AN ABSTRACT OF THE THESIS OF

John Augustus Tanaka for the degree of Master of Science

in Rangeland Resources presented on July 29, 1982

Title: Evaluating the Relative Worth of Public Range Improvements to a Cow-Calf Ranching Operation Through Computer Simulation

Abstract approved: Redacted for Privacy

Richard Frank Miller

A computerized ranch simulation model of an eastern Oregon cattle ranch was tested for its ability to evaluate the economics of public rangeland improvement practices. The model was used to estimate likely impacts of various public policy alternatives for rangeland improvement on the relative profitability of a 400 mother cow ranch operation under alternative cattle prices at constant costs. The simulation model described herein is a tool to assist in making decisions concerning the efficient use of available public resources (i.e., labor, capital) in agriculturally dependent areas.

Statistical analysis of the results showed the model was sensitive to different range improvement prescriptions at different sizes. The model was insensitive to changes caused by random forage production values. Subjective interpretation of annual changes in net worth among alternatives over time provided information useful for decision-making.

A scoping process was used to reduce the number of alternatives

for intensive evaluation. At each step in the scoping process a more specific decision criterion was imposed and the least desirable alternative(s) eliminated. When the number of alternatives was reduced to a manageable level or when decision criteria were exhausted, the remaining alternatives were compared on a year-by-year basis in order to ascertain if there were any qualitative differences.

From the private point-of-view, it could be inferred that public investments in range improvements would best be concentrated on projects with earlier returns. From the public decision-makers' point-of-view, this information would be only one of many decision variables to consider in the selection of an alternative.

Evaluating the Relative Worth of Public Range Improvements to a Cow-Calf Ranching Operation Through Computer Simulation

by

John Augustus Tanaka

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Commencement Date
June 1983

APPROVED:

Redacted for Privacy

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Date thesis is presented July 29, 1982

Typed by Gloria Wuoti for John Augustus Tanaka.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

We have not solved all our problems
   In some ways we feel we have not
   Completely solved any of them
The answers we have found only serve to
Raise a whole new set of questions
   We feel we are confused as ever
But we are confused on a much higher level
   About more important things.

Anonymous

With that thought in mind I would like to thank those who have helped me become "confused on a much higher level." To this end, I would like to thank Drs. R. F. Miller and W. E. Schmisseur, my major and minor professors, respectively, for their invaluable advice and assistance during the project and for their patience in awaiting the final product. There are many more at Oregon State who provided assistance at various points in the study, most notably C. Whitley (Agricultural and Resource Economics) and Drs. W. C. Krueger and T. E. Bedell (Rangeland Resources). Also with input, but no longer at Oregon State, were Drs. A. H. Winward and P. Case (Rangeland Resources and Forest Management, respectively).

I sincerely appreciate the cooperation and support I have received from the faculty and staff in the Division of Range Resources of the School of Renewable Natural Resources, University of Arizona during the completion of this thesis while employed as a member of the Range Research Task Force.

I would also like to thank Helen Dufur in Corvallis for typing an initial draft and Gloria Wuoti in Tucson for the final draft --

this assistance was invaluable. Last, but not least, I would like to thank my family for their support throughout all of this.

Evaluating the Relative Worth of Public Range Improvements to a Cow-Calf Ranching Operation Through Computer Simulation

INTRODUCTION

Statement of the Problem

Multiple use demands on public lands have given rise to the need for better decision-making information in order to meet these demands in an environmentally safe and economically sound manner. Because ranching is one of the most important economic industries in rural counties of eastern Oregon and because most of these ranches are seasonally dependent on forage from public lands, impacts on ranches resulting from public land use decisions should be determined and considered in the public land use decision-making process.

Public land managers have several options for increasing the carrying capacity of rangeland. These may be grouped into either canopy reducing-forage increasing improvement prescriptions or improvements to aid in cattle distribution. This study was designed to assist both public and private land managers in determining the impacts on a ranch enterprise from various canopy reducing-forage increasing improvement prescriptions.

Objective of the Study

The objective was to estimate economic impacts on a cow-calf ranching operation from public rangeland investment alternatives.

The goals to fulfill this objective were to define an "average" set of conditions for an eastern Oregon ranch and to examine likely impacts of alternative public rangeland improvement prescriptions on that ranch situation.

Public Rangeland Improvement Prescriptions -- Three general types of rangeland improvement practices were selected for study. These were differentiated by: (1) vegetation type, (2) expected forage response, and (3) follow-up cattle management required. A brief description of each alternative is presented below.

A forested land prescription (referred to as THIN) called for precommercial thinning of a mixed conifer stand and selectively seeding a forage mix into disturbed areas. THIN allowed light grazing the year following thinning and normal grazing the next year.

Two high desert rangeland prescriptions (RELEASE and SEED) called for sagebrush overstory removal on sites in different range condition. No other cultural treatments were required for RELEASE. SEED, however, required that a forage grass be seeded following overstory removal. RELEASE allowed normal grazing the year after the treatment, while SEED did not allow grazing until the second year after the treatment.

