential at maturity, when nutrition is not limiting, of 40 kg body weight and 4.0 kg milk at peak day of lactation.

TABLE 10. SIMULATED AVERAGE DAILY DAIRY MILK YIELD, KG PER DOE, AVERAGED OVER A 5-YEAR PERIOD, FOR DPG

Period average	BASE FORAGE			IMPROVED FORAGE		
	2 Does	4 Does	6 Does	2 Does	4 Does	6 Does
1	.22	.48	.58	.59	.49	.48
2	.21	.47	.48	.55	.61	.44
3	.19	.38	.38	.58	.74	.63
4	.21	.33	.26	.42	.69	.65
5	.26	.51	.33	.45	.68	.51
6	.32	.67	.35	.55	.69	.87
7	.29	.52	.30	.47	.63	.67
8	.37	.73	.46	.38	.52	.48
9	.34	.60	.31	.27	.49	.59
10	.37	.38	.32	.14	.66	.49
11	.29	.43	.31	.75	.54	.55
12	.23	.44	.16	.72	.51	.69
13	.35	.39	.38	.87	.58	.53
14	.23	.41	.41	1.00	.54	.68
15	.33	.72	.65	.89	.49	.49
16	.47	.78	.72	.73	.36	.69
17	.38	.53	.62	.49	.35	.50
18	.31	.52	.55	.44	.44	.49
19	.25	.46	.44	.40	.79	.55
20	.19	.36	.31	.36	.69	.53
21	.43	.32	.23	.87	.72	.41
22	.39	.49	.19	.67	.63	.52
23	.32	.54	.31	.61	.68	.55
24	.28	.58	.33	.46	.58	.51
Av. no. does lact/ period	1.01	1.88	2.84	1.15	2.23	3.43
Av. Total dairy milk/ day/flock	.30	.94	1.11	.66	1.32	1.92

Is the smallholder capable of or willing to maintain flocks of goats which range in size from 7 to 13 head?

Table 10 presents milk yield a producer could expect to receive throughout the year from various flock sizes. Average milk per day per doe reflects variations due to seasonal and other patterns that were simulated. Similar but different fluctuations occur for liveweight production. A more critical question of flock size is how consistent is yearly milk production. Table 11 presents the range of milk production by period for a 5 year span of time. Production varies from year to year for the same time period due to age effects of does, postpartum interval, and flock mortality. The critical point is; the frequency that milk yield falls to zero. Milk yield of the 2, 4, and 6 doe flocks fell to zero at least once for 92, 46 and 17% of the periods during 5 years. In terms of consistency and reliability of milk supply, the 6 doe flock had an advantage over smaller flock sizes; i.e., during five years, a family would be without milk only for four 15-day periods per year.

The simulations performed in this section provide insight into the production response patterns of goats in different flock sizes. The model was not constructed to answer economic or sociological aspects of these scenarios. However, the simulations do point to an area of needed research, thus fulfilling one of the objectives of systems analysis at the biological level.

TABLE 11. RANGE OF AVERAGE DAILY DAIRY MILK YIELD FOR EACH 15-DAY PERIOD OVER FIVE YEARS OF SIMULATION ON IMPROVED PASTURE[a]

Period	No. Does		
	2	4	6
1	0 - 1.96	0 - 2.28	.84 - 5.40
2	0 - .82	1.17 - 2.91	.22 - 2.92
3	0 - .91	.92 - 2.92	.32 - 3.40
4	0 - .75	.74 - 3.48	.26 - 3.08
5	0 - 1.64	.40 - 4.44	0 - 1.86
6	0 - 1.00	.34 - 4.16	.99 - 2.54
7	0 - .93	.27 - 3.76	.71 - 2.12
8	0 - .76	0 - 3.04	.56 - 2.60
9	0 - .65	0 - 1.64	.94 - 3.48
10	0 - .43	.33 - 1.86	0 - 1.88
11	0 - 2.17	.26 - 1.90	.93 - 4.50
12	0 - 2.46	0 - 2.16	.66 - 2.82
13	0 - 3.86	.90 - 1.88	.54 - 3.75
14	0 - 3.54	0 - .89	.95 - 3.08
15	0 - 3.12	0 - .77	.96 - 4.44
16	0 - 2.58	0 - 1.59	1.02 - 3.84
17	0 - 1.70	0 - .96	.81 - 2.52
18	0 - 1.30	.36 - 2.04	.51 - 3.65
19	.58 - 1.04	.87 - 2.78	1.23 - 3.90
20	0 - 1.78	.52 - 3.78	.84 - 1.52
21	.22 - 2.10	.22 - 2.98	.58 - 3.42
22	0 - 1.90	0 - 2.42	.20 - 3.24
23	0 - 1.75	0 - 3.33	0 - 3.30
24	0 - 1.50	0 - 3.06	0 - 4.68

[a] The range includes the lowest and highest flock yield during each period over a five year span.

