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CATTLE AND WILDLIFE RANCHING IN ZIMBABWE: AN ECONOMIC AND ECOLOGICAL ASSESSMENT

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TABLE OF CONTENTS

ABSTRACT ii

1. Introduction 1

2. The Policy Analysis Matrix and Its Extensions 2
- 2.1 The Traditional PAM 2
- 2.2 An Extended PAM Framework 3
- 2.3 Incorporating Time: Present Value PAMs 5

3. Cattle and Wildlife Ranching in Zimbabwe 8
- 3.1 General Background 8
- 3.2 The World Wildlife Fund Ranching Survey 10

4. Computing PAM Budgets from Survey Data 12
- 4.1 Basic Budget Calculations 12
- 4.2 Special Problems 12

5. Computing Cattle and Wildlife PAMs 14
- 5.1 Present Value PAMs for Cattle (Degradation Model) 14
- 5.2 Present Value PAM for Cattle (Stationary Model) 19
- 5.3 Present Value PAM for Wildlife 20
- 5.4 Comparison of Private and Social Profitability Across PAMs 21

6. Policy Implications and Needed Research 22
- 6.1 Policy Summary Based on Survey Data 22
- 6.2 Institutional Issues 23
- 6.3 Recent Policy Changes 23
- 6.4 Suggestions for Further Policy Reform 24

7. Research Needs 26

APPENDIX A: Range Ecology in Arid and Semi-Arid Africa
APPENDIX B: Analysis of Overstocking

BIBLIOGRAPHY

Abstract

In recent years increasing attention is being given to the sustainability of rangeland use in Africa's arid and semi-arid areas. It is now widely understood that the incentives to maintain sustainable ranching systems are influenced both economic and institutional policies. The former is represented by the effects of price distortions, usually implemented through interventions in international trade and by macro policies that influence the exchange rate. The latter emerges in the presence of incomplete markets that do not take into account externalities or fail to incorporate user costs.

The present paper implements an extended version of the Policy Analysis Matrix (PAM) methodology that permits the simultaneous examination of economic and environmental distortions. When applied to the case of livestock in Zimbabwe, the results show that a trade-off exists between correcting price distortions and decreasing the stocking rate to recommended levels. The greater the value of cattle, a commodity that is currently taxed, the greater will be the costs of implementing a technology that has desirable social characteristics but permits fewer animals per hectare.

Alternative ecological models are also examined in the paper. Questions have been raised by prominent range scientists about the validity of using a long-run equilibrium model of the livestock sector in a situation where there is a great deal of inter and intra-seasonal variation in weather. The assumption that range vegetation will degrade under long-run grazing pressure is countered by an argument that the short-run effects of erratic rainfall and temperatures are more significant than long-run environmental processes. These two views of range ecology lead to significantly different government policy prescriptions.

1. INTRODUCTION

In recent years, increased attention is being given to the sustainability of rangeland use in Africa's arid and semi-arid areas. Increases in human population and livestock numbers have prompted fears that grazing pressure will lead to overgrazing, range degradation and, ultimately, to desertification. This paper examines the economic and ecological issues raised by this prospect as they pertain to the use of rangeland in the semi-arid areas of Zimbabwe's Natural Regions IV and V. It summarizes the results of a comprehensive survey of cattle and wildlife ranches as well as alternative models of range ecology to arrive at suggestions for utilizing these rangelands in an economically and ecologically sustainable manner.[1]

The methodology used to analyze the results of the survey and the ecological models is an extension of the Policy Analysis Matrix (PAM).[2] PAM's are based on a simple budgeting approach that looks at enterprises from two different perspectives: that of the private sector (financial analysis) and that of society (economic analysis). The extension is to recognize that, as a result of market failures, the economics of natural resource use may also differ between what is privately profitable and what is socially desirable. Incorporating such objectives as "sustainability" explicitly in the analysis makes it possible to distinguish between those traditional policy measures that affect commodities and those that have a bearing on environmental objectives.

The first section of the paper discusses the methodology of the PAM and its extensions. Subsequent sections describe the cattle and wildlife industry in Zimbabwe, present data from an extensive survey of livestock ranching, and compute values for the extended PAM. As might be expected in a country that has a history of heavy government involvement in the economy, the divergences between what is privately and socially profitable are substantial.

Attempts to extend the analysis and to develop sustainable enterprises that can be contrasted with present practices turn out to raise important ecological questions to which no definitive answers are available. Accordingly, PAMs are developed for alternative specifications of the ecological parameters for cattle and wildlife ranching. The results point to the need for research on physical parameters of the system to determine where the country's comparative advantage in livestock production lies.

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[1] The survey was undertaken by Doris Jansen in association with Ivan Bond and Brian Child for the World Wildlife Fund Multispecies Project in Harare. The full report is available as WWF MAPS Project Paper No. 27. (Jansen, Bond and Child, 1992.)

[2] The original methodology is presented in Monke and Pearson, *The Policy Analysis Matrix in Agricultural Development* (Cornell University Press, 1990). The extensions to natural resource issues can be found in Stefano Pagiola, "Use of Cost-Benefit Analysis and the Policy Analysis Matrix to Examine Environmental and Natural Resource Issues", Agricultural Policy Analysis Project II, Food Research Institute, 1991.

2. THE POLICY ANALYSIS MATRIX AND ITS EXTENSIONS

2.1 The Traditional PAM

The PAM methodology is based on enterprise budgets that reflect the costs, returns, and profits of producing a particular commodity. Private profits, shown in the top row of the PAM, are computed from the physical input-output data and domestic market prices. The private profit calculation provides information on the incentives faced by the private sector; it also gives an indication of the competitiveness of the economy. Substantial private profits suggest that there are rents accruing to the ownership of fixed factors due to market imperfections. Private losses suggest the opposite. Losses cannot be sustained over time with the result that the values of factor prices will have to decline.

Table 1: The Policy Analysis Matrix (PAM)

	Tradables		Domestic	
	Revenues	Costs	Factors	Profits
Private	A	B	C	D
Social	E	F	G	H
Divergence	I	J	K	L
Private profits	D = A-B-C	Nominal protection coefficient		A/E
Social profits	H = E-F-G	Effective protection coefficient		(A-B)/(E-F)
Output transfers	I = A-E	Private resource cost (PRC)		C/(A-B)
Input transfers	J = B-F	Domestic resource cost (DRC)		G/(E-F)
Factor transfers	K = C-G			
Net transfers	L = D-H			

The second row of the PAM utilizes the same input-output coefficients as the private profits row but multiplies them by social rather than private (market) prices. For tradables, these

prices are obtained from international markets. For domestic factors, they are obtained from the opportunity cost of factors (land, labor, and capital) to the economy. A positive value for H, the measure of social profits, is an indication that internationally priced value-added is greater than the cost of domestic factors used in the production process. Commodities that show positive social profits are said to have a comparative advantage in production.

Policy effects and market failures, shown in the bottom row, constitute the difference between private and social values of outputs and inputs. These divergences provide insights into the extent of policy interventions in the form of taxes, subsidies, trade restrictions and exchange rate distortions. They also point to imperfections in the functioning of commodity and factor markets. The sum of the policy effects constitutes net transfers to or from producers of a particular crop. Net transfers also indicate the difference between private and social profits for the commodity system.

2.2 An Extended PAM Framework

The extended PAM analysis is a response to the issue of "sustainability" in agricultural production. Admittedly, the term is not easy to define and has become a catch-all for a wide variety of environmental concerns.[3] Some analysts have proposed demanding standards that translate into maintenance of physical capital, e.g., water tables must not decline or soil depths must not be depleted. Others have proposed that the maintenance of yields is a more appropriate measure although there is usually an additional proviso that this not be done by transferring resources from other sectors, i.e., using fertilizer produced from fossil fuels would not be allowed. A still broader definition would include measures of farm income in the definition. Sustaining yields would not be sufficient if this implied that per capita incomes decline over time.

In the extended PAM analysis, the definition of what constitutes a sustainable system is provided at the outset by the researcher. Presumably it is a farming system that can be maintained over the long run and thus accounts adequately for user costs.[4] It should also limit externalities to an acceptable level.[5] However, in the type of budget-based approach used in the PAM analysis, there is no guarantee that the system chosen for its desirable properties is socially optimal. The comparison is between an "unsustainable" system (the currently observed system) and an alternative "sustainable" system described by a second set of technical or input-output relationships.

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[3] For a more rigorous treatment of the entire issue of sustainability, see Stefano Pagiola, "Soil Conservation and the Sustainability of Agricultural Production," Ph.D. Dissertation, Food Research Institute, Stanford University, 1993.

[4] User cost refers to the opportunity cost of using resources in the present that would otherwise be available to produce commodities in the future.

[5] Externalities occur when production systems interact physically in the absence of markets that adequately compensate the gainers and losers. For example, a farming system that results in substantial soil erosion and subsequent silting of downstream reservoirs creates an external cost to reservoir users that should be charged against the farming system.

The sustainable technology employed in the alternative system may involve modifications of the existing activities. For example, sustainability in the livestock industry may require a reduction in the number of cattle allowed on the range. Sustainability may also involve a transformation of the production system if income levels cannot be maintained under the old system. In Zimbabwe, wildlife may be superior to cattle in preserving both producer incomes and the environmental quality of the country's arid rangeland.