Each prescription was tested at three alternative acreages. Because expected forage responses vary by improvement practice and land type, no attempt was made to equate total forage responses among prescriptions. For example, the small acreage used for THIN may or may not produce the same amount of total usable forage as the small acreage of either RELEASE or SEED.

Ranch Variables -- Average cattle prices and forage response indices were selected as variables that would likely have significant impacts on ranch net worth. All other components of the "average" set of ranch conditions were held constant.

Cattle prices were selected because they may be the most important single factor affecting ranch profitability with possible impacts on relative positioning of the alternatives. Initially, actual cattle price cycle data sets were used but they tended to confound the results making them uninterpretable. Therefore, three price sets were selected and assumed to represent the average price for the life of the experiment.

Forage production was adjusted each model year based on a randomly selected precipitation index. There were two reasons why this index was the only random variable in the simulation, these were: (1) with a limited number of computer runs too many random variables would confound the results and (2) some randomness was desired in order to statistically test model sensitivity to other variables. In addition, random forage fluctuations in the model would require more realistic ranch responses to forage surpluses and shortfalls.

Hypotheses

Several hypotheses were made prior to the experiment concerning expected effect that variables would have on the firm. These hypotheses, listed below, were intimately related to the selection of variable levels used in the experiment.

1. Given that an enterprise's annual net worth is changed primarily by the difference between gross receipts and gross expenses (cash and non-cash), it was expected that alternative average cattle prices would affect net worth more than any other single factor.

2. Given a constant set of costs, it was expected that a realistic break-even average set of cattle prices could be determined.

3. Given that all improvement prescriptions were implemented in the second year, it was expected that the major economic impacts from the action could be observed by the time normal grazing had resumed in all prescriptions.

4. Given a constant herd size, it was expected that: (A) improvement prescriptions with longer rest following implementation would be worse off economically in the short-term than those with less rest; (B) larger acreage sizes for each prescription would have more adverse economic impact on net worth values in the short-term than the same prescription at lesser sizes, and; (C) long-term benefits from larger acreage sizes within a given prescription would be greater than benefits from smaller sizes.

5. Given the often stated view of the effects "good" and "bad" years have on ranch income, it was expected that randomizing forage production levels to reflect drought, normal, or high production years would cause significant differences among replications.

RESEARCH APPROACH

In order to determine economic impacts on a cattle ranch from public range improvement investment alternatives, two courses of action are possible. The first is to conduct actual experiments on operating ranches and follow their progress through time. The second is to design a computer model of the ranching system and use it to conduct the experiments. The problems associated with conducting large scale, long-term research on operating ranches may be overcome by utilizing the second course of action.

Because a modern ranch can be described as a complex interrelationship among physical, biological, and economic systems, systems simulation modeling was selected as a reasonable method for achieving the objectives of the study. A simulation model of a ranch can be used to help determine expected results from an alternative before it is actually implemented on the ground. Analysis of simulation results can be aided by holding all nonrelevant variables static and only varying those of primary interest. A more detailed discussion of systems simulation may be found in Appendix A-1.

In this study, the model was used to test a factorial arrangement of cattle prices, improvement prescriptions, and prescription acreages. Each combination was simulated and the results were both objectively and subjectively analyzed. Objective analysis should be limited to a form of sensitivity analysis. This is because the model has not been validated and basing decisions strictly on real numbers may prove misleading. Therefore, the subjective analysis provides information on how input changes, subjected to the same solution algorithm, affect the relative rankings among alternatives. This information should be useful in making decisions since it does not imply that the net worth will change by the specified amount. Rather, it only implies that one alternative appears to be better overall than another.

EASTERN OREGON RANCH SIMULATION MODEL

The eastern Oregon ranch simulation model was adapted from the Beef-Forage-Grain Production Model as described by Sonntag and Klein (1977). The model includes forage and grain production sub-enterprises which exist to support the beef production sub-enterprise. The ranch model will be discussed in terms of the objective function used, the relevant features of the three sub-enterprises, and the variables used in the experiment.

Objective Function

The objective function of the ranch model used to differentiate alternatives was terminal net worth of the ranch. Terminal net worth was measured at the end of the tenth simulated year.

Model Features

Cattle ranches may be typified as specialized agricultural firms involved primarily in the production of red meat. The modern ranch is composed of many parts linked together through complex inter-relationships. In an eastern Oregon cow-calf operation, a base herd of mother cows, replacement heifers, and bulls is maintained throughout the year. Replacement heifers are normally retained from the calf crop. Calves are typically born in early spring, weaned in fall, and sold shortly thereafter.

The base herd must be fed and/or pastured throughout the year.

One scenario for providing feed and forage is grazing lower elevation ranges in spring and fall, grazing upper elevation ranges in the summer, and feeding hay and/or grain or grazing grain stubble and hay aftermath in late fall and through the winter. Supplemental feeding with hay and/or grain can occur any time the nutritional level of the feed is insufficient. Many operators in eastern Oregon produce their own hay and grain for feeding, although in poor forage production years they may be forced to purchase feed from outside sources.

