Simulation of costs and benefits of supplementing milking cows with legumes during the dry season in two hillside regions of Nicaragua

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Abstract

Objectives of this study were to compare costs and expected benefits of feed supplementation in cattle with alternative shrub legumes during the dry season using as a case study the hillsides of Central Nicaragua. The information used was gathered in a survey of 32 farms in the states of Boaco and Chontales in Central Nicaragua. The survey was designed to determine herd structure, land use patterns, milk and beef production, and use of inputs for animal nutrition, in order to estimate production, reproductive parameters and employment of family/contracted labor, as well as indicators of profitability of the alternatives under study. To calculate the economic return to the investment in alternative forages, a simulation model that applies optimization techniques through linear programming, implemented as a spreadsheet, was used to perform an *ex ante* evaluation of the costs and benefits of different land use alternatives and of interactions between technological components and biological productivity. The model compares the costs and benefits of the traditional feeding system versus an improved feeding system.

The traditional system consists of grazing naturalized pastures (*Hyparrhenia rufa*) during the rainy season. In the dry season producers supplement the herd with small areas of king grass (*Pennisetum* spp.). The improved feeding system consists of establishing forage legumes for dry season feeding as a supplement to replace king grass during the dry season. Supplements to evaluate are the shrub legume *Calliandra calothyrsus* as partial replacement of the herbaceous high quality legume *Vigna unguiculata,* commonly known as Cowpea. Under the new feeding system, herd size can be increased by 60% due in part to the increase in stocking rate as well as to the increase in the quality of the diet offered with higher protein content. This increase in herd size raises both milk and beef output that generates an increase in farm income by 1.8 times more (i.e., from $1,314/farm/yr to $2,386). The economic return to family labor is increased by 20% to $ 5.26/day equivalent to 2.3 times higher than the local wage rate. The adoption of Vigna (Cowpea) after the harvest of maize/beans and a shrub legume as Calliandra to replace king grass seem to have the potential to significantly improve the productivity in smallholder farms. with the resulting increase in the economic return to family labor.

Key Words: dry season feeding, family labor, legumes, milk productivity

Introduction

The history of livestock production in the tropics, which is based on extensive grazing, indicates that one of the main constraints faced by current production systems is the limited forage on offer in terms of quantity and quality, which becomes more critical during the driest periods of the year (Rivas and Holmann 2005). Research has identified improved and alternative forage grasses and legumes with the potential to increase animal productivity per unit of area, allowing an alternative use of the land, with livestock production in those areas considered most fragile (Holmann and Lascano 2001).

The greatest barriers to widespread adoption are the lack of information on their use and integration into feeding systems, and a demonstration of their economic viability. Moreover, because small producers frequently get involved in mixed livestock/crop systems, making decisions about how to use resources is a complex process. In Nicaragua, one of the main land use alternatives is raising cattle under grazing. Almost two-thirds of the land apt for agriculture is under permanent pastures. Therefore, problems related to pasture use and management have a high impact on conservation and productive use of the region's land resources. This fact is more relevant if we take into account that nowadays a large fraction (i.e., 60%) of the area under permanent pastures in Central America faces problems of low or decreasing productivity due to mismanagement and resulting erosion (CATIE 2002; Holmann et al 2004).

Objectives

The objectives of this study were to compare the costs and expected benefits of feed supplementation in cattle with alternative shrub legumes during the dry season using as a case study the hillsides of Central Nicaragua.

Material and methods

Sampling

The information used was gathered in a survey of 32 farms in the states of Boaco and Chontales in Central Nicaragua, characterized by hillside terrains. These two states have a mean temperature of 25 Celsius and a mean annual rainfall of 1,300 mm distributed over a six-month rainy season that goes from May to November. These interviews were conducted at random in the main livestock areas by the technical staff of local institutions responsible for livestock research and technology transfer. The survey was designed to determine herd structure, land use patterns, milk and beef production, use of inputs for animal nutrition, in order to estimate production, reproductive parameters and employment of family/contracted labor, as well as indicators of profitability of the alternatives under study. This baseline information served as platform to design scenarios which were assessed from the economic viewpoint, using the simulation model presented below.

The empirical simulation model

To calculate the economic return to the investment in alternative forages, a simulation model that applies optimization techniques through linear programming, implemented as a spreadsheet, was used to perform an *ex ante* evaluation of the costs and benefits of different land use alternatives and of interactions between technological components and biological productivity (Holmann and Estrada 1997). The model assumes that the objective of producers is to maximize annual net income.