Replacement Policy

A brief note on replacement policy should be mentioned. Simulations were performed with 2 types of replacement policies: 1) keeping female replacements after weaning only if a doe had died or was sold, and 2) keeping all kids to 1 year of age before selling them or adding them to the flock. The results from these simulations showed that by following the first option the flock was unstable, that is, productivity was erradic; e.g., milk yield was often zero. Periods of low productivity were caused by not having a replacement doe kid which was old enough to breed and begin lactation after a short interval when an older doe died or was culled. Keeping young does to 1 year of age allowed a smoother transition of does exiting and entering the flock. Therefore, it appears clear smallholders should always keep at least 1 yearling doe as a replacement at all times.

ECONOMIC ANALYSIS OF MILKING TREATMENTS

A partial economic analysis of DPG milking practices and forage improvement was reported by Mukhebi et al. (1985). Using marginal net benefit (MNB) and benefit cost ratio (BCR), the methods of milk extraction previously discussed were analyzed. Benefit cost ratios indicated that all treatments tested, in both locations, with unimproved and improved forage, were superior to letting the kid have unrestricted access to its dam's milk (table 12). Generally, feeding the kid .5 kg of its dam's milk (treatment 3) had the highest benefit cost ratio indicating a larger return to the smallholder. There were instances where the 1/2 total milk practice (treatment 2) was equal to

or only slightly below treatment 3. In all cases treatment 3 and 2 were superior to allowing .3 kg of milk for kid consumption (treatment 4).

Examination of marginal net benefits (table 13) showed the additional monetary value of incorporating one of the milking practices into the production system. As with BCR, all experimental treatments would provide smallholders with a greater return per kid weaned. However, the farmer would receive more money by practicing treatment 4, in both locations with unimproved and improved forages. Treatments 2 and 3 yielded similar monetary advantage with unimproved forages. Using improved forages made a greater difference between treatment 2 and 3; treatment 3 ranked higher than treatment 2.

Evaluating BCR for unimproved vs improved forage showed that improving the forage base across the different treatments resulted in small and slightly negative differences for some treatments (table 14). The negative value would indicate that there is no benefit for the smallholder to incorporate improved forages. It is of interest to note that treatment 1 (the control) had the lowest ratio in both locations. Within the Hamisi location the only positive BCR was for treatment 4 with treatment 3 ranking second but, having a negative BCR. In Masumbi treatments 2 and 3 had positive BCR indicating that with improved forages these milking practices should be followed.

Although the implementation of improved forages does not seem to provide the benefit expected, further analyses must be conducted.

TABLE 12. BENEFIT COST RATIOS FOR PRE-WEANING FEEDING PRACTICES FOR DPG ON IMPROVED AND UNIMPROVED FORAGES IN HAMISI AND MASUMBI CLUSTERS[a].

Treatment[b]	Unimproved forage	Improved forage	Unimproved and Improved forage
		Hamisi Cluster	
1		CONTROL	
2	2.3	2.4	2.4
3	2.3	2.9	2.6
4	1.7	2.0	1.9
		Masumbi Cluster	
1		CONTROL	
2	2.1	2.4	2.3
3	2.4	2.8	2.6
4	1.8	2.0	1.9

[a] From Mukhebi et al., 1985.

[b] Treatments 2, 3 and 4 as test treatments over treatment 1, as the control where treatment:
1 = Unrestricted feeding of mother's milk
2 = Feeding 1/2 of mother's milk
3 = Feeding .5 kg of mother's milk
4 = Feeding .3 kg of mother's milk

TABLE 13. MARGINAL NET BENEFITS PER WEANED KID FOR VARIOUS PRE-WEANING FEEDING PRACTICES IN HAMISI AND MASUMBI CLUSTERS, KSHS/WEANED KID[a].

Treatment[b]	Unimproved	Improved
	Hamisi Cluster	
1	CONTROL	
2	77.42	86.51
3	71.30	95.00
4	91.79	119.85
	Masumbi Cluster	
1	CONTROL	
2	71.33	85.22
3	74.33	93.53
4	94.25	118.05

[a] From Mukhebi et al., 1985.

[b] Treatments 2, 3 and 4 as test treatments over treatment 1, as the control where treatment:
1 = Unrestricted feeding of mother's milk
2 = Feeding 1/2 of mother's milk
3 = Feeding .5 kg of mother's milk
4 = Feeding .3 kg of mother's milk

TABLE 14. BENEFIT COST RATIOS FOR PRE-WEANING FEEDING PRACTICES OF GOATS ON IMPROVED VS UNIMPROVED FORAGE, HAMISI AND MASUMBI CLUSTERS[a].