The production of feed and cattle requires physical inputs such as buildings, land, machinery, capital, and labor. Relative profitability of the firm depends on the costs of these physical inputs, the prices for the products, and the overall efficiency in converting inputs to outputs.

The ranch simulation model is an abstraction of the feed-to-beef production process. It is based on the premise that the firm produces end products from intermediate products and elemental inputs, and that intermediate products are produced from other intermediate products and elemental inputs. The model divides a year into twenty-six bi-weekly periods through which products are moved much the same as they are in an actual ranching situation.

The primary end product of a ranch is production of red meat (pounds of calves). The base herd, an intermediate product, is maintained by utilizing the intermediate products of forage and grain. The intermediate products are produced by also using elemental inputs such as seed, fertilizer, land, and labor. Elemental inputs may be introduced into the firm any time they are required.

Model use begins with the user inputting data representing the resources of an on-going ranching operation at a given point in time. From this "initial" situation the operation is simulated for one to ten years. The model tracks the resource flows, as governed by decision rules and production relationships specified both by user input and in the model, through each bi-weekly period for the life of the simulation.

Discussion of the ranch model will focus on those portions relevant to the simulation study. The points to be covered relate primarily to forage and feed production for the production of calves for sale and maintenance of the beef herd. The initial ranch situation used in the experiment will be presented in a later section.

Forage and Feed Production -- Within the model, land is divided into either pasture or crop land. Deeded pasture lands are further divided into improvable range, unimprovable range, improved range, grain stubble fields, and hay aftermath fields. Public range is treated by the model as animal unit months (AUMs) of forage, which would correspond to the licensed level. Therefore, total acres of public range is irrelevant to this model. Because improvements were on discrete acres, total forage allocated to cattle on public range was converted to an AUM basis in order to be compatible with the model structure. Thus, deferment resulted in fewer total AUMs for that season, and future increases resulted in more total AUMs. Crop land is divided into grain and hay fields. Average production values for each land class and total AUMs of public range are designated at the initialization for each simulation run.

The equation used in the model for relating average annual pasture production to the amount available in each bi-weekly period was developed by Sonntag and Klein (1977):

$$PP_k = \sum_{j=1}^{n} PA_j \; AY_j \; R \; U_{ij} \; Y_{ij} \; (1.0 - PD)$$

where: PP_k = pasture production in period k,

PA_j = acres of pasture type j,

AY_j = average yield of pasture type j,

R = rainfall index related to random fluctuations,

U_{ij} = use rate for pasture type j in season i,

Y_{ij} = yield index for pasture type j in season i, and

PD = pasture deterioration rate.

Acres (PA_j) and average yields (AY_j) for each pasture type are single, constant values provided for the specific operation being evaluated. The rainfall index (R) is randomly selected for each simulated year in order to represent natural variability expected in forage production.

The use rates (U_{ij}) for each pasture type and season of use are shown in Table 1. These represent the amount of current years growth that can be removed without pasture deterioration. Table 2 shows how these values are affected by a pasture yield index, Y_p (related to R and different than Y_{ij}). Although values for Y_p can be any real number, values shown in Table 2 demonstrate that heavier utilization rates are allowed in poor forage production years and vice verse.

TABLE 1 -- Use Rates (Uij) by Pasture Type and Season of Use[1]

	Season of Use				
Pasture Type	All Year	Spring	Summer	Fall	Winter
Improvable Native	.55[2]	.55	.55	.75	.75
Unimprovable Native	.55	.55	.55	.75	.75
Crested Wheatgrass		.75	.75		
Grain Stubble				1.00	1.00
Hay Aftermath				1.00	1.00

1 - Adapted from Sonntag and Klein (1977).

2 - Assumes normal precipitation and a grazing method that allows for maximum plant growth. Values represent proportion of current years growth safely removable by cattle.

TABLE 2 -- Use Rates (Uij) as Affected by a Pasture Yield Index (Y_p)[1]

	Average Use Rate		
Pasture Yield Index	.55	.75	1.0
.50	.78	.88	1.0
.75	.66	.81	1.0
1.00	.55	.75	1.0
1.25	.44	.69	1.0
1.50	.32	.62	1.0

1 - Adapted from Sonntag and Klein (1977).

The yield indices (Y_{ij}) for each pasture type and season of use are shown in Table 3. The yield index assumes that maximum forage growth (AY_j) occurs by summer and, therefore, use in any other season means that there is less than the maximum amount available.

The pasture deterioration rate is put in to reflect forage losses due to factors other than cattle consumption. The deterioration can be due to factors such as trampling, wildlife, or natural losses.

Grain and hay crops are produced to meet feed requirements of the herd. Annual yields are computed from total acres times average yields. Variability in production was not assumed since these crops are produced by intensive methods (i.e., irrigation, fertilization) to smooth out the peaks and valleys of native range production.