Table 2: Extended PAM Framework

Table 2A	Unsustainable PAM			
	Tradables		Domestic	
	Revenues	Costs	Factors	Profit
Private	A	B	C	D
Social	E	F	G	H
Divergence	I	J	K	L
Table 2B	Sustainable PAM			
Private	A′	B′	C′	D′
Social	E′	F′	G′	H′
Divergence	I′	J′	K′	L′
Table 2C	Economic and Environmental PAM			
Private	A	B	C	D
Social	E′	F′	G′	H′
Divergence	I″	J″	K″	L″
Table 2D	Cost of Moving to a Sustainable Ranching System			
Private	A-A′	B-B′	C-C′	D-D′
Social	E-E′	F-F′	G-G′	H-H′

The extended analysis proceeds by comparing the second (sustainable) PAM to the traditional (observed) PAM in order to (a) ascertain the cost of compliance of moving from an unsustainable to a sustainable system, and (b) determine the total transfers (economic and environmental) between private producers and society as a whole.

Table 2 demonstrates the calculations of an extended analysis. Table 2A is simply the traditional PAM based on observed (unsustainable) practices. Private and social profits are computed in the manner described above. Table 2B is based on a set of technical coefficients that are deemed to be sustainable over the long run. The private and social prices used in the computation of profitability are the same prices used in Table 2A.

Table 2C is obtained from the private profits row of the unsustainable PAM and the social profits row of the sustainable PAM. The former reflects existing practices, the latter reflects a production system whose long term effects are considered socially desirable. The "Divergences" row in the economic and environmental PAM therefore encompasses both the difference between private and social prices and the physical difference between sustainable and unsustainable production practices.

Table 2D shows the compliance costs of moving from a unsustainable to a sustainable system. Private costs are those that will be felt by producers and are defined as the difference between the private profits in the unsustainable and sustainable PAMs. In the presence of externalities and unrecognized user costs, they are the disincentives for producers to move to a new system. The social costs row reflects the difference between the two systems measured in social prices.

2.3 Incorporating Time: Present Value PAMs

Most of the traditional PAMs computed in the literature are static, i.e., they refer to a single period. Most natural resource problems, however, arise because of the effects on resources of a production process over time. These considerations can be captured by computing the present value (PV) for each of the PAM cells.

Figure 1 displays a multi-period resource problem. The horizontal solid line simulates a sustainable ranching system in which the productivity of the range is maintained over time. Stocking rates are kept at levels that utilize the forage produced in one period without impairing the ability of the vegetation to recoup and provide a constant source of animal nutrition.

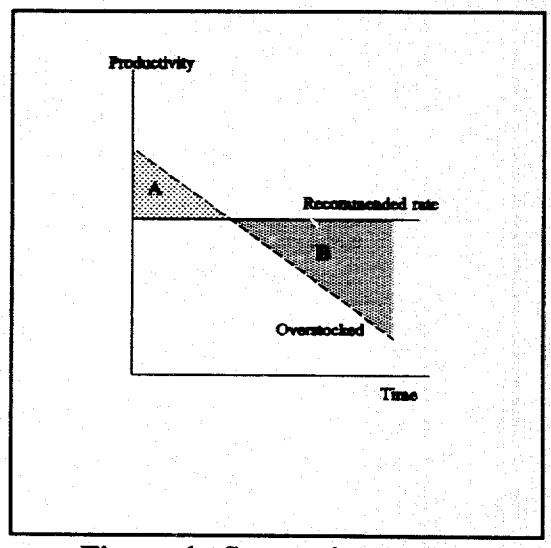

Figure 1: Succession Model

The dotted line simulates an unsustainable system in which stocking rates result in a decline in the range's productivity over time. Initially, the stocking rate leads to higher off-take as measured in units of livestock product. But because the vegetation is being grazed intensively and is not being permitted to recoup to a long-term

sustainable level, future years are characterized by ever decreasing forage availability.[6]

It is obvious from the diagram that the rapidity with which degradation occurs is an important determinant of whether an "investment" in a more sustainable system will be profitable. The shaded area labeled A subtracts from the cash flow of the system since it reflects income foregone as the stocking rate is lowered. However, in the long run, ranches following recommended sustainable stocking levels will obtain incremental returns shown as the shaded area B. Rapid degradation produces a smaller A (negative cash flow) and a larger B (positive cash flow). The result is consistent with the intuition that the faster the degradation in productivity--and the decline in revenues--occurs, the greater will be the returns to remedial action.

The second determinant of the profitability of implementing a sustainable ranching system is the rate of time preference or the discount rate. As can be seen from the net present value formula given below, high discount rates mean that future benefits are reduced relative to those in the near term.

$$NPV = \frac{(B_1-C_1)}{(1+r)^1} + \frac{(B_2-C_2)}{(1+r)^2} \ldots + \ldots \frac{(B_T-C_T)}{(1+r)^T} = \sum_{1}^{T} \frac{(B_t-C_t)}{(1+r)^t}$$

where B = Benefit, C = Costs, r = interest rate, and t = time.

The time dimension of resource use can be reflected in the PAM framework by computing present value PAMS. This presentation has the same form as Table 2 but, instead of a single period, the cells represent the present value of a stream of revenues, costs, and profits. Once the present value of these cash flows have been computed, the PAM analysis can continue along the same lines as the static, one-period PAM.

When the degradation rate and the discount rate are both incorporated in computing the NPV of the difference between sustainable and unsustainable PAM net revenues, a low degradation rate and a high discount rate will make efforts at converting to a more sustainable ranching system less profitable than if the opposite were true.

NPVs may also be computed for *stationary* systems. Stationary systems simply repeat themselves in each time period. Although the ideas are being debated intensely in range management circles, a number of researchers have argued that many of the arid and semi-arid rangelands exhibit this type of behavior. According to this school of thought, although there are substantial year-to-year variations in range productivity, these are caused by sporadic rainfall and not by any type of cumulative degradation. (In the range management literature, systems that exhibit stationary behavior are sometimes called "state and transition" systems.)

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[6] The ecological relationship between grazing pressure and the condition of the range is discussed extensively in Appendix A.

At this writing, the choice of the most appropriate ecological model for Zimbabwe is still controversial. However, as the difference between the computations for degrading and stationary PAMs makes clear, the assumption about the relationship over time between animals and the range is an important determinant of appropriate public policy. (The literature on the ecological basis for alternative range management models is reviewed in Appendix A.)

3. CATTLE AND WILDLIFE RANCHING IN ZIMBABWE

3.1 General Background

The country is divided into five natural regions, of which regions IV and V are devoted primarily to extensive cattle and wildlife ranching. In these areas, rainfall is the major factor in determining land use. Zimbabwe has a single rainy season (November to March) with about 65 percent of the country receiving less than 750 mm per annum. In Natural Region IV, which covers 37 percent of the country, rainfall varies between 450 and 650 mm annually. It is subject to periodic seasonal droughts and severe dry spells during the rainy season. Natural Region V, comprising 27 percent of the country is subject to erratic rainfall usually below 650 mm annually.

The beef industry

Since the late 1890s, the cattle industry in Zimbabwe has been one of the three most important agricultural sectors (with tobacco and maize) in an economy dominated by agriculture. Rangelands in the large scale private sector were developed solely for cattle production and cattle monoculture was the only commercial enterprise until the advent of game ranching following the 1960 Wildlife Conservation Act. (Child, 1988).

The national cattle population has increased since Independence in ****. The average growth rate in the total herd over the 1980-90 period has averaged 1.7 percent per annum although there has been some interruption in this trend, usually associated with drought years (1982-84 and 1987) when there were cutbacks in the herd. In 1992 the southern half of the country suffered from a drought and much forced destocking took place. In 1979 the communal areas held 54 percent and the commercial farms 46 percent of the national herd. By 1990 the large-scale commercial farms' share had decreased to 28 percent of the national total of 6.1 million head and had declined in numbers by 29 percent (to 1.7 million head).

A number of factors have contributed to the decline in the commercial herd:

- A loss of confidence among white farmers about their status after Independence;
- The acquisition of farms and ranches by the government for resettlement schemes;
- The government's erratic pricing policy, unsuited to livestock's planning cycles
- Several years of drought during the early 1980s.
- A shift to more attractive alternatives such as wildlife or horticultural crops.

While there are some feedlots in the south of the country, the higher price of feed (most of which has to be brought into the region) means that cattle fattening is not widely practiced in Natural Regions IV and V. There is only limited scope for out-of-season finishing of cattle once the summer grazing starts to deteriorate (from about July onwards after the rainy season of December to March). Normally cattle are marketed off grass, with little or no supplementary feeding, at 3.0 to 3.5 years of age.

Pricing and marketing of cattle, particularly in the commercial sector, is dominated by the activities of the Cold Storage Commission (CSC), a wholly owned government parastatal. It has the primary responsibility for purchasing cattle throughout the country, processing the animals at abattoirs, and then selling the products on both the local market and for export. It currently has five abattoirs, three of which are EEC export-approved, four feedlots, three cold storage and processing centers, 14 ranches and over a hundred sales pens throughout the country. There are also eight licensed private abattoirs. The CSC currently has a monopoly on export sales of beef and, until recently, on the supply of meat in the urban areas.

