MANAGEMENT STRATEGIES AND CLIMATE IMPACT CHANGE ON RANGELANDS[1]

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ABSTRACT - A hydrologic-based forage production simulation model (PHYGROW) and a population mixture simulation model (POPMIX) were used respectively to simulate forage production and carrying capacity of a subtropical shrubland complex of over 34 species grazed by various ratios of cattle and goats with a population of indigenous animals (white-tailed deer) over a 20 year simulated weather profile. The Farm Level Income and Policy Simulation Model (FLIPSIM) were used to evaluate and quantify the impacts of alternative management strategies and climate change on grazingland ecosystems. The study was carried out to analyze the feasibility and profitability of a representative cattle goat farm in the South Texas. On average, net cash farm income under 50:50 cattle:goat ratio and climatic conditions falls by as much as 2% relative to 70:30 for the farm studied. Real net worth for the farm declines as much as 9.4% and 16% over the study period under the highest to lowest cattle:goat ratio and, dry to normal climatic conditions, respectively. The modeled results produced useful information showing the socioeconomic consequences for a typical South Texas farm impacted for alternative management strategies and climatic conditions.

Index terms: simulation, economic impacts, grazingland ecosystem.

IMPACTO DE MUDANÇAS DE ESTRATÉGIAS DE MANEJO E DO CLIMA EM PASTAGEM NATIVA

RESUMO - Modelos de simulação de forragem (PHYGROW) e de simulação de populações mistas de animais (POPMIX) foram usados respectivamente para simular produção de forragem e estimar a capacidade de suporte numa complexa área de pastagem nativa com mais de 34 espécies de plantas arbóreo-arbustivas na qual pastejavam bovinos e caprinos com uma população de animais nativos (veado) num período de 20 anos. Utilizou-se um programa de simulação em uma propriedade (FLIPSIM), para avaliar e quantificar os impactos de estratégias de manejo alternativas e de mudanças climáticas no ecossistema pastagem nativa. O principal objetivo do estudo foi o de unir os modelos já desenvolvidos. Com este procedimento integrado, o estudo procurou analisar a viabilidade e lucratividade de uma fazenda representativa da produção de bovinos e caprinos no Sul do Texas. Em média, a renda líquida da fazenda, com a relação bovino:caprino 50:50 e condições climáticas, cai cerca de 2% em comparação com a relação 70:30 na fazenda estudada. O acervo de bens em termos reais referentes à fazenda declina cerca de 9,4% e 16% no período de estudo, quando passou da mais alta para a mais baixa relação bovino:caprino, bem como quando passou da condição climática seca para a normal. Os resultados do modelo produziram informações úteis que mostram as conseqüências socioeconômicas numa propriedade típica do Sul do Texas, afetada por estratégias de manejo alternativas e por condições climáticas.

Termos para indexação: simulação, impactos econômicos, ecossistema pastagem nativa.

INTRODUCTION

The ordinary problems of managing rangelands challenge the capacity of contemporary decision makers, institutions and scientists to integrate ecological, economic and social information.

Ecological modeling of climate change effects on rangelands fails to account for direct human effects resulting from various factors such as population growth, economical activities, technology and

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policy. On the other hand, socioeconomic modeling tends to focus on the quantifiable factors (e.g., population market, demand, etc.) while neglecting the ecological and climatic change (Frederick, 1994).

The first step toward better integrated assessment of the effects of climate change on rangelands should be linked with existing models. Thus, new modeling approaches are needed to better deal with the biophysical uncertainty and complexity of the impacts of technological and climate change on rangelands (Conner, 1994).

A substantial portion of livestock production in the world takes place on grazinglands with arid or semi-arid climates (Holecheck et al., 1989). Consequently, these areas are sensitive to changes in the environmental conditions with which they are associated, and also to climatic variations and changes in land use.