The model calculates animal productivity based on mathematical equations of nutrient requirements of dairy cattle obtained from the National Research Council of the National Academy of Sciences from the United States (NRC 1989). The user gives the model information on forage biomass production by season of the year and its corresponding nutritive quality. The model then matches animal nutrient requirements with nutrient supply and predicts animal productivity.

Traditional feeding system vs. improved system

The model compares the costs and benefits of the traditional feeding system versus an improved feeding system. The traditional system consists of grazing naturalized pastures (*Hyparrhenia rufa*) during the rainy season. In the dry season producers supplement the herd with small areas of king grass (*Pennisetum* spp.). The improved feeding system consists of establishing forage legumes for dry season feeding as a supplement to replace king grass during the dry season. Supplements to evaluate are the shrub legume *Calliandra calothyrsus* as partial replacement of the herbaceous high quality legume *Vigna unguiculata,* commonly known as Cowpea.

Calliandra is a perennial shrub legume, native to the humid and subhumid regions of Central America and Mexico which was introduced to many other countries in South and Central America as well as in Asia and Africa. It tolerates acidic, low fertility soils and drought and could be planted in hillside areas near the milking area for use in a cut-and-carry system. Vigna is an annual crop, known for its high forage quality, both in terms of digestibility and protein content. However, on infertile soils it would require fertilization for good yields and irrigation in the dry season, making it unaffordable for smallholders as an alone protein source for animal nutrition. Therefore it could be planted after the maize is harvested at the end of the rainy season using the residual moisture in the soil for hay production after 6-7 weeks. As the harvested amount would not cover the needs it could be complemented by Calliandra, which stays green through the whole dry season and could be grown as living fences or in areas unsuitable for crop cultivation. Table 1 contains the milk yield response of milking cows to the traditional feeding system and to the improved system. Research results have shown that for milking cows the highest replacement of Cowpea by Calliandra still suitable in terms of dry matter intake and milk yield is around 67% (Bernal et al 2006). Hence the assessment in this study was calculated on base of these data. Higher proportions of Cowpea, if available will result in higher milk yields.

Table 1. Milk yield response to cows on the traditional and improved feeding systems

Diet	**Milk production, kg milk/cow/day**
Traditional feeding system: Cows grazing Jaragua (*Hyparrhenia rufa*) during dry season and supplemented with king grass [1]	2.3
Improved feeding system:	
· Cows grazing during dry season and supplemented with Calliandra alone, daily intake: 1.2 kg DM/cow/day [2]	3.6
· Cows grazing during dry season and supplemented with a mixture of Calliandra (67%) and Vigna (33%), daily intake: 2.6 kg DM/cow/day [2]	4.4

[1] *Two kilograms of dry matter per cow per day, Holmann and Rivas 2005*

[2] *Bernal et al 2006*

Table 2 contains the forage parameters (biomass production and nutritive quality for both rainy and dry seasons) of the traditional and improved feeding systems which are needed as inputs to run the simulation model.

Table 2. Forage parameters of traditional and improved feeding systems used to run the model in some farms in Boaco and Chontales en Nicaragua

Parameters	**Traditional technology**		**Improved technology**		
	Hyparrhenia rufa	**Pennisetum spp.**	***Hyparrhenia rufa***	***Calliandra calothyrsus***	***Vigna unguiculata***
Useful life, years	6	10	6	12	1
Rainy season					
Production of edible biomass, kg DM/ha[1].	3,500	10,000	3,500	2,000	2,700
Crude protein, %	8	8	8	15	18

In vitro dry matter digestibility, %	50	60	50	55	80
Dry season					
Production of edible biomass, kg DM/ha[2]	700	0	700	500	0
Crude protein, %	4	5	4	15	0
In vitro dry matter digestibility, %	35	45	35	50	0
Loss due to trampling, %					
Rainy season	25	0	25	0	0
Dry season	20	0	20	0	0
Maximum transfer of rainy season biomass to dry season, kg DM/ha[3]	1,050	10,000	1,050	2,000	2,700
Establishment cost, US$/ha	100	258	100	365	175
Maintenance/harvest cost, US$/ha	28	129	28	113 [a]	113 [a]

1 During the six-month rainy season

2 During the six-month dry season

3 Amounts to 20% of rainy season biomass production.

a Estimate based on 50 man-days per year

Table 3 contains input and output prices as well as the maintenance costs of both the traditional and improved feeding alternatives under evaluation.