Both producer and wholesale/retail pricing is controlled by the government. Producer prices are set primarily on the basis of cost of production, although many other factors, including the need to maintain beef at an affordable price, also enter into the negotiations.

Zimbabwe has the advantage of an EEC beef quota for which it receives virtually internal EEC prices. Currently 9,100 tons may be exported annually at prices considerably higher than could be obtained on world or local markets. Since the CSC has a monopoly on beef exports, this extra revenue is paid to CSC as export earnings and reduces CSC's operating deficit.

Access to the EEC market is restricted to cattle coming from a zone declared to be free of foot and mouth disease (clear zone) and is dependent on no outbreaks in that zone. An outbreak shortly before the granting of the quota stopped exports for over a year and a second outbreak in April 1989 again stopped exports for more than a year and a half. Yet a third outbreak occurred in October 1991 which stopped exports until February 1992.

Critics charge that EEC beef exports to date have been a net loss to the country. This is because the increase in revenue resulting from exports to the EEC at higher than world prices is considerably smaller than the investment the government has made in upgrading its abattoirs and strengthening its veterinary controls in order to meet the rigid health regulations of the EEC.

The wildlife industry

Zimbabwe is fortunate in having one of the richest wildlife resources remaining in Africa. Wildlife represents a multi-million dollar asset to the country. Sizable numbers of a wide variety of species exist on some 110,380 square kilometers or 28 percent of Zimbabwe. They coexist alongside people on approximately 56,500 square kilometers. This marks a substantial increase from 1960 when only about 26,000 square kilometers was designated as wildlife land and there were only three game ranches totalling 350 square kilometers in area.

Wildlife ranching on commercial farmland has become increasingly popular in recent years. Previously, wildlife were seen as a means of increasing meat production, but presently wildlife ranching is centered on safari hunting. The industry also includes non-consumptive tourism, live animal sales, and intensive ranching of crocodiles and ostriches. Prior to Independence there were 13 registered safari operators; by 1986 there were 55, and the latest estimate of active safari operators is over 150. (Kaufman, pers. comm).

The Gwaii Valley (Natural Region IV), bordering Hwange National Park, exemplifies the transition from conventional cattle production into hunting and then into tourism. Although much of the tourism is based on game viewing within Hwange National Park, the wildlife numbers on many of the commercial properties are now sufficient to support tourism. Similar non-consumptive developments are now taking place on a commercial property adjacent to Gona-re-zhou National Park in the Lowveld. (Natural Region V) With the increasing demand for wildlife based tourism, there has been a proliferation of mini-game ranches or "safari farms" throughout the country with small confined wildlife populations in scenic settings.

Live animal sales (wildlife auctions) have become more frequent in recent years, but domestic sales are constrained by veterinary restrictions, implemented in order to satisfy the EEC requirements for Zimbabwe's beef export quota. All animals being moved between veterinary zones must be quarantined. Blood samples are taken at capture and then again after six weeks, and animals must be clean before they can be moved. This adds considerably to the cost of capture for producers in the quarantined zones.

3.2 The World Wildlife Fund Ranching Survey

The principal objective of the WWF survey was to assess the absolute and relative viability of cattle ranching and/or wildlife utilization on commercial ranch land in Natural Regions IV and V. The survey thus focused on the question of which animal-based production systems would appear to be the most viable under existing government policies as well as alternative policies required by the recently launched ESAP (Economic Structural Adjustment Program). The latter is designed to liberalize pricing and marketing policies as well as to reform trade and exchange rate policies.

Detailed financial and management data were collected during personal visits to a randomly selected sample of 89 ranches. Only ranches above 1,200 hectares were surveyed. To the extent possible, equal numbers of cattle only, wildlife only and combined cattle and wildlife enterprises were selected. The ranches in each natural region were sub-divided into three broad geographical areas, spreading from West to East. In Natural Region IV these are the Hwange area (Gwaii and Matetsi), Bulawayo area (Nyamandlovu, Bubi, Inyathi, Lower Khami, Shangani) and the Masvingo/Mberengwa area. In Natural Region V, the areas surveyed were West Nicholson, Mwenezi and Chiredzi areas.

Forty-five of the ranches have only cattle enterprises, 12 have only wildlife enterprises, while 32 have both types of operations. For these 32 ranches having both types, revenue, recurrent costs and capital costs were apportioned between the two operations and thus there are two separate financial and economic indicators for these ranches: one for the cattle enterprise and one for the wildlife enterprise.

Cattle only ranches are on average smaller than wildlife only ranches and mixed enterprise ranches (cattle and wildlife) are larger on average than single enterprise ranches. Ranches in Natural Regions V also tend to be larger than those in Natural Region IV. Of the 89 ranches in the survey, 29 are less than 10,000 hectares, 33 are between 10,000 and 20,000

hectares, and 19 are between 20,000 and 40,000 hectares. Eight ranches are more than 40,000 hectares in size.

For the purposes of the PAM analysis, the ranches were divided into two groups based on their stocking rates. The 54 ranches whose stocking rates exceeded the rates recommended on the basis of the biomass norms computed in Appendix B were labeled as "overstocked" and, in the degradation model, "unsustainable." The 23 ranches whose stocking rates fell within the recommended norms were called "sustainable." Separate budgets were calculated from weighted averages of the two groups. These budgets are the basis for the PAMs used in the comparisons shown below. Approximately 70 percent of the ranches fell in the overstocked category; 30 percent were deemed to be sustainable. Wildlife enterprises were also evaluated using biomass calculations; none fell into the overstocked category.

4. COMPUTING PAM BUDGETS FROM SURVEY DATA

Cost and returns budgets for cattle and wildlife were developed according to the methodology laid out in Monke and Pearson (1990).

4.1 Basic Budget Calculations

Revenues: Gross revenues were obtained by multiplying output by private and social prices. Private prices are those reported by ranchers. Social prices are a weighted average of the export price (EEC and non-EEC) and the local sales price. Exports account for approximately two percent of the CSC's sales. The remainder of the meat purchased and processed by the CSC is sold to local butchers. The weighted average of the export price and the local sales price yields a meat price that is 25 percent above the private prices paid to farmers.

Inputs: Variable costs were estimated from the responses to the survey. Domestic prices and physical input-output relationships were used to compute values for private value added. International prices converted at the equilibrium exchange rate and measured at the farm gate were used to compute social costs.

Domestic costs: The private and social costs of mobile domestic resources (labor and capital) were computed using their domestic prices and their opportunity cost to the economy, respectively. Zimbabwe has a highly developed infrastructure, good communications between the rural and urban areas, and a reasonably well functioning labor market. It was therefore assumed that the observed domestic prices for labor were also a reasonable approximation of labor's social contribution. For family managerial labor, the wages paid to hired managers on corporate farms was used as the price of labor.

The cost of capital was determined from an average of estimated asset values supplied by ranchers. An interest rate of 10 percent was used to compute capital recovery costs.

Profits: Profits are the residual after all costs, including the normal rate of return on capital assets excluding land, have been accounted for. They thus include the returns to land, the only truly fixed domestic resource that has no alternative use outside the agricultural sector.

4.2 Special Problems

Exchange rate: Computing the export and import parity prices used in a PAM analysis requires that an equilibrium exchange rate be estimated. It is difficult to estimate such a rate in Zimbabwe because the pent-up demand from prior periods of shortage makes any short-run estimate suspect. However, in 1990, there was a consensus among economists that Zimbabwe's currency was overvalued by at least 50 percent during the survey period. This estimate was based on an examination of inflation rates, changes in the external terms of trade, and calculations based on elasticity estimates for demand and supply curves of foreign exchange. The 50 percent premium on foreign exchange was used for all estimates requiring an equilibrium exchange rate.

Land: The treatment of land depends upon the intent of the analysis. In the PAMs reported below, the level of the analysis is the economy as a whole. The estimates of comparative advantage reflect the opportunity cost of resources to the entire society. At issue is the efficiency with which labor and capital are used in the livestock sector as compared to their returns in non-agricultural pursuits. At this level of analysis, land, since it is assumed to be fixed to agriculture, has no opportunity cost.

In a sector (as opposed to economy-wide) analysis, the investigation focuses on the efficiency with which commodities use resources that have opportunity costs *within* the agricultural sector. If labor and capital markets are functioning, there should be no need to adjust the prices of mobile factors. However, in a sector analysis, land must be priced. At the sector level, land has an alternative use, namely, the production of other commodities. Its opportunity cost would be determined by the returns from alternative crop and livestock enterprises.

5. COMPUTING CATTLE AND WILDLIFE PAMS

The results of the single-period budgets exercise were used to compute a series of NPV PAMs.

5.1 Present Value PAMs for Cattle (Degradation Model)

The PVs in Table 3A were computed assuming a two percent decline per annum in gross revenues and a discount rate of 10 percent for both private and social calculations, i.e., no allowance was made for the fact that the social discount rate is likely to be less than the private rate. The interpretation of the PAM follows directly from the earlier exposition of the PAM methodology.

Overstocked (unsustainable) PAM:

In Table 3A revenue computed at social prices is significantly above the same physical output measured at private prices (A-E). The negative value in the divergence row indicates a transfer from producers to the rest of society of Z$142.02 per hectare. In looking at the budget figures, it is obvious that a large portion of this tax on producers is coming from an overvalued domestic currency. When hard currency, in which at least part of the income from livestock is denominated, is converted to domestic currency using an equilibrium exchange rate, output prices increase by 50 percent. The government's control of livestock prices that results in a significant reduction in producer prices is also a important determinant of sustainability.