There are several reasons for suspecting that rangelands would be very sensitive to the interactive effects of climate change. First, the quantity and seasonal distribution of precipitation is very important in determining the management productivity and distribution of rangelands. Second, reduction in precipitation associated with increase in temperature may cause accelerated human-caused degradation of ecosystems. This range deterioration, a reduction of the range forage production potential, is a consequence of complex processes that negatively alter plant cover, composition, and/or soil characteristics of rangelands. Third, the deterioration of rangelands have occurred in a relatively recent period of time that coincides with their increased utilization for the production of domestic animals (Parton et al., 1994). Despite the potential importance of socioeconomic impacts of climate change on rangelands, current assessments of these impacts on rangelands are limited by the lack of adequate integrated models.

Currently, agricultural models are used to set initial conditions for the economic models, or specific management practices are set as a background for the agricultural models. The application of dynamic vegetation growth models has not been considered in these models (Souza Neto, 1996). Thus, it can be hypothesized that advances in integrating ecological and socioeconomic models can be instrumental in developing the capability to assess the impact of climate change on rangelands.

This study addresses this hypothesis and presents an integrated approach for linking ecological and socioeconomic models in an innovative way that can help policy analysts and policy makers sort through the numerous impacts assessments, and theory extend their information base. The idea was to integrate the use of the Farm Level Income and Policy Simulation Model - FLIPSIM (Richardson & Nixon, 1986) with a Phytomass Growth Simulation Model - PHYGROW (Texas A&M University, 1995) and an animal production and forage use simulator (Population Mixture Simulation Model - POPMIX), a component decision tool in the Grazingland Applications -GLA (Stuth et al., 1990). This is the basis for this study.

The central purpose of an integrated assessment model is to organize complex technical information across disciplines. This study aimed at analysing the feasibility and profitability of a representative farm facing natural events and influences under different climate and enterprise mix scenarios.

MATERIAL AND METHODS

Data were assembled for a typical South Texas farm comprised of 30% clay loam and 70% sandy loam range sites. Thirty eight critical plant species or functional groups were identified in the area of study. Experts provided growth, preference and hydrological attributes of each species/functional group. Vegetation survey of the La Copita Research Area - Texas was used to determine de Witt relative yield values for each specie/functional group for model plant communities in the region. Relative yield value are the proportion (%) of full potential occupancy of a single species or functional group on a plant community. Soil layer characteristics of model soil typical of each range site were assigned based on predominate acreage available in soil survey of the region. In order to generate a long-term historical data set to develop weather parameters, the USCLIMATE (Hanson et al., 1994) was geographically adjusted for elevation, annual precipitation and latitude/longitude at the La Copita Research Area. The soil layer characteristics, surface features, species/functional group, plant communities, relative yield (Tables 1 and 2), and weather generator parameters were entered into PHYGROW to generate forage production. The inventory of available forage (simulated) using two different types of soil, clay loam and sandy loam, was combined to create data to be used in the POPMIX. Then

TABLE 1. Soil and plant parameters used for simulating forage production in the clay loam range site[1].