Beef Production -- Feed and forage requirements for growth of the calves and maintenance of the base herd are computed for each bi-weekly period. These requirements are expressed as the amounts of digestible energy and crude protein required by each class of animal. Digestible energy requirements will determine the need for feeding hay or grain to supplement native forage. The total diet will determine the need for feeding supplemental protein.

The digestible energy requirement equations used in the model were presented for each class of animal by Sonntag and Klein (1977):

TABLE 3 -- Effect of Season of Use on Total Available Forage Yield (Yij)[1]

Pasture Type	Season of Use: All Year	Spring	Summer	Fall	Winter
Improvable Native	.73[2]	.73	1.00	.95	.85
Unimprovable Native	.73	.73	1.00	.95	.85
Crested Wheatgrass		1.00	.80		
Grain Stubble				1.00	1.00
Hay Aftermath				1.00	1.00

1 - Adapted from Sonntag and Klein (1977).

2 - Assumes that maximum growth occurs in summer on native range and spring for crested wheatgrass stands. Thus, use in any other season results in lower total yields.

Bulls = $DE_{1k} = 76\ W_1^{.75}$

where DE_{1k} = kcal of digestible energy required per bull per day in period k, and

W_1 = mature weight of bulls.

Cow in summer = $DE_{2k} = 98.7\ W_{2k}^{.75} + 4534R_2$

where DE_{2k} = kcal of digestible energy required per cow per day in period k,

W_{2k} = average weight of cows in period k, and

R_2 = daily weight gain for mature cows to recover weight lost in calving.

Cows in winter = $DE_{2k} = 76\ W_{2k}^{.75}\ P_1 + (76\ W_{3k}^{.75} + 3484R_3)P_2$

where P_1 = proportion of herd composed of mature cows,

P_2 = proportion of herd composed of first-calf cows,

W_{3k} = average weight of first-calf cows in period k, and

R_3 = daily weight gain required for first-calf cows to reach mature cow weight.

Replacement heifers = $DE_{3k} = 76\ W_{4k}^{.75}\ (1. + .578R_4)$

where DE_{3k} = Kcal of digestible energy required per heifer per day in period k,

W_{4k} = average weight of replacement heifers in period k, and

R_4 = daily weight gain of replacement heifers

(R_4 = 1.35 from weaning to breeding,
R_4 = 1.0 from breeding to first calving,
R_4 = 1.8 from calving to weaning of first calf).

Once digestible energy requirements for each time period are computed, they can be converted to pounds of forage required for the herd. Conversion was assumed to be 1000 kcal of DE/lb of air-dry forage. In the model the digestible energy was converted as shown by Sonntag and Klein (1977):

$$PR_k = \sum_{m=1}^{n} AN_{km}\ DE_{km}\ PPH_m/1000.$$

where: PR_k = pasture requirement in period k,
AN_{km} = number of animals of class m in period k,
DE_{km} = digestible energy requirements of animal class m in period k, and
PPH_m = proportion of DE from pasture for animal class m.

If pasture production required is more than that produced, the deficit will be made up by feeding hay and/or grain. Crude protein content of the total diet is then computed and compared to crude protein requirements. Percent crude protein values used are presented in the initialized ranch situation. If the requirement is greater than that found in the diet, a protein supplement is purchased and fed.

As a result of the balanced diet the firm is able to produce a calf crop. In addition to the sale of calves, the firm is able to gain additional revenues from the sale of cull cows and bulls as well as excess hay and grain. Nevertheless, the profitability of the firm is based on its ability to economically produce forage, hay, and grain and efficiently convert it into calves for sale.

Model Variables

Within the model three factors were varied -- improvement prescriptions, prescription acreages, and cattle prices. The canopy reducing-forage increasing improvement alternatives are described below, followed by the values used for alternative acreages and cattle prices.

Canopy Reducing-Forage Increasing Improvement Alternatives -- The range improvement prescriptions considered here have been grouped under the heading of canopy reducing-forage increasing practices in order to differentiate them from investments in structural range improvements such as fencing and water developments. The purpose of the prescriptions being considered was to produce more forage for domestic livestock and thereby increasing the carrying capacity of the land.

Three alternative improvement prescriptions were considered: (1) precommercial thinning of a mixed conifer stand followed by selective grass reseeding, (2) releasing native grasses on summer high desert range by overstory removal, and (3) reseeding grass on summer high desert range after overstory removal. The prescriptions related to each of these will be referred to as THIN, RELEASE, and

SEED, respectively.

Each alternative used a different set of heuristics to define how grazing would be allowed following the treatment. The treatment occurred in the second year of a ten year simulation. Since prescriptions were publicly financed the cost to the ranch for the treatment was assumed to be the price of the grazing permit plus the amount of non-use required if the area was being previously grazed. The ranch was required to find alternative feed sources equal to the amount of non-use required in RELEASE and SEED. When full use was reached following any of the treatments the ranch was not allowed to increase herd size. Instead, cattle were assumed to be moved from private pastures to the public allotment.