Table 3. Economic information for the assessment of new forage technologies in some farms in Boaco and Chontales, Nicaragua

Parameter	**Price**
Milk price, US$/kg	
- Dry season	0.22
- Rainy season	0.17
Beef price, US$/kg live weight	0.90
Wage rate, US$/day	2.27
Commercial livestock value, US$/AU[1]	
- Pregnant heifer	260
- Cow in production	420
- Culled cow	240
Cost of establishing legume alternatives, US$/ha	
- Calliandra	360
- Vigna	270
- King grass	260
- *Hyparrhenia rufa* (Jaragua)	110

1 AU = Animal Unit (live body weight of 400 kg)

The model did not include establishment time for *Calliandra calothyrsus* (about 12 to 18 month), as a slow transfer from one to the other system or already existing Calliandra occurrence was assumed.

Results and discussion

Livestock production system

Table 4 contains the animal productivity parameters of livestock production systems in Boaco and Chontales, Nicaragua used to run the simulation model obtained through the farm survey.

Table 4. Land use, herd structure, productive and reproductive parameters, and use of family and contracted labor in some farms in Boaco and Chontales, Nicaragua

Item	**Small (n=48)**
Total area, ha	**32.0**
- Native grass (*Hyparrhenia rufa*)	27.0
- King grass (*pennisetum* spp)	0.3
- Annual crops (maize/beans)	0.6
- Forest/others	4.1
Herd structure, # heads	**31.1**
- Milking cows	9.8
- Dry cows	4.0
- Heifers, > 2 years old	3.0
- Heifers, 1-2 years old	3.3
- Female calves, 0-1 years old	5.1
- Calves, 0-1 years old	4.5
- Young bulls, 1-2 years old	0.0
- Young bulls, >2 years old	0.5
- Bulls	0.9
Stocking rate, AU/ha	0.8
Milk production	**3.2**
- Dry season, kg/cow/day	2.3
- Rainy season, kg/cow/day	4.1
- Per lactation, kg/cow	774
Length of lactation, days	242
Annual mortality, %	
- Calves	9.3
- Adults	2.7
Annual calving, %	65
Annual replacement rate, %	15
Calf weaning weight, kg	104
Age at weaning, months	8.0
Labor, # people allocated full-time to livestock-related activities	
- Family member	1.0
- Contracted	0.0

As can be observed, most farm area is under native pastures with some small areas allocated to annual crops (maize and beans) for household consumption and small areas (0.3 ha) planted with king grass for dry season feeding in a cut-and-carry system. Herd size is about 14 cows, 10 of which are milking cows and the remaining dry. The stocking rate is 0.8 AU/ha, about the national average. This system relies on family labor for the routine chores, employing on average one full-time person.

The milk productivity in this system is low (i.e., 3.2 kg/cow/day), ranging from 4.1 kg/cow/day during the rainy season to 2.3 kg/cow/day during the dry season with a lactation length of 242 days, typical of the dual purpose system, yielding a milk production per lactation of about 774 kg milk. The production system also sells beef in the form of calves after they are weaned at about 10-12 months old and in the form of culled cows. About 75% of livestock income comes from the sale of milk and the remaining 25% from the sale of calves and cows (FECALAC 2006)

Results from the simulation analysis

Table 5 shows the mature cow inventory, milk and beef production, stocking rate, family labor use, and return to labor of the traditional (current) feeding system compared to the improved feeding system evaluated.

Table 5. Cow inventory, milk and beef production, stocking rate, gross income, family labor use, and return to family labor of traditional vs. improved technology of livestock production systems in Nicaragua

Variable	**Traditional Technology**	**Improved Technology**
Land use, ha		
· *Hyparrhemia* pasture	27.0	25.7
· King grass *(pennisetum* spp)	0.3	0.0
· Calliandra	0.0	1.6
· Vigna	0.0	0.6
Herd size, # adult cows	14.0	23.0
Milk output, kg/farm/d		
· Rainy season	34.9	57.5
· Dry season	23.3	38.4
Stocking rate, AU/ha	0.8	1.26
Beef output, kg farm/yr [1]	1,808	2,977
Gross income, US$/farm/yr	1,314	2,386
Labor use, # days/yr		
· Family	301	365
· Hired	0	89
Return to labor, $/day	4.37	5.26

[1] *Based on the amount of culled cows and weaned male calves sold per year*

Current situation

Under this scenario current land use maintains a herd size of 14 mature cows (where 10 are in milk and the remaining 4 are dry) producing an average of 4.1 kg milk farm/day during the rainy season and 2.3 kg milk/farm/day in the dry season which generates an annual income of US$ 1,314/farm/yr. This income translates into an economic return to family labor of US$ 4.37/day which is 1.9 times higher than the local wage rate of US$2.27/day.