Common name	RYI (%)	LAI_{mx}	BE	T_b (°C)	T_s (°C)	L_{turn} (%)	HUI_s	HUI_d	RT_{mx} (cm)	HT_{mx} (cm)	SC_{mx} (kg/ha)	L_{ratio} (%)	SAI_{mx}	L_{store} (mm)	S_{store} (mm)	$S{:}L_{part}$ (%)	S_{turn} (%)
Grasses																	
Hooded Windmillgrass	9.4	3.6	1.4	8	56	.75	–	–	60	50	5000	.90	.40	2.0	.20	.50	.05
Fringed Signalgrass	0.7	3.9	1.6	10	60	1.00	–	–	50	40	5000	.90	.40	1.6	.16	.50	.05
Halls Panicum	0.7	3.6	1.4	8	56	.75	–	–	70	50	6000	.90	.40	2.6	.26	.50	.05
Perennial Threeawn	19.4	3.1	1.1	2	50	.75	–	–	60	40	4500	.90	.30	2.2	.22	.50	.05
Red Lovegrass	0.4	3.5	1.1	10	60	1.10	–	–	60	30	4500	.90	.30	2.2	.22	.50	.05
Pink Pappusgrass	.04	3.6	1.4	10	60	1.00	–	–	60	50	4500	.90	.40	2.2	.22	.50	.05
Slim Tridens	0.7	3.4	1.2	8	56	2.00	–	–	70	50	4000	.90	.30	2.4	.24	.50	.05
Texas Grama	.04	3.5	1.2	8	56	.75	–	–	60	40	4500	.90	.30	1.6	.16	.50	.05
Common Witchgrass	3.2	3.3	1.1	10	60	.75	–	–	50	30	3500	.90	.30	1.6	.16	.50	.05
Four-flower Trichloris	.04	3.9	1.6	10	60	1.00	–	–	70	60	5500	.90	.40	2.4	.24	.50	.05
Fall Witchgrass	1.1	3.5	1.3	2	50	.75	–	–	50	50	4000	.90	.30	2.0	.20	.50	.05
Forbs																	
Orange Zexmania	24.1	3.4	1.1	10	60	.50	–	–	100	70	5000	.40	.25	1.6	.16	.25	.05
Purple Gerardia	4.8	3.2	1.3	8	56	.50	–	–	90	50	4000	.50	.25	1.6	.16	.40	.05
Texas Palafoxia	4.8	3.2	0.9	2	54	.50	210	335	85	50	3500	.60	.25	1.0	.10	.30	.05
False Ragweed	4.8	3.9	1.2	10	60	.50	–	–	100	60	5000	.30	.30	1.5	.15	.60	.05
Shrubs																	
Brasil	8.2	3.5	0.9	2	56	.50	–	–	120	180	5000	.09	.30	1.5	.15	.20	.10
Coma	0.3	2.8	0.9	10	60	.50	–	–	100	140	4000	.09	.30	1.4	.14	.20	.10
Lotebush	0.3	3.2	1.0	10	60	.50	–	–	100	140	4000	.05	.30	1.4	.14	.20	.10
Lime Pricklyash	6.2	3.1	1.2	8	56	.50	–	–	130	200	4500	.16	.30	1.6	.16	.20	.10
Shrubby Bluesage	0.1	3.7	1.1	6	50	.50	–	–	100	150	5000	.10	.40	1.6	.16	.20	.10
Texas Colubrina	2.0	3.5	1.2	8	56	.50	–	–	100	120	5000	.09	.40	1.4	.14	.20	.10
Texas Persimmon	4.8	4.6	1.3	8	56	.50	–	–	130	180	5000	.12	.50	1.5	.15	.20	.10
Whitebrush	2.8	3.5	0.9	10	60	.50	–	–	130	200	5500	.09	.40	1.3	.14	.20	.10
Desert Yaupon	0.1	2.5	0.9	8	56	.50	–	–	120	100	3500	.09	.30	1.3	.13	.20	.10
Granjeno	0.1	2.5	.09	10	60	.50	–	–	120	140	4000	.09	.30	1.2	.12	.20	.10

[1] RYI is the relative yield index; LAI_{mx} is the leaf area index at peak standing crop; BE is the dry matter: radiation energy conversion factor (g/MJ); T_b is the plant's base growth temperature (°C); T_s is the plant's suppression growth temperature (°C); L_{turn} is the turnover percentage as a percent of standing crop (%); HUI_s is the heat unit index at the point where LAI begins to decline; HUI_d is the heat unit index at physiological maturity (i.e. starts to drop leaves); RT_{mx} is plant's maximum rooting depth at peak standing crop; HT_{mx} is the plant's average height at peak standing crop (cm or meters); SC_{mx} is the peak standing crop (kg/ha); SAI_{mx} is the stem area index for maximum standing crop; L_{store} is the amount of water stored on stem after all water has dripped/run off; $S{:}L_{part}$ is proportion of laminar flow from leaf running down stem; S_{turn} is the turnover percentage as a percent of total stem biomass.

TABLE 2. Soil and plant parameters used for simulating forage production in the sandy loam range site[1].