Forested Areas -- Community types were selected as the forest homogeneous response unit upon which prescription effects could be estimated. The mixed conifer community type with greater than forty percent cover was used in the simulation for the prescription described below. This community type was described as a complex of ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), and Douglas-fir (*Pseudotsuga menziesii*) (Hall 1973).

THIN called for pre-commercial thinning of the mixed conifer stand followed by reseeding disturbed areas with a mixture of grasses such as orchardgrass (*Dactylis glomerata*), timothy (*Phleum pratense*), and smooth brome (*Bromus inermis*) and adding a nitrogen-fixing legume such as white clover (*Trifolium repens*) (Hedrick *et al*. 1968, Helvey and Fowler 1979). Light grazing was allowed in the third year at twenty-five percent of available forage. Normal grazing was assumed to occur in the fourth year.

Pretreatment forage production was assumed to be zero (Hall 1973). This was assumed to be due to either a lack of understory vegetation or because the area was inaccessible to cattle. Normal year forage production after THIN was assumed to be 400 lb/ac (McClure 1958, McConnell and Smith 1965, 1979, Schwendiman 1968, Sassaman *et al*. 1973).

Non-forested Areas -- Range sites were selected as the homogeneous response unit for non-forested rangelands. The high desert of eastern Oregon was selected as the major land type upon which the publicly financed prescriptions were implemented. The range site used to define coefficient values for RELEASE and SEED was assumed to be dominated by mountain big sagebrush (*Artemisia tridentata* var. *vaseyana*) and bluebunch wheatgrass (*Agropyron spicatum*). This range site was assumed to be in fair and poor range condition for RELEASE and SEED, respectively. Range condition, as used here, means the relative value of the present plant community for domestic livestock grazing.

On range sites in fair condition RELEASE called for sagebrush overstory removal by either prescribed burning, mechanical treatment, or herbicide treatment. Native grasses would then be released from overstory competition and allowed to spread. Grazing was allowed in the year following the treatment. Pretreatment forage production was assumed to be 250 lb/ac (Hyder and Sneva 1956, Hedrick *et al*. 1966). Following treatment normal year forage production was assumed to be 450 lb/ac (Hedrick *et al*. 1966, Miller *et al*. 1980).

On range sites in poor range condition SEED called for removal of the sagebrush overstory by either prescribed burning, mechanical treatment, or herbicide treatment and following it with a grass reseeding project. For the coefficient value it was assumed that crested wheatgrass (*Agropyron cristatum*) was seeded. Grazing was not allowed until the fourth simulation year (two years after treatment). Pretreatment forage production was assumed to be 50 lb/ac (Hedrick *et al*. 1966, Sneva and Rittenhouse 1976). Following treatment, normal year forage production was assumed to be 675 lb/ac (Hyder and Sneva 1963, Hedrick *et al*. 1964, Sneva and Rittenhouse 1976).

Prescription Acreages -- Table 4 shows the prescription and acreage combinations evaluated in the model. Acreages were selected in order to represent the range of project sizes expected to occur on public lands within a given year on an average grazing allotment.

Cattle Prices -- Table 5 shows the alternative sets of average cattle prices used. These price sets were assumed to represent average values for the cattle price cycle ranging from optimistic to pessimistic. They were based on the actual cattle price cycle experienced in eastern Oregon from 1967 to 1977.

TABLE 4 -- Prescription X Size

	SIZE (ACRES)		
	Small	Medium	Large
PRESCRIPTION			
THIN	200	500	1000
RELEASE	500	1000	2000
SEED	200	500	1000

TABLE 5 -- Average Price Sets for Classes of Cattle

	PRICES ($/cwt)		
	Low	Moderate	High
CATTLE CLASS			
Cull cows	25.00	38.00	63.00
Bulls	20.00	30.00	50.00
Steer calves	29.00	44.00	73.00
Heifer calves	26.00	39.00	65.00

"INITIALIZED" RANCH SITUATION

A "typical" eastern Oregon ranch situation was defined for the purposes of this study. Values used were obtained from a wide variety of sources. Specific values are documented in Appendix A-2 of the thesis associated with this paper. In general, they were derived from literature searches, rancher interviews, and previous work at Oregon State University.

The typical ranching situation used can be shown in two ways. First, all physical resources at the disposal of the rancher will be depicted. Second, values for important coefficients will be presented.

Table 6 shows the initial physical inventory of the ranch. In addition to the items shown the ranch was assumed to have all necessary machinery to conduct all of its operations.

Table 7 shows values relevant to the beef herd. Table 8 shows values relevant to forage and feed production. Table 9 shows values relevant to the financial aspects of the ranch enterprise.