Inputs have been held constant over the assumed planning horizon of 20 years because the number of animals has been held constant. Degradation has been defined in terms of reduced meat output. The negative number for the cost transfer, like the negative revenue transfer, shows the effect of an overvalued domestic currency on tradable costs, e.g., veterinarian supplies and fuels. The tradable variable costs described in the discussion of ranch budgets are considerable higher when measured at social prices than at private prices. The negative value in the divergences row thus marks a subsidy to producers of Z$47.08 per hectare.

Profit transfers reflect the sum of two mechanisms, an output price that taxes ranchers and input prices that subsidize them. The latter do not offset the former and the negative net effect shown in the lower right hand corner of the unsustainable PAM confirms the substantial "tax" on ranchers (Z$92.90) that results from current macro policies and government controlled domestic prices.

The degradation rate and the discount rate both play important roles in determining the results shown in Table 3A. For example, if the degradation rate were only 1 percent per annum, the private NPV of cattle ranching over 20 years discounted at 10 percent interest would rise to a minus Z$92.47, i.e., ranchers would lose less. If annual productivity were to decline at 3 percent, the NPV of ranching would be a negative Z$115.51.

Table 3: Present Value PAMs Computed from Survey Data

Table 3A	Unsustainable PAM (Overstocked) N = 54			
Z$/ha	Tradables		Domestic	
	Revenues	Costs	Factors	Profit
Private	189.01	129.66	163.89	-104.54
Social	331.03	176.74	165.93	-11.64
Divergence	-142.02	-47.08	-2.04	-92.90
Table 3B	Sustainable PAM (Recommended Stocking) N = 23			
Private	177.08	122.00	116.47	-61.39
Social	316.02	182.36	118.51	15.15
Divergence	-138.94	-60.36	-2.04	-76.54
Table 3C	Economic and Environmental PAM			
Private	189.01	129.66	163.89	-104.54
Social	316.02	182.36	118.51	15.15
Divergence	-127.01	-52.70	45.38	-119.69
Table 3D	Cost of Destocking to Recommended Levels			
Private Prices	11.93	7.66	47.15	-43.15
Social Prices	15.01	-5.62	47.42	-26.79

The negative private profitability shown in the PAMs in Table 3A means that domestic factors (capital and labor) used in the private sector are not actually being paid their opportunity cost. At the prices and production relationships assumed, ranchers are unable to set aside sufficient capital to replace their existing stock or to pay themselves the equivalent of manager's wages. (The most likely effect is to forego replacement of buildings, fencing, boreholes and other equipment.)

These results are also sensitive to the discount rate. At a 2 percent degradation rate, a discount rate of 5 percent yields a private NPV of minus Z$160.49 as opposed to minus Z$104.54 at 10 percent. A discount rate of 20 percent yields a rate of minus Z$55.44. Although these result may seem counter-intuitive, they occurs because of the negative terms in the cash

flow. The higher the discount rate, the more these negative terms are discounted and the less effect they have on losses, i.e., the greater is the sum total of discounted returns.

Recommended stocking (sustainable) PAM

The present value of entries in the recommended stocking PAM in Table 3B were computed using a zero degradation rate and a 10 percent discount rate. Social NPVs again exceed private NPVs because of the impact of macro policy and government procurement on livestock prices.

Variable costs have been reduced in the sustainable PAM to reflect the lower stocking rates. However, they exhibit the same relationship between private and social prices observed in Table 3A. Livestock output on the revenue side, in addition to being taxed by government intervention in the meat market, also suffers from the effects of macro policy. Imported tradable inputs are subsidized by the same mechanism.

Although gross revenues per hectare in the recommended stocking PAM are less than the revenues in the overstocked PAM, the loss per hectare is less. The relative profitability of the sustainable ranching systems results from lower domestic factor costs. These lower costs are due primarily to the smaller investment in livestock required to maintain recommended stocking rates, i.e., to lower opportunity costs of capital. It appears from the data that the results obtained by Child (1988)in his analysis of overstocking, i.e., that the rate of reproduction declines, is borne out at the aggregate level.[7] Overstocked ranches achieve a lower return on their investment in animals than do ranches stocked at the recommended rates.

An economic and environmental PAM

Table 3C combines the elements of the previous PAMs to produce a PAM that captures both the divergence between private and social prices--the "economic" part of the PAM--and the difference in technology between the sustainable and unsustainable ranching systems. A "sustainable" ranching system has been defined as socially desirable. Hence the PAM in Table 3C yields a "Divergence" row that combines both economic and environmental departures from efficiency-oriented social policy.[8]

The divergence in the gross revenue column (-Z$127.01) between private and social revenues reflects, of course, the difference between private and social beef prices. It is smaller than the distortion in gross revenues in either Table 3A or 3B because distorted output prices have been applied to smaller output on the sustainable ranches than on the overstocked ranches. However, the losses in net revenues (Z$-119.69) are greater because they now include, not only

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[7] This analysis is summarized in Appendix B.

[8] It is again important to point out that the type of budgeting approach utilized in constructing PAMs does not permit statements about optimal environmental policy. Rather, it explores the comparison between budgets based on observed practices and practices that have been identified as being socially "desirable." Technical relationships that possess such characteristics would have to address well known sources of market failure such as externalities and unrecognized user costs.

the divergence between private and social prices, but the social losses arising from the failure of the overstocked ranches to use resources efficiently. Social profits are clearly superior under recommended stocking rates. They arise because of relatively high capital-output ratios. In comparing the two systems in the PAM analysis, in addition to policy distortions, society loses because of the low reproduction rates and low capital-output ratio of the overstocked ranches compared to ranches that use more conservative stocking policies.

Cost of compliance with destocking regulations

The combined PAMs also yield interesting information on the *cost of compliance* that ranchers would face if some type of sustainable stocking regulation was implemented. Table 3D shows that the cost of compliance measured in gross revenues would be considerably higher at social prices than at private prices. Currently, ranchers are being taxed, i.e., the direction of transfers is from the cattle industry to the economy as a whole. Moving to a sustainable system at the current depressed prices would be less costly than if ranchers were receiving the export parity price for their animals.

The cost of compliance is less at private prices. Obviously, at the current distorted prices, it would be advisable for ranchers to switch to a sustainable agricultural system. When the returns to cattle ranching are low as they are now, it pays to think in terms of the long run. Admittedly, the costs of destocking are also negative at social prices, but the results are less attractive than when returns to cattle are low. At world prices, the costs of compliance increase substantially and the NPV of the cost of destocking, although still negative, is less attractive than it is at current prices. (Smaller numbers--larger negative numbers--mean lower costs.)

Often, when incorporating resource use in PAMs, efficient economic policies and desirable environmental outcomes reinforce one another. The classic case is a subsidy on pesticides. But there is nothing universal about this result as the cattle PAMs indicate. Moving in the direction of more efficient price policies increases the costs of moving to a more sustainable ranching system implemented either through regulation or by the use of financial incentives.

Internal rates of return to destocking

The cost of compliance provides some evidence about the incentives ranchers have to move toward a more sustainable ranching system. The material presented in the cattle NPVs can also be utilized to derive private and social internal rates of return (IRRs) to the destocking decision.[9]

[9] The internal rate of return is defined as the interest rate that would set the NPV of a cash flow of to zero. It is the price that could be paid for the "investment" that creates the difference between two cash flows. In this case, the investment consists of initial income foregone when moving to a sustainable ranching system.

Subtracting the net revenues of the unsustainable ranching system from the sustainable system yields a stream of *net benefits* to destocking.[10] As Figure 1 shows, in the degradation model, the cash flow will be negative initially as the higher off-take from the intensive use of the range exceeds the sustainable off-take. This is reversed over time and the sustainable system begins to yield more output than the unsustainable system .

In the situation captured in the survey of livestock ranches, it appears that the degradation of the overstocked ranches has already reached a point where the net revenue stream from the intensive use of the range is less than the returns from less intensive recommended practices. In the case of *private prices*, the profits (D) of the PAM are lower for the overstocked system than for the recommended system beginning with the first year. Because overstocking results in declining revenues, this means that there is never a negative term in the flow of net benefits. The IRR is such cases is undefined.

At social prices, the situation is somewhat different in that the higher prices for cattle produce a negative value for in the first few years of the net benefit flow. (Area A in Figure 1 exists.) But the IRR in the 2 percent degradation case is 40 percent, well above the 10 percent cost of capital assumed in the study. Consequently, moving to the sustainable system would still make economic sense even if macro policy and beef price reforms were implemented. However, reducing grazing pressures when cattle prices are high is obviously less attractive than moving to a smaller herd when the returns to cattle ranching are low.

Sensitivity analysis in the social prices case shows how significant assumptions about the *rate of degradation* are to the IRRs of destocking (Table 4). It is clear that investments in destocking have a higher rate of return when declines in productivity are taking place rapidly than when they occur gradually over a long period of time.

Table 4: Rates of Return on Converting to Recommended Stocking

	Degradation Rates		
	1%	2%	3%
IRR at private prices	undefined	undefined	undefined
IRR at social prices	.17	.40	.61

[10] *Net revenue* is the difference between costs and returns, i.e., the computations that yield the D and the H of the PAM analysis. *Net benefit* is the difference between two net revenue flows, in this case the result of subtracting the net revenues of the unsustainable system from the net revenues of the sustainable system.