Common name	RYI (%)	LAI_{mx}	BE	T_b (°C)	T_s (°C)	L_{turn} (%)	HUI_s	HUI_d	RT_{mx} (cm)	HT_{mx} (cm)	SC_{mx} (kg/ha)	L_{ratio} (%)	SAI_{mx}	L_{store} (mm)	S_{store} (mm)	$S{:}L_{part}$ (%)	S_{turn} (%)
Grasses																	
Hooded Windmillgrass	14.8	3.6	1.4	8	56	.75	–	–	60	50	5000	.90	.40	2.0	.20	.50	.05
Fringed Signalgrass	3.5	3.9	1.6	10	60	1.0	–	–	50	40	5000	.90	.40	1.6	.16	.50	.05
Halls Panicum	3.5	3.6	1.4	8	56	.75	–	–	70	50	5000	.90	.40	2.6	.26	.50	.05
Perennial Threeawn	9.9	3.1	1.1	2	50	.75	–	–	60	40	4500	.90	.30	2.2	.22	.50	.05
Red Lovegrass	1.5	3.5	1.1	10	60	1.1	–	–	60	30	4500	.90	.30	2.2	.22	.50	.05
Hairy Grama	1.5	3.4	1.3	10	60	1.1	–	–	60	30	4000	.90	.30	1.6	.16	.50	.05
Thin Paspalum	1.5	3.4	1.2	8	56	2.0	–	–	70	50	4000	.90	.30	2.6	.26	.50	.05
Texas Grama	0.9	3.5	1.2	8	56	.75	–	–	60	40	4500	.90	.30	1.6	.16	.50	.05
Grassbur	0.5	3.3	1.1	10	60	.75	–	–	50	30	3500	.90	.30	1.6	.16	.50	.05
Forbs																	
Orange Zexmania	41.7	3.4	1.1	10	60	.50	–	–	100	70	5000	.40	.25	1.6	.16	.25	.05
Broom Weed	4.2	3.4	1.1	10	60	.50	–	–	120	60	5000	.50	.25	1.6	.16	.40	.05
Texas Palafoxia	4.2	3.2	0.9	2	54	.50	210	335	85	50	3500	.60	.25	1.0	.10	.30	.05
Silky Evolvulus	4.2	3.0	0.8	8	56	.50	–	–	70	40	3500	.80	.20	1.0	.10	.40	.05
False Ragweed	4.2	3.9	1.2	10	60	.50	–	–	100	60	5000	.30	.30	1.5	.15	.60	.05
Shrubs																	
Brasil	1.2	3.5	0.9	2	56	.50	–	–	120	180	5000	.09	.30	1.5	.15	.20	.10
Honey Mesquite	0.2	2.8	0.9	10	60	.50	–	–	180	500	5000	.09	.30	1.4	.14	.20	.10
Huisache	0.3	2.5	1.0	10	60	.50	–	–	130	200	4000	.05	.30	1.4	.14	.20	.10
Lime Pricklyash	0.2	3.1	1.2	8	56	.50	–	–	130	200	4500	.16	.30	1.6	.16	.20	.10
Shrubby Bluesage	0.1	3.7	1.1	6	50	.50	–	–	100	150	5000	.10	.40	1.6	.16	.20	.10
Texas Colubrina	0.5	3.5	1.2	8	56	.50	–	–	100	120	5000	.09	.40	1.4	.14	.20	.10
Texas Persimmon	0.1	4.6	1.3	8	56	.50	–	–	130	180	5000	.12	.50	1.5	.15	.20	.10
Texas Kidneywood	0.3	2.5	1.1	10	60	.50	–	–	130	100	4500	.09	.30	1.3	.13	.20	.10
Agarito	0.1	2.5	0.9	6	50	.50	–	–	130	100	4000	.20	.30	1.3	.13	.20	.10
Succulents																	
Texas Pricklypear	1.2	1.6	0.3	10	60	.10	–	–	130	80	2500	.80	.10	0.6	.06	50	.01

[1] RYI is the relative yield index; LAI_{mx} is the leaf area index at peak standing crop; BE is the dry matter: radiation energy conversion factor (g/MJ); T_b is the plant's base growth temperature (°C); T_s is the plant's suppression growth temperature (°C); L_{turn} is the turnover percentage as a percent of standing crop (%); HUI_s is the heat unit index at the point where LAI begins to decline; HUI_d is the heat unit index at physiological maturity (i.e. starts to drop leaves); RT_{mx} is plant's maximum rooting depth at peak standing crop; HT_{mx} is the plant's average height at peak standing crop (cm or meters); SC_{mx} is the peak standing crop (kg/ha); SAI_{mx} is the stem area index for maximum standing crop; L_{store} is the amount of water stored on stem after all water has dripped/run off; $S{:}L_{part}$ is proportion of laminar flow from leaf running down stem; S_{turn} is the turnover percentage as a percent of total stem biomass.

a transect production was estimated, and the forage (dry weight) for each specie was attached to POPMIX. The results of stocking rates provided by the POPMIX model were used to generate basic input scenarios to be used in the FLIPSIM. Two cattle:goat ratios, 70:30 and 50:50 were selected to represent alternative management strategies available to a farm operator.