TABLE 6 -- Physical Inventory

Beef Herd

Bulls	15
Cows	340
Bred heifers	60
Replacement heifers	60

Forage and Feed Base

Grain inventory	1500 bushels
Hay inventory	720 tons
Grain land	160 ac
Grass-legume hay land	150 ac
Pasture - improvable native	1550 ac
- unimprovable native	2100 ac
- crested wheatgrass	300 ac
- hay aftermath	150 ac
- grain stubble	160 ac
Federal grazing permit	300 au/season

TABLE 7 -- Beef Herd Coefficient Values

		Pasture	Hay	Grain
Diet Proportions -				
Breeding Herd:	early winter/early spring......	0.8	0.2	
	winter (5 months).............		0.9	0.1
	summer........................	1.0		
Replacement Heifers	....		0.7	0.3

Calving Rate (%) - cows.....................................95
- heifers.....................................87

Calf Birth Weight (lb)- from cows...............................75
from heifers..............................70

Average Daily Gains (lb/day) - calves from cows.....................1.75
calves from heifers.................1.50
replacement heifers.................1.35
bred heifers to calving.............1.00
bred second calf heifers to weaning..0.75

Breeding Herd Replacement Rate (%)................................15

Conception Rate (%)...95

Mortality Rates (%) - bulls...................................... 0.0
cows....................................... 1.5
calves..................................... 2.5

TABLE 8 -- Forage and Feed Coefficient Values

Pasture Yields (lb air-dry/ac)	improvable native	300
	unimprovable native	225
	crested wheatgrass	715
	grain stubble	200
	hay aftermath	300
Hay Yield (lb air-dry/ac)	first cut	1.75
	second cut	2.50
Crude Protein Content (%)	grain	8
	grass-legume hay	8
	fall and winter pasture	5
	spring and summer pasture	13
Land Values ($/ac)	improvable native	20
	unimprovable native	15
	crested wheatgrass	30
	grain land	1000
	hay land	500
Annual Land Costs ($/ac)	improvable native	0.02
	unimprovable native	0.02
	crested wheatgrass	0.22
	grain land	5.50
	hay land	5.15
Total Cost For Federal Grazing ($/AUM)		10.68

TABLE 9 -- Financial Coefficients

Interest Rates on Loans (%)	30 years	6.5
	20 years	6.5
	15 years	6.5
	10 years	8.0
	5 years	8.0
	3 years	8.5
	Short-term capital	9.0
Repayment Periods (Years) -	Buildings	10
	Machinery	5
	Breeding Stock	3
	Land	>15

Cash on Hand = $10,000

Minimum Living Expense = $ 5,000/year

Wages for Seasonal Labor = $2.50/hour

METHODOLOGY

Results from the simulation experiment represent relative values for investment alternatives run through the same solution algorithm. As such, subjective analysis of the results may provide the greatest amount of information. Nevertheless, results obtained by using high average cattle prices were statistically analyzed to test the model's sensitivity to the variables.

Statistical Methods

The factorial experiment (prescription x acreage) for the high average cattle price set was replicated five times. Variation among replications was caused by randomly ordering rainfall indices (1967-1977) for each simulation run.

Sensitivity of the model to the variables was detected by analysis of variance. The model was considered sensitive when computed F-values exceeded the expected values at the 0.01 percent level of significance.

Research Technique

To begin the ranch simulation experiment, the model was initialized with hypothetical data for an average 400 mother cow ranch operation located in rural eastern Oregon. Each public rangeland improvement prescription was then simulated at alternative prescription sizes and at different average cattle price sets. All other coefficient values, factor costs, and factor prices were held constant.

Following the sensitivity analysis on the high average cattle price experiment data described earlier, variables found to have non-significant impacts on terminal net worth were considered no further. Simulation runs were then made using the remaining average cattle price sets for each improvement prescription x prescription size combination.

It was determined that the objective function alone was not sufficient to differentiate among the impacts of the various alternatives. Thus, in this case, terminal net worth was not adequate as a variable on which to base a choice. Therefore, in order to compare differences among alternatives, relative changes in annual net worth over the life of the experiment for each alternative were used as the decision criteria.

The data were grouped by different variable combinations and graphed accordingly. These graphs provided visual representations of the relationships among variables. The graphs were used to obtain relative rankings of the alternatives when changes were followed through time. This subjective analysis focused on identifying the "best" alternative in terms of overall impact on the ranch enterprise.

The analysis involved a series of scoping steps where some alternatives were rejected without intensive analysis. Each successive scoping step involved a more detailed aspect to the data represented in the graphs. Following the scoping process, each remaining alternative was compared to all other alternatives in order to determine the final selection.

ANALYTICAL RESULTS

Results from this study will be presented in two forms. First, because terminal net worth values were selected as the objective function, data from the five replications using high average cattle prices are presented in Table 10. The analysis of variance conducted on this data is presented in Appendix B. Graphs of RELEASE replications are shown in Appendix C.