5.2 Present Value PAM for Cattle (Stationary Model)

As noted previously, recent thinking about range management in the arid areas of Africa has raised questions about the validity of the degradation model. Despite the support given this model by the foregoing analysis, the computations used to divide sustainable and unsustainable ranches are based on minimal empirical data. The results are suggestive but not conclusive. Other range management studies done under similar conditions make a strong case for an alternative model, one in which the long-term stocking rate plays only a modest role. This literature is reviewed in detail in Appendix A, but it has the effect of placing a greater emphasis on the short-run response to unpredictable events via the movement of animals and supplementary feed than on long-run environmental concerns.

Table 5: Net Present Value Cattle PAMs (Stationary Models)

Table 4	Cattle PAM (Stationary Model) N = 54			
Z$/ha	Tradables		Domestic	
	Revenues	Costs	Factors	Profit
Private	214.37	129.66	163.89	-79.18
Social	375.45	176.74	165.93	32.78
Divergence	-161.08	-47.08	-2.04	-111.96

The PVs of PAM in Table 5 provide an illustration of the effect of removing the degradation rate from the returns to overstocked ranches. Of course, additional costs, which have not been included explicitly, would be required to move the animals in years of low rainfall or to provide supplementary feed.[11] Revenues, costs, and profits in the stationary model are now, in effect, based on expected values. It is assumed that over the time horizon being considered, the good and bad years will even out. The problem is to keep the herd more or less intact in below average years to so that above average returns can be realized in good years. What distinguishes the state and transition ecological model from the model used to compute the earlier PAMs is the absence of any assumption that overstocking in bad years will set in motion an ecological process that ultimately leads to a reduction in range productivity.

[11] Many of the ranchers who participated in the survey from which the data for the PAMs were drawn have been "overstocked" for years. Hence it is reasonable to assume that the cost of maintaining their herds by spatial dispersion or by supplementary feeding have been included in their responses.

As would be expected, the NPV of the stationary model (Z$-79.18) is considerably above the NPV of the of the degradation model (Z$104.54). Private profits are still negative, but less than they were when degradation was assumed. Social profits (Z$ 32.78) are actually positive and, with the larger number of animais involved, are greater than those obtained when using recommended practices. (Again, it is important to remember that the costs of mobility and supplementary feeding have not been included in the budgets.)

In all likelihood, ranchers engage in adjustments at the margin that involve decisions about both long-run stocking rates and responses to short-run events. What is at issue is the optimal production response to a highly uncertain production environment. The problem is sufficiently complex so that its full analysis is beyond what can be done with simple PAM models. It requires a stochastic dynamic programming framework. Although more demanding technically, further research along such lines would provide important insights that have direct relevance for socially desirable government policy responses.

5.3 Net Present Value PAM for Wildlife

Table 6 shows a PV PAM for wildlife. Budgets for wildlife operations were obtained in the same ranch survey that produced costs and returns for cattle enterprises.

Table 6: Present Value PAMs for Wildlife

	Wildlife PAM N = 44			
Z$/ha	Tradables		Domestic	
	Revenues	Costs	Factors	Profit
Private	156.48	72.28	82.75	1.45
Social	216.67	73.56	87.60	55.51
Divergence	-60.19	-1.28	-4.85	-54.06

The interpretation of wildlife PAMs follows the analysis conducted earlier. Wildlife services are comprised mainly of hunting and photographic safaris purchased almost entirely by foreign tourists. Hence, like all PAMs constructed in this series, private revenues reflect the tax imposed by an overvalued exchange rate. Inputs are also affected by the exchange rate but their negative sign implies a subsidy, not a tax. The wildlife PAM indicates that wildlife are both privately and socially profitable but receive negative incentives of Z$54.06 per hectare primarily as a result of government macro policies.

5.4 Comparison of Private and Social Profitability Across PAMs

Table 7 summarizes the results of the profitability calculations shown in the cattle and wildlife PAMs. In the first column, activities are ranked by private profitability. At the top is wildlife. It benefits both from positive (albeit small) profits per hectare and from a lack of range degradation. As might be expected, the degradation model ranks last. Long-term declines in range productivity have a negative effect on the NPV of private profits. The rankings change only slightly when enterprises are ordered by social profits. Wildlife is still more profitable than cattle, but the stationary cattle model with its larger number of animals is now more profitable than the recommended stocking model.

Table 7: Comparison of Profitability in the Cattle and Wildlife PAMs

NPV of Private and Social Returns to Cattle and Wildlife Ranching			
	Private Profits		Social Profits
Wildlife	1.45	Wildlife	55.51
Cattle (recommended)	-61.39	Cattle (stationary)	32.78
Cattle (stationary)	-79.18	Cattle (recommended)	15.5
Cattle (overstocking)	-104.54	Cattle (overstocking)	-11.64

6. POLICY IMPLICATIONS AND NEEDED RESEARCH

6.1 Policy Summary Based on Survey Data

Many of the policy implications of the PAM analysis have already been discussed. The summary ratios shown in Table 8 bring these results together. Again, enterprises have been ranked by their private profitability. This is given by the private resource cost (PRC), a ratio computed by dividing the costs of capital and labor by value added. Profits defined in this way include returns to land as part of the profit residual. (A PRC less than one indicates that private profits are positive.) However, all domestic factors--including family labor and capital--have been priced at their opportunity cost.

Table 8: Summary Policy Coefficients

Summary Ratios Showing Transfers and Profitability				
	NPC	EPC	PRC	DRC
Wildlife	.72	.59	.98	.61
Cattle (stationary)	.57	.43	1.93	.84
Cattle (recommended)	.57	.41	2.11	.89
Cattle (overstocked)	.57	.38	2.76	1.08

The nominal protection coefficients (NPC) are the ratio of domestic prices to internationally determined export and import parity prices. A value less than one indicates that the commodity is being taxed. The NPCs are the same for all cattle operations because they simply reflect domestic and international prices of cattle. All show the effects of the overvaluation of the official exchange rate. It, along with the government controlled beef price, is the most powerful determinant of the "tax" on Zimbabwe's livestock producers.

The effective protection coefficient (EPC) is the ratio of value-added at domestic and international prices. A value less than one indicates net taxation. In this case, the effect of the output tax on producers resulting from the exchange rage differential is mitigated by an opposing subsidy on input costs resulting from the same mechanism. EPCs differ between ranching systems because of the physical input-output coefficients for ranching systems differ.

The domestic resource cost ratio is computed by dividing domestic resources valued at their opportunity cost to the economy by value-added at border prices. It is again important to remember that the costs shown do not include a charge for land. Land, in the PAM computations carried out above, is one of the residual claimants for profits along with management, the

willingness to undertake risk, and entrepreneurial skills generally. Based on this (standard) line of argument, Zimbabwe currently has a comparative advantage in using its range resources to produce wildlife. (Wildlife also yields the highest private return to capital.)

6.2 Institutional Issues

Government policy is most obvious when it is implemented through price distortions. Less obvious but equally powerful is macro policy, especially the exchange rate. However, the country's institutional and legal structure also play a vital role in determining private incentives.

Veterinary restrictions

Veterinary restrictions result from the need to meet EEC export requirements regarding foot and mouth. In order to be able to export meat to the EEC, cattle are forbidden to move "on the hoof" outside the red zones. They can only move from the green zone into the red zone.[12] This considerably restricts the marketing opportunities and the production system options for producers in these areas. Forty-eight out of 77 (nearly two-thirds) of the cattle enterprises in the sample are within the red or buffer zones, and thus adversely affected by these veterinary restrictions. Enterprises in the restricted zones received on average $94 per head less in cattle revenue than those outside these zones.

Non-availability of Key Inputs

The PAM only indirectly reflects the adverse effect of non-availability of some imported inputs and capital equipment on cattle enterprises. The non-availability and shortages are a direct consequence of trade and exchange rate policy which results in foreign exchange controls and import restrictions. While higher prices reflecting "scarcity premiums" are part of the PAM analysis, and serve to partially offset the favorable effect on costs of the maintenance of an overvalued Zimbabwe dollar, the non-availability of key inputs, such as veterinary requirements and vehicles, is not. Since the survey was completed, many more items are placed under the Open General Import Licensing (OGIL) system of the Economic Structural Adjustment Program (ESAP) and shortages have lessened. However, producers still require foreign exchange for items placed on OGIL and this is still difficult to obtain for most cattle producers. Ranchers with wildlife as well as cattle enterprises are better off than cattle only ranchers because wildlife generated foreign exchange revenue qualifies for the export retention scheme.

6.3 Recent Policy Changes

The Economic Structural Adjustment Program is a blend of structural reforms and macroeconomic stabilization measures designed to address the key policy constraints that

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[12] The *red zone* defines an area in which foot and mouth disease is endemic. In the *green (buffer) zone*, foot and mouth outbreaks are being controlled by a vaccination program. The export of animals to the EEC is only permitted from the *clear zone*.

hampered Zimbabwe's development in the 1980s (World Bank, 1991). Implementation, begun in late 1990, has included relatively aggressive exchange rate management, a reduction in the fiscal deficit, new investment guidelines, more flexibility in price and wage setting, a foreign exchange retention system an the model expansion of OGIL (Open General Import License) provisions.