Twenty years of simulated forage production and associated stocking rates from POPMIX (Table 3) were divided into two ten-year periods; one representing normal conditions scenario with 30% drought years and the other representing dryer climatic scenario with about 50% drought years. Normal years are considered to be those that have less than 20% deviation of the long term average stocking rate, output from POPMIX, of a 20-year simulation. The stocking rates for the four ten-year period scenarios were used with a set of decision rules prescribed by range animal scientists and ranch managers familiar with cattle and meat goat enterprises in the South Texas area to estimate animal production levels and deviations from normal (average) annual operating cost for the two enterprises. The input of PHYGROW and POPMIX will create the basic scenarios for the representative farm, for which economic performance will be simulated by FLIPSIM. The annual animal production levels and operating cost deviations were used as input data in the FLIPSIM. This whole-farm model is needed because it allows the incorporation of risk and uncertainty, financial and accounting components, and institutional farm policies into the calculations of economic performance of the farm.

The models work independently, and are controlled by the analist. The interrelations between the models and the steps to perform this study are included in Table 4.

Descriptive data for the representative farm used in this study are summarized in Table 5. Information to describe the representative farm for the FLIPSIM model was obtained from budgets developed by extension farm ranch management specialist in the region of interest.

In this study, the representative farm represents average management using sound, accepted production and management practices. The South Texas cattle and goat farm has 493 goats and 466 cows (Table 5). The farm grazes 630 animal units on 5,000 ha of rangeland owned. The combined stocking rate is 7.9 ha per AU. The initial value for the livestock on the farm was estimated at $213,240.00. More complete details about the representative farm used in this study can be found in Souza Neto (1996).

RESULTS AND DISCUSSION

Two cattle:goat ratios were selected based on trends in the region for expanding meat goat populations; 70:30 and 50:50. Although daily information of forage growth, species selection, and soil moisture were available, only annual production and consumption data were used in this analysis.

The 70:30 and 50:50 ratios yielded stocking rates of 1.48 and 1.34 AUM/ha, respectively. The standard deviation of stocking rate was 0.72 and 0.65 AUM/ha, respectively for cattle. Goat stocking rates and standard deviations for the 70:30 and 50:50 ratios were 0.119 (SD=0.06) and 0.15 (SD=0.07), respectively.

After running the 20-year analysis of the 70% and 30% goat demand ratio, there were 9 "normal" stocking years for goats and 7 for cattle (Fig. 1). Normal years are those with less than 20% deviation of the long-term average stocking rate of a 20-year simulation. Below normal stocking years (-20 to -50%) for cattle and goats comprised 25% of the years. Cattle would experience a higher percent of extremely low stocking years than goats (15% vs. 10%). Ten percent of the years experienced stocking rates greater than 50% above normal stocking levels. Analysis of 50:50 ratio resulted in similar trends.

A summary of selected indicators of the economic and financial condition of the representative farm that would be expected after ten years under each of the four prescribed scenario can be found in Table 6. Under normal weather scenario, the 70:30 cattle:goat ratio produces less decline in real net worth, higher average annual cash receipts and net income, but lower average annual returns to assets and equity and higher net income risk index than does the 50:50 ratio.

Under the dryer weather scenario, declines in real net worth are greater, cash receipts, net incomes and returns to assets and equity are lower regardless of cattle:goat ratio than under normal weather scenario. As in the normal weather scenario, however, the 70:30 cattle goat ratio produces higher receipts and net income risk index than the 50:50 ratio.

TABLE 3. Combined stocking rates simulated with POPMIX to set different weather scenarios.