Second, because the focus of this study was to provide information for decision-making, annual net worth data of each tested alternative will be presented in various ways to aid in the analysis. As an example of annual change in net worth data obtained from the model, results from THIN 200 ac at high average prices are shown in Table 11. Average annual change in net worth data for each factorial combination are shown in Appendix D. Data presented in Appendix D are shown graphically in Figures 1 through 6 in different combinations.

Figures 1, 2, and 3 show graphs grouped by average cattle price sets. Figures 4, 5, and 6 show graphs grouped by improvement prescriptions. These figures show years one to seven (instead of ten) because changes in relative positioning remained fairly constant after year seven.

Ten year average annual percent return on equity values are presented in Table 12. Ten year average increases or decreases in annual net worth for each alternative are shown in Table 13. Average increases or decreases in annual net worths for the second through fifth simulated years are shown in Table 14.

TABLE 10 -- Terminal Net Worth Values ($) from the High Average Cattle Price Set Experiment

Prescription	Replication	Acreage Size		
		Small	Medium	Large
THIN	1	1064459	1053199	1050290
	2	1061640	1058900	1048782
	3	1061517	1055910	1048783
	4	1062470	1056234	1043548
	5	1060813	1055020	1045479
RELEASE	1	1060862	1051087	1039411
	2	1062202	1054311	1037777
	3	1062904	1054105	1036402
	4	1060115	1056772	1041123
	5	1059544	1055485	1039155
SEED	1	1054334	105559	1048820
	2	1054679	1054827	1047538
	3	1053718	1053069	1046744
	4	1054716	1054588	1050661
	5	1052231	1055254	1046800

TABLE 11 -- Average Annual Change in Net Worth Values ($) for THIN at Small Acreage and High Average Cattle Prices

END OF YEAR	NET WORTH
1	35,800
2	31,600
3	38,300
4	43,500
5	45,500
6	55,000
7	55,500
8	46,600
9	57,400
10	53,900

FIGURE 1 -- Comparison of Average Annual Net Worth Changes Among Prescriptions Using Low Average Cattle Prices