Improved feeding system

Assuming that the current farm area allocated to maize/beans is planted with Cowpea each year at the end of the rainy season, and the area planted to Calliandra is estimated to provide a combination of 67% Calliandra to 33% Cowpea, then the area planted with Calliandra is 1.6 ha, replacing the area under king grass.

Under the new feeding system, herd size can be increased up to 23 cows (i.e., 60% more) due in part to the increase in stocking rate by 58% from 0.8 AU/ha to 1.26 AU/ha as well as to the increase in the quality of the diet offered with higher protein content. This increase in herd size raises both milk and beef output that generates an increase in farm income by 80% more (i.e., from US$1,314/farm/yr to US $2,386). The economic return to family labor is increased by 20% to $ 5.26/day equivalent to 2.3 times higher than the local wage rate.

Sensitivity analysis

Sensitivity analysis makes it possible to study the magnitude and pattern of variations of the initial solution, regarding changes of critical variables such as technical parameters, productivity, prices, or costs.

Table 6 shows the sensitivity of net income regarding a 10% improvement in herd fertility and productivity and a 10% reduction in calf mortality and livestock prices for both the traditional and improved feeding systems in both communities. The sensitivity analysis is partial in nature. In other words, the level of the variable under study changes while those of the other variables remain constant.

Table 6. Sensitivity analysis of net income after 10% increases in herd fertility and productivity and 10% reductions in mortality due to improved nutrition and prices of livestock products in the production systems of Nicaragua used in this study

Parameter	Change in net income, %	
	Traditional Technology	**Improved Technology**
Herd fertility (+10%)	+ 20.9	+ 16.2
Milk productivity (+10%)	+ 15.1	+ 12.7
Beef productivity (+10%)	+ 7.5	+ 5.1
Calf mortality (-10%)	+ 0.2	+ 0.1
Milk price (-10%)	- 16.2	- 14.7
Beef price (-10%)	- 11.3	- 10.2

Results of the sensitivity analysis indicate that two technical parameters (fertility and milk production per cow) and one economic parameter (farmgate price for milk) have the greatest impact on the net income of livestock producers.

A 10% increase in herd fertility compared with the current calving rate improves income by 21% in the traditional system and by 16% in the improved feeding system. The second most important parameter in terms of its impact on income is milk productivity. A 10% increase in current milk production per cow results in 15% more income in the traditional system and 13% more in the improved feeding system.

Beef and milk prices are decisive if regional producers need to adjust to the new economic framework resulting from the Free Trade Agreement between Nicaragua and the USA. A 10% reduction in the farmgate price for milk would imply a decrease in total farm income of 16% in the traditional feeding system and 15% in the improved feeding system. A 10% reduction in beef price would lead to a drop in income (10-11%), but not as much as when milk prices fall, because dual-purpose production systems depend mostly on the sale of milk or fresh cheese for income and cash flow.

A 10% increase in beef productivity (measured as calf weight at weaning and culled cows) leads to a small increase in income of 5-7.5%. Calf mortality has little influence on livestock-derived income. A 10% reduction in current calf mortality increases income by less than 1% in both feeding systems considered. In brief, fertility and milk productivity are the most decisive parameters because, for each percentage point increase in these parameters, the response in terms of income is more than proportional.

Reduced cost and shadow price

These two economic concepts are common in linear programming analyses. In the present case, the *reduced cost* shows the income that is lost by forcing the model to include in the solution forage that has not been considered in the optimal solution. The shadow price, also known as scarcity price, represents the maximum amount of money that a farmer would be willing to pay per additional unit of a given limiting factor that was exhausted in the production process (Bartl et al 2008).

In this study, eliminating one hectare of king grass to replace it with one of Calliandra or Vigna would increase farm net income by US$46/ha/yr. The shadow price of land is about US$34 per ha. This means that a producer would be willing to pay up to US$ 34 per year to lease an additional hectare of land for livestock production using the technology alternative based on improved forages.

However, it has to be admitted, that the results obtained by this simulation can only be seen as guideline but that field trials are required to confirm these results.

Conclusions

- The alternative feeding system discussed in this study can improve rural livelihoods in smallholder farms in Nicaragua.
- The adoption of Vigna (Cowpea) after the harvest of maize/beans and a shrub legume as Calliandra to replace King grass seem to have the potential to significantly improve the productivity in smallholder farms. These changes in the management system can increase the stocking rate and milk production of farms with the resulting increase in the economic return to family labor.
- Field trials are required to confirm these data.

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