Year	Stocking rate[1]						Stocking rate[2]					
	Cattle			Goats			Cattle			Goats		
	ha/AU	AUM/ha	ha/hd	ha/AU	AUM/ha	ha/hd	ha/AU	AUM/ha	ha/hd	ha/AU	AUM/ha	ha/hd
1	6.67	1.80	7.0	80.3	.15	6.42	7.64	1.57	8.02	62.1	0.19	5.01
2	5.76	2.08	6.05	70.71	0.17	5.66	6.49	1.85	6.82	55.5	0.22	4.44
3	21.53	0.56	22.61	262.22	0.05	20.98	23.38	0.51	24.54	204.64	0.06	16.37
4	3.85	3.12	4.04	50.07	0.24	4.01	4.23	2.84	4.44	38.70	0.31	3.1
5	7.42	1.62	7.79	95.14	0.13	7.61	8.08	1.48	8.49	73.86	0.16	5.91
6	7.19	1.67	7.55	90.68	0.13	7.25	7.83	1.53	8.22	70.32	0.17	5.63
7	11.14	1.08	11.70	133.88	0.09	10.71	12.09	0.99	12.70	104.34	0.12	8.35
8	6.79	1.77	7.13	83.61	0.14	6.69	7.38	1.63	7.75	64.91	0.18	5.19
9	6.41	1.87	6.73	85.18	0.14	6.81	7.05	1.70	7.40	65.78	0.18	5.26
10	11.08	1.08	11.64	156.14	0.08	12.49	12.17	0.99	12.78	119.91	0.10	9.59
11	8.92	1.34	9.37	106..21	0.11	8.50	9.71	1.24	10.19	82.81	0.14	6.63
12	13.33	0.90	13.89	154.78	0.08	12.38	14.51	0.83	15.24	121.04	0.10	9.68
13	7.50	1.60	7.87	92.11	0.13	7.37	8.16	1.47	8.57	71.43	0.17	5.71
14	9.25	1.30	9.71	121.80	0.10	9.74	10.16	1.18	10.67	93.98	0.13	7.52
15	22.24	0.54	23.35	275.08	0.04	22.01	24.16	0.50	25.37	214.50	0.06	17.16
16	10.10	1.19	10.61	124.38	0.10	9.95	11.00	1.09	11.55	96.56	0.12	7.73
17	10.88	1.10	11.42	125.15	0.10	10.01	11.82	1.01	12.42	97.92	0.12	7.83
18	17.66	0.68	18.54	20.13	0.06	16.17	19.22	0.62	20.18	158.44	0.08	12.68
19	3.64	3.30	3.82	45.41	0.26	3.63	3.99	3.01	4.18	35.17	0.34	2.81
20	12.86	0.93	13.51	177.41	0.07	14.19	14.20	0.85	14.91	137.03	0.09	10.96
Mean	10.21	1.48	10.72	126.62	0.12	10.13	11.16	1.34	11.72	98.47	0.15	7.88
Std	5.08	0.72	5.33	61.50	0.06	4.92	5.49	0.65	5.77	48.02	0.07	3.84

[1] Combined stocking rate at 70% cattle and 30% goats.
[2] Combined stocking rate at 50% catttle and 50% goats.

TABLE 4. Steps in analysis of socioeconomic impacts of change on rangelands using current models[1].

Step number	Discrimination	
1	Select representative farms for modeling. Farms should be representative of resources, size and tenure of production units and production practices in a specified portion of the study area.	
2	Run PHYGROW for each representative farm for each year in the 20-year period.	
	Input data	Output
	a. climate b. soils c. hydrology d. vegetation	a. forage production by type (grass, forb, browse) by season, by year
3	Run POPMIX and ASP models for each representative farm for each year in the 20-year period.	
	Input data	Output
	a. initial animal inventories and characteistics by kind and class and class (including vegetation preference rating) b. husbandry practices c. production goals d. forage/feed availability by type, by season, by year	a. animal b. forage production yield and inventory by kind and class by year.
4	Run FLIPSIM model for each representative farm for each year in 20-year period under different scenarios.	
	Input data	Output
	a. beginning financial characteristics of farm b. annual institutional and macroeconomic parameters c. annual enterprise production requirements (factors) and product and factor prices and/or probability distributions	a. end of planning period financial characteristics of farm b. annual cash flow c. probability of farm survival and/or growth over planning period.
5	Repeat steps 2-4 and compare results under different scenarios to determine the impacts of change (climate, technological or institutional) on future socioeconomic characteristics of the representative farm and make inferences about region of interest.	