The financial data collected during the survey for the cattle and wildlife enterprises pertain to the 1989/90 period and thus reflect pre-ESAP policies. The adjustments made to private prices in order to obtain social prices in the PAM analysis do, to a certain extent, mirror the policy changes that have subsequently taken place under ESAP. For example, the dollar has been devalued by over 150 percent and CSC's cattle prices have risen considerably. However, many policies have not been changed and thus much of the analysis of the effect of policies presented in the cattle and wildlife PAMs, remains valid.

6.4 Suggestions for Further Policy Reform

Policy reforms affecting the cattle industry

Any reform of cattle pricing and marketing is linked closely with reform of the CSC. Nearly all the cattle ranchers interviewed felt that some reform of the CSC was needed, since they viewed it as an extremely inefficient marketing organization. However, nearly all of the ranchers felt that the CSC could play a valuable role in the industry and most felt it should be reformed rather than simply abolished or privatized. Several ranchers suggested that it be purchased and run by the Cattle Producer's Association or a new body whose shareholders would be comprised largely of cattle producers.

Private abattoirs should be allowed to compete with each other and the CSC. Conversely, the CSC should be allowed to compete with the private sector. This could perhaps best be achieved by administratively separating the CSC's export sales, drought-relief and communal area sales operations from normal commercial domestic sales. The latter would then be charged with competing freely with private sector operations. If it could not compete, these operations should be privatized.

Policies reforms affecting wildlife enterprises

Government reforms are moving in the direction of eliminating negative (disincentive) policy effects. The real devaluation of the Zimbabwe dollar, as well as the increase in the percent of foreign exchange exporters can retain under the export retention scheme (ERS), are both having positive effects on the viability of wildlife enterprises. This is particularly true for wildlife enterprises whose revenue base is hunting or photographic safaris, aimed at an international market and payable in hard currency.

Live animal sales are still as negatively affected by government trade policy. Exports of sable and ostrich are prohibited and export of other species still require substantial administrative hurdles. There seems to be little justification for the restrictions from an ecological point of view. The ban on ostrich exports appears to be financially motivated, with the aim of restraining the

price of ostriches for new domestic producers at the expense of foreign exchange earnings to the country and to those producers who presently have animals they wish to export.

Live animal sales are also negatively affected by the veterinary restrictions which require lengthy quarantine periods before movement of animals out of the red zone is allowed. As with cattle, these veterinary restrictions can cause considerable financial losses to producers in the red zone. For example wildlife in red zones, which are severely affected by drought, cannot be translocated to areas in green zone where feed is available.

Live animal sales, as well as culling activities, are also adversely affected by government policies that limit the number of game capture teams in operation. Stringent licensing requirements and shortage of the necessary imported capture equipment have prohibited new entrants to the wildlife management services industry. At present there are only five, with limited competition due to overlapping ownership and management. Within the limits of animal welfare, these restrictions should be removed, while simultaneously investigating alternative technologies for wildlife capture.

Many wildlife producers are also affected adversely by the ban on buffalo throughout most of the country. This is motivated by the desire to restrict foot and mouth outbreaks which would be detrimental to the cattle industry. But the detrimental impact of this policy on the wildlife industry appears not to be fully appreciated. There is evidence that the presence of buffalo can roughly double the revenue a wildlife enterprise can earn from hunting. Over half of the wildlife ranchers would like to introduce buffalo onto their properties.

Suggestions for changes in land policy

Although the survey interviews were conducted prior to the enactment of the Land Acquisition Bill, many ranchers expressed uneasiness over land policy, including the view of some politicians that wildlife is not an "acceptable" land use. In the intervening months, policy change has had the effect of increasing ranchers uncertainty and fears regarding their right to continue to engage in either cattle or wildlife enterprises on their properties. Some ranchers may be postponing needed farm maintenance and improvement expenditures, including boreholes and fencing. While not reflected in the PAM, the uncertainty regarding government's plans regarding land acquisition is having a negative effect on cattle and wildlife enterprises. Many jobs as well as foreign exchange earnings to the country could be lost. Early designation by the government of areas it plans to acquire or regulate will alleviate present uncertainties.

The results of this survey indicate that after reforms wildlife, as well as cattle, can be efficient and profitable activities in Natural Regions IV and V--how efficient and profitable depends on the circumstances of individual ranches, including management, vegetation and access to markets. Any policy to limit the freedom of landholders to choose the enterprises that are most profitable for them would be ill-advised as it would have negative effects on employment, income, as well as foreign exchange earnings.

7. RESEARCH NEEDS

This study has presented a single and necessarily incomplete "snap-shot" of 89 ranches during the 1989/90 period. The environmental analysis presented here clearly shows the need for further research into the effects of stocking rates on herd productivity and on soil loss. The proposal to maintain substantial herds during periods of drought by moving animals from the affected areas or by supplementary feeding rather than by forced marketing deserves further study. In all likelihood, ranchers are adjusting their herds at the margin and are pursuing mixed strategies that incorporate both a sense of the appropriate long-term stocking level and a response to what they perceive as short-term drought conditions. Ranchers who are adverse to risk will hold herd sizes down to insure that there will be sufficient forage to avoid distress sales under adverse conditions. Less risk averse ranchers will be willing to gamble in order to have herds that can reap the benefits of good years. Choices in both cases are dependent, not only on perceptions and willingness to tolerate uncertainty, but on the resource position of the rancher as well. (Fortunately, Zimbabwe's commercial banking sector is reasonably well developed so that the effect of capital market imperfections is less than it would be for small communal farmers facing the same problem.)

But the optimal trade-off between the long run and the short run is very much influenced by assumptions about the potential for range degradation, i.e., by the ecological model that should underlie range management decisions. Government intervention in the cattle market has been a significant disincentive to maintain herds and, to date, has acted to retarded stocking rates. As market liberalization occurs and cattle become more profitable, the pressure to add animals will increase. Knowledge of the physical parameters that are key determinants of the most appropriate strategy will thus become even more relevant than it has been in the past.

APPENDIX A: Range Ecology in Arid and Semi-Arid Africa

Economists seeking to develop models of African livestock enterprises are dependent on range management and animal husbandry research for a number of important physical parameters. Static models require estimates of the production of forage under various management regimes, the nutritional value of local vegetation, and the ability of livestock to convert forage nutrients to meat and milk. Dynamic models require additional information on calving and survival rates, and most importantly, they need multi-period relationships between grazing pressure and forage production to form the model's equations of motion.

The data required to estimate these parameters have always been hard to obtain. Measuring inputs and outputs in situations where grazing is the major source of forage and animals are constantly on the move is extremely difficult. As a consequence, the recent debate over the relationship between animals and forage in semi-arid regions has been hard to resolve. To some range management experts, the observed degradation of the range that is evident in many areas is the result of overgrazing, often exacerbated by concentration of the animal population around artificial water sources. Other experts have argued that the observed desertification is nothing more than the result of a long period of low rainfall. In this view, long term destocking as a response to environmental degradation is unnecessarily expensive. Livestock mobility and supplementary feeding are the keys to successful range management.

The equations of motion that link time periods in dynamic models are obviously quite different in the scenarios described above. In the first scenario, overgrazing interacts with the characteristics of different forage plants such that over time, unpalatable--and hence unproductive--species gradually gain control of the land. In the second scenario, there is no relationship between periods except for the serial correlation of rainfall. The range may decline in productivity over the period of the drought but the decline is not linked to long-run stocking rates.

The alternative views about the causes of range degradation are examined in greater detail below. Each is seen to be the product of a different underlying ecological model. The implications for the stocking rate parameters that are needed to investigate livestock policy and responsible resource use are developed in the final section of the Appendix.

The Debate: Degradation and Its Causes

Sandford summarizes the traditional view of livestock and the environment as follows:

> " . .the Mainstream view holds that most of the world's rangelands are suffering from desertification and that, although in some cases unwise attempts to cultivate rangelands have been the culprit, in most cases the cause of desertification is overgrazing by domestic animals. Desertification has speeded up during the last century and overgrazing is due to an increase in the density of livestock, partly caused by a decline in the area of rangelands but mainly by an absolute increase in livestock numbers. This increase in livestock numbers is, in turn, attributed to one or more of a number of causes acting alone or in conjunction with each other. One cause is an increase in the number of pastoralists and this triggers both a demand for more livestock to support the extra

pastoralists and also a greater supply of herding labor to look after the extra stock. Another cause is thought to be an improvement in veterinary medicine and services which has reduced or eradicated many of the previous causes of livestock mortality and thus removed the main limitation to the growth of livestock populations. A third cause is thought to be traditional economic and social systems which place a very high social value on the accumulation of livestock numbers rather than, for example, on the economic value of output from these livestock or on environmental conservation." [Sandford, 1982, pp 11-12.]

Sandford [1983], and more recently Behnke, Scoones and Kerven [1993] and Abel [1993] point out a number of problems with this mainstream view and its policy implications. First, they question the definition of degradation being used. In Southern Africa, land is in the official view degrading if:

- shrub encroachment is occurring
- species composition is shifting from perennial to annual grasses, and from more to less palatable species;
- bare ground is increasing and grass cover and litter decreasing;
- the rate of soil loss is increasing.