Treatment[b]	Benefit cost ratios of improved over unimproved forage
	Hamisi Cluster
1	-0.6
2	-0.5
3	-0.1
4	0.1
	Masumbi Cluster
1	-0.3
2	0.1
3	0.2
4	-0.3

[a] From Mukhebi et al., 1985.

[b] Treatments are:
1 = Unrestricted feeding of mother's milk
2 = Feeding 1/2 of mother's milk
3 = Feeding .5 kg of mother's milk
4 = Feeding .3 kg of mother's milk

These initial economic analysis do provide insight as to which milking practices should be recommended. As should be expected they vary with location and forage base. Further interaction among the SR CRSP projects as more data are collected should provide more complete and definite answers to these types of questions.

CONCLUSIONS

The collaboration between the SR CRSP in Kenya and MALD is structured as a set of integrated projects designed to develop technology packages required to implement viable DPG production in western Kenya. Members of the SR CRSP team and MALD associates have recognized that no one technology package will be adequate for all smallholders in the different environments which exists in western Kenya. Therefore, a series of technology packages will have to be developed for the different production scenarios. At this time such packages have not been developed. However, this publication is a first step in the direction of formulating a consensus on practices that should be included and the amount and type of flexibility the technology packages should have.

Simulations evaluating body size and milk producing potentials to incorporate optimal breeding objectives indicated that a doe with the genetic potential for a mature size of 40 kg and peak day milk production of 4.0 kg results in the near maximal level of productivity which the forage resource would adequately support. We concluded that a doe of this genotype would be able to withstand the environmental variations and challenges which occur in western Kenya. As a result

of these simulations, a target was set for the SR CRSP breeding project to develop and select their composite synthetic DPG breed. Further simulations examining different genotypes indicated that a doe with mature size of 40 kg and peak day milk production of 3.0 kg could be almost as effectively used by smallholders. Although it was less productive than the 40/4.0, it may serve as an interim genotype that smallholders could use until the 40/4.0 DPG becomes available.

Numerous alternatives in nutrition were simulated. Generally, the results showed that successful DPG introduction and propogation requires increases in forage quantity and/or quality, especially during the dry periods. Several ways in which this problem may be solved were identified. First, feed could be shifted from times of excess to times when there is a shortage; this requires a means by which feed may be satisfactorily stored for short periods. Second, higher quality supplements such as sudangrass, pigeon pea and sesbania can be fed at critical times. The critical times at which supplements are fed can be based upon either forage quality (e.g., a crude protein level of 7% or less) or body condition of the goat. The latter has advantages in that a goat can be supplemented according to its individual condition and requirements. For example, one doe may be lactating and therefore need supplemental feed whereas a dry doe might not. However, our simulations show that with the use of sudangrass and pigeon pea supplements, the production of DPG does will still be nutritionally inhibited with energy being the most deficient. Therefore, a method of providing a forage which will overcome the

deficit is of high research priority (at this time sesbania appears to be a forage which can help alleviate this problem).

Simulations of the procedure for extracting milk for human consumption indicated that there are two methods which have potential use in the smallholder context, extracting either 1/2 the total milk produced or allowing the kid to suckle no more than .5 kg. The .5 kg procedure may be more acceptable to a smallholder with a large flock of does, because it results in a higher level of milk offtake, even though the length of time that milk can be extracted is shorter than for 1/2 extraction. The 1/2 extraction has the advantage of yielding milk for a longer period of time than the .5 kg practice.

Simulated comparisons of flock size showed that at least 6 does are necessary to attain the SR CRSP goal of 200g milk/day for every family member. Over a 5-year period, it was found that 2-doe flocks could have zero dairy milk yield for 92% of the year; for 4-doe flocks milkless-days dropped to 46% of a year, while the 6-doe flock had zero milk production only 17% of the year.

Replacement policies are critical in assuring the smooth transition between generation of DPGs. If the transition is not smooth, gaps occur in milk availability to the smallholder's family. Simulations indicate that smallholders should always keep at least one yearling replacement doe on the farm. Keeping only younger replacements will result in decreased flock productivity. Additional simulations are being performed to more fully address this problem.

The next phase of simulations will be to initiate synthesizing various production packages, using the different technologies which have been developed to date, for farmers with different resource bases in different locales. This will require an integrated effort of all SR CRSP projects, including economics and sociology, and should yield results which will help more sharply focus research on the critical issues of DPG use and implementation.

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