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[1] Source: Adapted from Conner (1994).

TABLE 5. Characteristics of a representative farm in the South Texas[1].

Characteristics	South Texas cattle goat farm
Total animal units (AUs)	630
Goats	
Nannies (no)	493
Replacement (no)	100
Bucks (no)	30
Cattle	
Cows (no)	466
Replacement (no)	72
Bulls (no)	12
Assets	
Land ($1,000)	5,559,750
Machinnery ($1,000)	78,336
Livestock ($1,000)	213,240
Total ($1,000)	6,117,942
Efficiency measure	
Calving (%)	93
Kid crop (%)	150
Steer weaning weight (kg)	250
Goat weaning weight (kg)	16

[1] Source: Adapted from Souza Neto (1996).

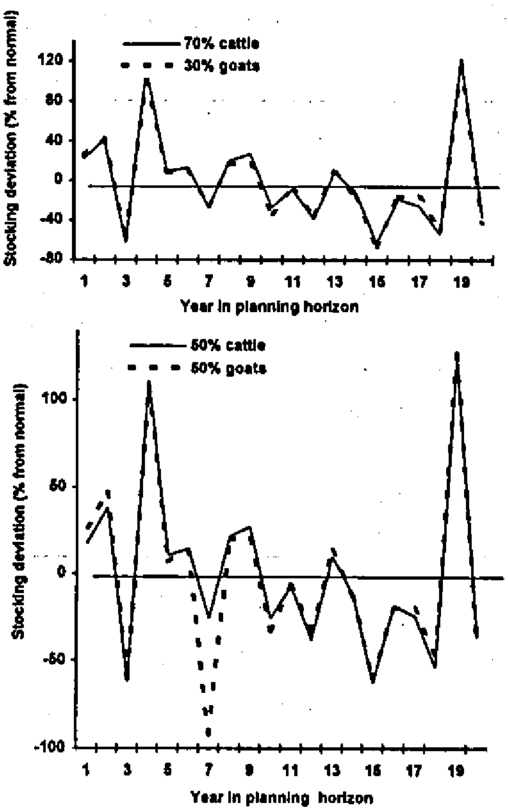

FIG. 1. Simulated annual deviation from 20-year average stocking rate of a mixed livestock population (70:30; 50:50) cattle: goat ratio with a resident herd population of white-tailed deer (4.86 ha/head).

TABLE 6. Implications for alternative stocking rate for a South Texas cattle and goats farm under two climate scenarios[1].

Indicators	Weather			
	Dry		Normal	
	70:30	50:50	70:30	50:50
Change in Real Net Worth 1996-2005 (%)	-2.65	-2.9	-2.12	-2.46
Cash Receipts 1996-2005 ($1,000)	220.57	211.54	225.97	218.37
Expenses to Receipts 1996-2005 (%)	50.9	49.6	47.1	46.19
Net Cash Farm income 1996-2005 ($1,000)	110.72	108.6	122.19	119.75
Risk Index for Annual Net Cash Income (%)	14.95	9.96	2.00	0
Average Return to Assets 1996-2005 (%)	0.48	0.57	0.50	0.59
Average Return to Equity 1996-2005 (%)	0.40	0.53	0.43	0.55

[1] Source: Souza Neto (1996).

CONCLUSIONS

1. Higher ratio of goat to cattle stabilize annual variation in stocking as ecological conditions shift from a grassland domain to a shrubland domain and climatic conditions become drier.

2. Goats while generally less profitable than cattle, require less annual operating cost, less capital investment and exhibit less variation in annual receipts and net income.

3. The lower variation in net incomes from goats compared to cattle is due both to the goats' forage availability being less impacted by variations in annual precipitation and less year-to-year change in prices received for meat goats compared to weaned calves sold from the cow-calf enterprise.

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