[Field 1978, Rattray 1960 as quoted in Abel, 1993]

According to conventional range science, carrying capacity has been exceeded when there is a downward trend in forage production, forage quality or soil. Thus a change in composition from perennial species to annuals caused by grazing is seen as degradation even when this is reversible.

Other authors choose to reserve the term degradation for cases in which the loss of range productivity is irreversible. Rangeland degradation is equated with the long-lasting or permanent loss of an economic good, or more specifically, an irreversible decline in livestock production. They define range degradation as follows:

"Range degradation is an effectively permanent decline in the rate at which land yields livestock products under a given system of management. 'Effectively' means that natural processes will not rehabilitate the land within a timescale relevant to humans, and that capital or labor invested in rehabilitation are not justified...This definition excludes *reversible* vegetation changes even if these lead to temporary declines in secondary productivity. It includes effectively irreversible changes in both soils and vegetation." [Abel and Blaikie, 1990]

This definition of degradation reflects only the productivity of the specified system. It takes no account of species composition or serial stage, except as part of the process of degradation or rehabilitation.

Underlying Ecological Models

The debate over the definition of degradation is dependent on the analyst's underlying ecological model. *Succession theory* has traditionally been used in North America and then expanded globally. An alternative *state-and-transition theory* has more recently been applied to the arid and semi-arid tropics characterized by low and uncertain rainfall.

Successional Model: The traditional concept of rangeland carrying capacity rests on theories of plant succession and reflects the process whereby one community of plants replaces another. Succession theory assumes that a single and persistent vegetation, the climax vegetation, dominates a site with a particular soil type and climate. If a climax cover is disturbed, plants are pushed back along the successional sequence, but return to the climax through a predictable sequence of intermediate stages.

In a grazing system the disturbance to the climax vegetation is provided by grazing animals. Their presence pushes the mix of plants back to some form of sub-climax. The task of the range manager is to balance grazing pressure against the regenerative capacities of the vegetation, maintaining a stable sub-climax which yields a steady flow of animal products. Carrying capacity is the stocking density at which this balance can be achieved.

When pushed beyond this threshold of carrying capacity, the vegetation of a range deteriorates because its regenerative powers are destroyed, and it regresses back through the successional stages. Experienced range managers can estimate range condition by observing indicator plant species which are sensitive to the effects of grazing. These species increase, decrease or invade a range depending on the intensity of grazing pressure. Vegetation change, it is argued, is an "early warning" of declines in other parts of the grazing system, e.g. soil loss or livestock production [Stoddart et al, 1975 as quoted in Cousins,1992, p. 21]

The traditional view of range dynamics is captured in Figure 1. The solid line represents the productivity over time of a range that is managed according to recommended stocking rates. Productivity in this case is defined in terms of the amount of livestock product (not numbers of animals) that is harvested. The dotted line represents the productivity of range that is being overgrazed. It begins--initially--above the sustainable herd size because the range is being used intensively. However, in this model, overstocking leads to long-run degradation and a decline in the range's productivity. In the medium run, the total level of productivity declines to the point where the off-take of animals is equal to a more conservative harvesting policy. Subsequently, the range becomes even more degraded and productivity falls as the succession of

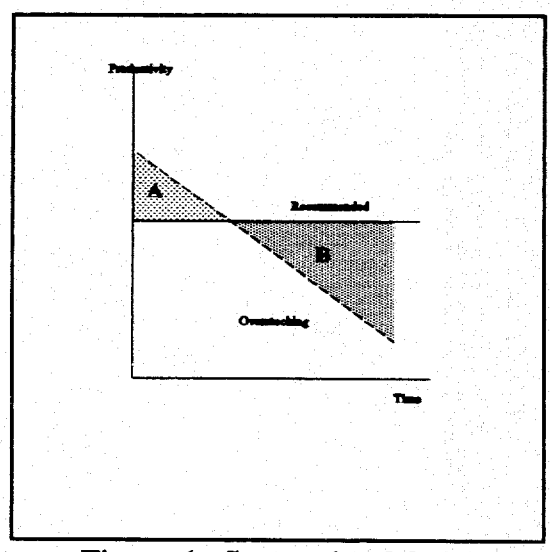

Figure 1: Succession Model

plants becomes more and more unpalatable to the animals who are foraging for food.

Economists are very interested in the rapidity with which degradation takes place because of its implication for the computation of the rate of return on destocking.. Implementation of recommended stocking rates have, in the short-run, a negative influence on cash flow (A). Fewer animals are permitted to graze which has the effect of decreasing off-take in the initial years of destocking. However, over most of the period, the "overstocked" line is well below the recommended practices line indicating that ranchers would benefit from smaller herds (B). From the graph, it is evident that the more rapidly the degradation takes place, the greater are the economic incentives to reduce herd size. (The area shown as A is smaller and the area shown as B is larger.)

Ranchers who have high discount rates will obviously find destocking more costly than those who have lower rates of time preference. The initial losses at the beginning of the period are not reduced significantly by a high discount rate but the compounding of the discount rate rapidly reduces future values. With high discount rates, the distant years make only a minimal positive contribution to the net present value of the destocking decision. Therefore, degradation that takes place over a long period plus a high rate of time preference for present over future returns can combine to yield rates of return on destocking that make it a poor investment.

Non-equilibrium Grazing Systems: State and Transition Model

The traditional notion of *carrying capacity* is based on a pattern of negative feedback which produces a stable equilibrium between plant and animal populations. Animal numbers are controlled through the availability of forage plants and the availability of forage is controlled by animal numbers. Equilibrium systems assume that conditions for plant growth are relatively constant.

The erratic and highly variable rainfall found in many parts of Africa creates a different environment for plant growth. In such situations, non-biological variables of moisture and temperature have a greater impact on flora than marginal changes in grazing pressure. In a model characterized by highly fluctuating climatic conditions, within-period rainfall, not the pattern of previous grazing, is the variable which limits animal populations. The underlying dynamics are not those of a system that converges to an equilibrium, but can be best described as a non-equilibrium, "event-driven" system. Changes brought about by year-to-year variations in rainfall in such systems are not regarded as "degradation" or desertification, since these terms are usually reserved for long-term declines.[13]

Recently a "state-and-transition" model of vegetation change has been put forward for rangelands not in equilibrium [Westoby, et al, 1989]. The model makes no attempt to describe a single successional pathway. A range may move from one state to a number of different states,

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[14] There is some evidence for long-term changes in the state of vegetation, but none for long-term changes in range productivity. See Sanford, 1983, (p. 13)for a more detailed discussion of the evidence.

or return to its original state, due to factors different from those causing the initial change. Transitions are triggered by natural events such as fire or weather or by management actions, such as changing the stocking rate, burning, or fertilization.

If alterations in state of the range are caused by different combinations of factors, of which grazing pressure is but one, then the effects of a particular stocking rate will be unpredictable unless all the other factors are known. Management of arid rangelands is thus not a question of maintaining a single, conservative stocking rate, but rather of facing "an oncoming stream of events," and attempting to "seize the opportunities and evade the hazards, so far as possible." This is referred to as "opportunistic management." [Westoby, et al, 1989, p. 271]

If an event-drive model is the correct one for Africa's semi-arid rangelands, rangeland as well as management techniques must differ from those developed primarily in North America. There is no single carrying capacity that can be recommended as "correct" in order to prevent degradation; rather, opportunistic, event-driven management must be employed, the essential ingredient of which is herd mobility.

When animals are confined to one place, their numbers and productivity are limited by the scarcest resource in the scarcest season in that location. Under equilibrium conditions, where range productivity is reliable and can be controlled to some extent by management, the costs of immobility are modest. Mainstream range management techniques such as pasture rotation can be used to dampen resource fluctuations within a delimited area. Conservative stocking rates can provide a buffer of surplus forage, fencing and the placing of water points can promote efficient forage consumption, and cultivated pastures offset forage shortages.

In non-equilibrium systems, mobility and/or supplemental feeding are the key elements of a management strategy. Movement is a means of reducing the stress caused by the wide, unpredictable and largely uncontrollable swings in productivity which characterize these systems. Movements may be regular and seasonal, as in many pastoral production systems involving transhumant cycles, or a highly contingent response to unpredictable events such as localized rainfall deficits, disease outbreaks, borehole breakdowns or fires. The livestock producer's strategy is to move animals sequentially cross a series of environments which reach their peak carrying capacity at different times.

Mobile herds moving from ecological zone to zone can avoid resource-scarce periods and exploit optimal periods in each area they enter. The resulting a total livestock population and level of productivity under such a scheme is well above what could be achieved by confining separate herds to individual areas. What Sandford has called "opportunistic strategies" are rational responses to constantly changing ecological conditions. [Cousins, 1993]

Rangeland Classification

Range managers and government policymakers need to make a distinction between rangelands in which non-equilibrium models are relevant and those in which conventional models involving successional theory and concepts like carrying capacity are appropriate. Several authors have suggested that, as rainfall becomes lower and more erratic, the likelihood of non-

equilibrium dynamics increases. In wetter areas, equilibrium patterns are likely to be more applicable. In areas with both wet and dry periods there may be shifts between equilibrium and non-equilibrium dynamics. Soil type and associated vegetation also have an influence: on heavier clay soils with high nutrient levels primary productivity will be unstable over time due to the infiltration properties of these soils, leading to large fluctuations in livestock population numbers. By contrast, areas with lighter soils will show much more stability. [Behnke and Scoones, 1993]

These differences in rangeland type influence the choice of management intervention. In conditions where equilibrium dynamics are at work the regulation of stock numbers may be appropriate. In nutrient-poor range types investment in high quality grass or tree species may be worthwhile. Conversely, in non-equilibrium conditions a management strategy based on opportunistic responses and mobility will be needed. Where nutrients are not limiting but feed quantity may be a constraint, seasonal fodder biomass shortages can be offset by interventions such as increasing the supply of browse.

Potential biological and physical indicators of range degradation have been proposed, including changes in soil, vegetation and livestock condition and output. However, vegetation change is of no intrinsic interest unless it also provides reliable evidence about changes in livestock productivity. For example, the high stocking rates maintained by some pastoralists will almost certainly alter "pristine" or "climax" vegetation. The range management question is not about the condition of the range per se, but about the long-run sustainability of the ranching system.[14]

Behnke and Scoones [1992, p.18] note:

> Direct examination of rangeland vegetation does not answer this question. Large fluctuations in species composition, plant biomass and cover are characteristic of arid and semi-arid rangelands subjected to erratic rainfall. Because the vegetation in these areas is continuously disturbed, it has adapted to disturbance and possesses an enhanced capacity to recover from disturbance [Walker, et al, 1981] The productivity and composition of such rangelands may be unstable in the short run, but resilient over the long term. [Holling, 1973]
>
> In such an environment, degradation could be said to occur only when the vegetation had crossed, or was at risk of crossing, critical thresholds which prevent or severely inhibit its subsequent return to a more productive state. In practice, the problem is to distinguish between drought induced fluctuations and permanent changes in vegetation states. [Grouzis, 1990] Current knowledge of the dynamics of savanna ecosystems frequently does not permit the distinction to

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[15] As Wilson and Tuper (1982, p. 689) have observed, "agriculture in general is based on the modification or replacement of natural vegetation, and rangeland, although only partially modified, must be assess on the same basis." Very few would conclude that an English sheep paddock or a Javanese rice paddy were degraded solely because, several centuries previously they had replaced a temperate or a tropical forest.

be made with confidence, although future research may eventually clarify the issue [Friedel, 1991; Laycock, 1991]. As a result, it has thus far proved very difficult to differentiate between permanent human-induced degradation, as opposed to temporary rainfall-induced vegetation change [Alchrona, 1989; Warren and Agnew, 1989; Tucker et al, 1991]

Abel points out that classical succession theory and the carrying capacity concept stress the stability of rangeland systems, and degradation is then thought to be occurring when that stability is disturbed. He argues that stability is not achievable under highly variable rainfall. However, a property of an unstable system is likely to be resilience--the ability to recover from perturbation. The large variations in rainfall and herbivore numbers characteristic of semi-arid range promote resilience. [Abel, 1993, p. 3.22]

The carrying capacity concept encourages management for stability. Walker and others [1981] suggest that a system managed for stability may become dominated by palatable grasses that are sensitive to grazing, at the expense of an ungrazeable reserve of unpalatable species. This system is likely to be denuded during drought and susceptible to degradation. Using the range more heavily encourages less palatable species, making it more resilient. In this sense instability promotes resilience. As Abel notes, if a primary aim of management is the persistence of ecological systems, the emphasis should be upon maintaining their resilience rather than seeking an unattainable stability. [Abel, 1993, p. 3.23]

Recent analyses of rangeland degradation in Southern Africa have minimized its extent and concluded that the traditional policy prescription of destocking is often inappropriate. [Tapson, Biot and Abel in Behnke and Scoones, 1993] These findings follow in large part from their assessment of degradation in terms of soil loss rather than vegetation change. Biot's soil loss model for a portion of the hardveld rangeland of eastern Botswana uses the concept of "soil life" or "residual soil suitability" to express the length of time a given level of output from the land can be maintained under different intensities of grazing. His estimation techniques provide an unexpectedly optimistic picture of soil loss on Botswana's communal rangelands. At the stocking densities prevailing at the time of his study, he estimates the residual soil life in his study area to be over 400 years.

Abel attempts to specify what might be an economically acceptable rate of degradation by comparing the economic costs to Botswana herd owners of maintaining current levels of soil loss versus reducing those levels. He bases his comparison on a model which predicts the immediate and long-term effects of two different stocking rates, the current stocking rate in the communal areas of eastern Botswana versus the lower, government-recommended stocking rates for these areas. Based on earlier estimations of herd productivity at these two stocking densities, he concludes that the lower, recommended density would significantly reduce the aggregated productivity of the communal herd and do so at considerable collective cost to herd owners. He shows that the current (high) and recommended (low) stocking densities produced virtually identical levels of soil loss between 1978 and 1988, given the pattern of rainfall in that period. He concludes that the immediate costs to producers of destocking would be heavy, while the long-term gains in reduced range degradation would be slight. Destocking should not be recommended. [Abel, 1993]

The "mainstream view" may have overstated the case that overgrazing is a principal cause of rangeland degradation and that rangeland degradation is widespread. Livestock numbers may be high or even increasing, but this does not necessarily imply that destocking would be a desirable investment. But care must be taken that the "re-think" of range ecology not understate the environmental impact. If mobility is impeded either by increasing costs or increasing population pressure on rangelands, degradation may result. Moreover, since the goals or objectives of pastoralists, ranchers, environmentalists and government range administrators are different, so are their views as to desirable or optimum stocking rates. To a staunch conservationist, even one head of cattle grazing on rangeland is one animal too many. To a pastoralist, there can never be too many animals! The task for policymakers is to try to reach a consensus on objectives for rangeland use, and to design and implement policies that will maximize their attainment, incorporating ecological, economic and cultural perspectives.

APPENDIX B: Analysis of Overstocking

There has been one study in Zimbabwe which attempts to quantify and cost the impact of cattle stocking rate on rangeland sustainability [Child, 1988] Child argues that the major factor causing the declining profitability of the cattle enterprises on Buffalo Range ranch in the Chiredzi area (Natural Region V) was degradation of the grass layer by the cattle it supported. Overstocking caused over-grazing with the result that less fodder was available for cattle in subsequent periods. Cattle production declined and with it cattle profitability. Unfortunately, this link between cumulative overgrazing and decline in herd productivity is based on one ten year period of data (1975-1985) for just one ranch.

Child estimated the degree of overstocking (or understocking) by comparing the actual stocking rate (kg of livemass/ha) with the carrying capacity according to the rainfall of that season as predicted by Coe et al (1976). The measures of overstocking were then cumulated by year.

Child then regressed calving rate against rainfall and against cumulative overstocking to assess the relationship. He found that rainfall had little direct effect on calving rates, but that 54 percent of the variation in calving rates could be explained by cumulative overstocking ($P < .001$). [Child, 1988, p. 433] He argues that this validates Bell's (1982) hypothesis concerning the ecological mechanisms that drive semi-arid, eutrophic savannas, confirming the theoretical arguments about the importance of herbivore-habitat interactions on productivity.

The average annual productivity on Buffalo Range in the 1970s was 14.68 kg livemass per hectare. By contrasting it with the more lightly stocked game section where productivity, if anything, improved, Child argues that overstocking degraded the cattle section until the average annual productivity fell to 8.2 kg livemass/ha by the 1980s, or by over 40 percent over a ten year period. Cumulative overstocking over this period was 93 kg/ha or 4.66 kg/ha/year. Given an annual loss of productivity of 0.32 kg/ha and an annual average rate of overstocking of 4.66 kg/ha, every kg of overstocking reduces productivity by 0.0687 kg livemass (.32/4.66).

This overstocking/herd productivity loss relationship was incorporated into the analysis of the WWF surveyed ranches, one of which was Buffalo Range, and many were in the same area (Chiredzi). First, the carrying capacity for each ranch was calculated according to rainfall using the relationship between rainfall and biomass derived by Coe et al (1976):

$$\text{Log}_{10}\ \text{Biomass (kg/km}^{-2}) = -1.095 + 1.685 \times \text{Log(Precipitation mm)}$$

The degree of overstocking was then calculated as the difference between the metabolic carrying capacity (estimated using Coe et al, 1976) and the metabolic biomass of both cattle and wildlife (in kg biomass per hectare). The metabolic stocking rate for cattle was calculated using six sex and age categories, and that for wildlife using average weights for each species.

The estimation of overstocking can be expressed algebraically as follows:
where

SR = stocking rate
CC = carrying capacity

$$\sum_{1}^{i} (SR_i - CC_i)$$

Rates of overstocking (metabolic biomass) were then converted back into LSUs (454 kilograms) using a divisor of $454^{0.75}$. This was necessary since estimates of the costs of overstocking used biomass, not metabolic biomass. The cost of overstocking was estimated by multiplying the rate of overstocking (biomass) by the per kilogram cost of overstocking. During the survey period one kilogram of livemass was valued at $1.65. Thus overstocking translates into a financial loss of $ .113 per kilogram overstocking per hectare.

The contribution of wildlife and cattle to overgrazing was allocated in direct proportion to their contribution to the grazing component of the metabolic biomass. The cost of overstocking is allocated to wildlife and cattle in the same proportion. For wildlife this is calculated according to the ratio of grass in the diet, while cattle are assumed to be grazers.

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