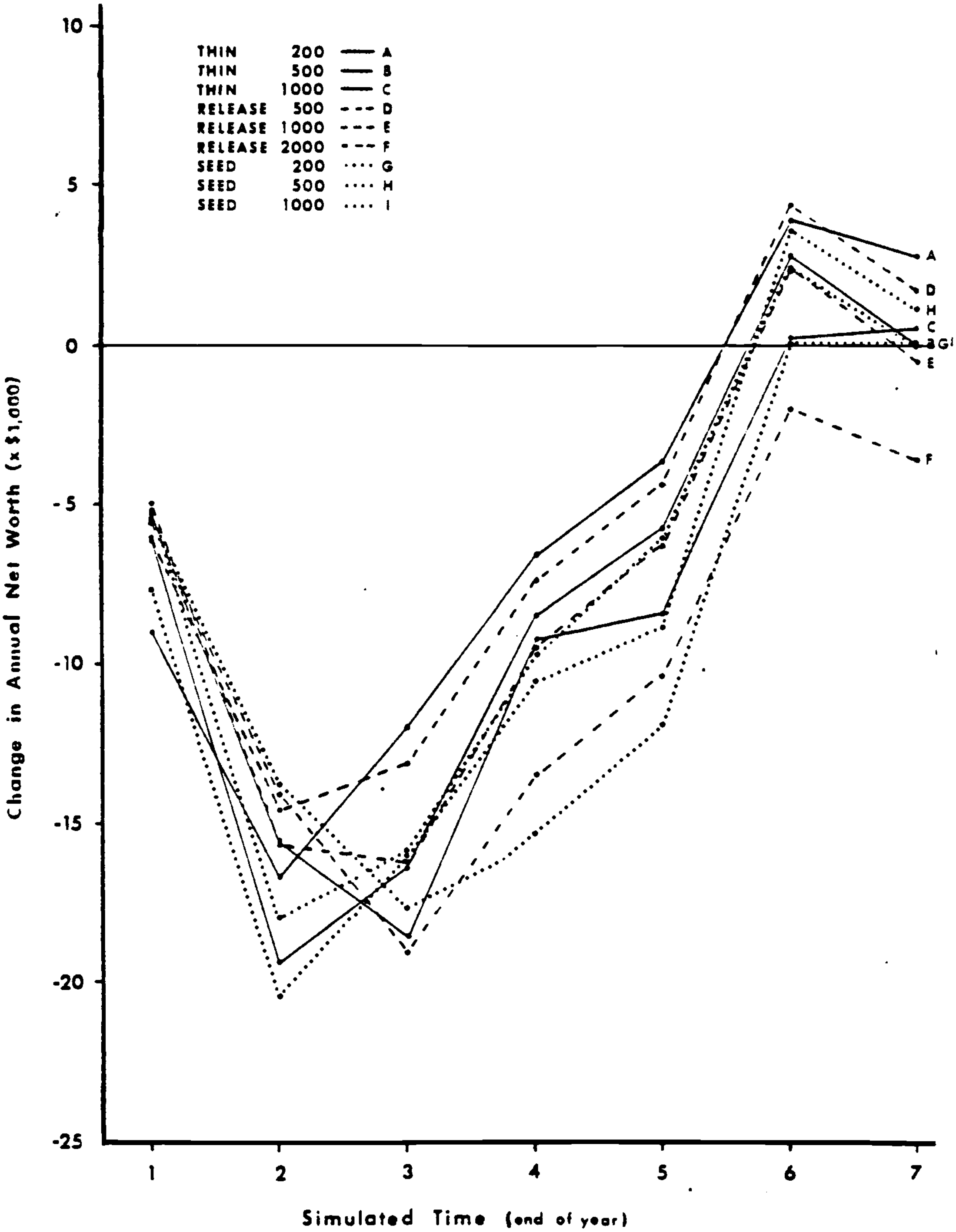

FIGURE 2 -- Comparison of Average Annual Net Worth Changes Among Prescriptions Using Moderate Average Cattle Prices

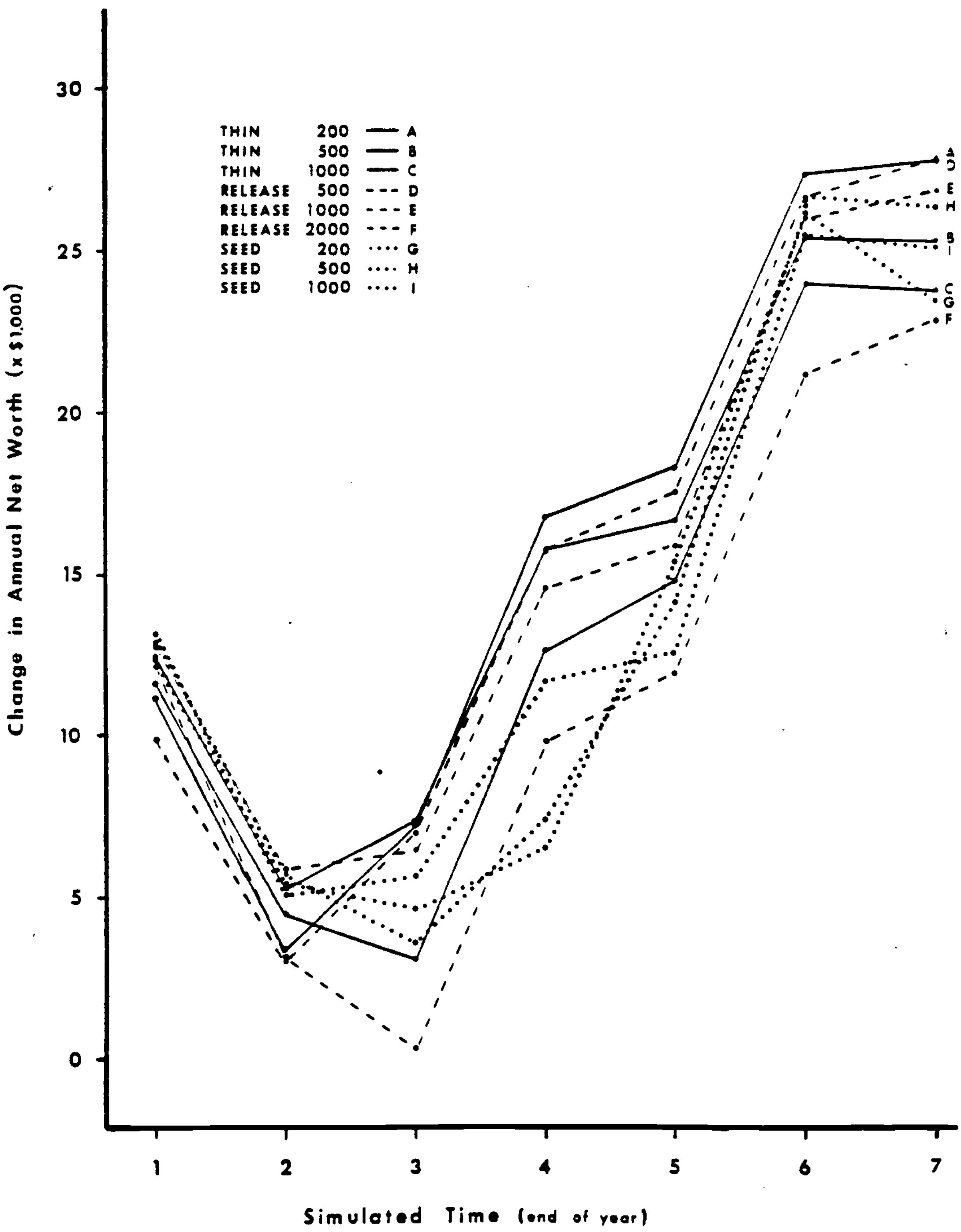

FIGURE 3 -- Comparison of Average Annual Net Worth Changes Among Prescriptions Using High Average Cattle Prices

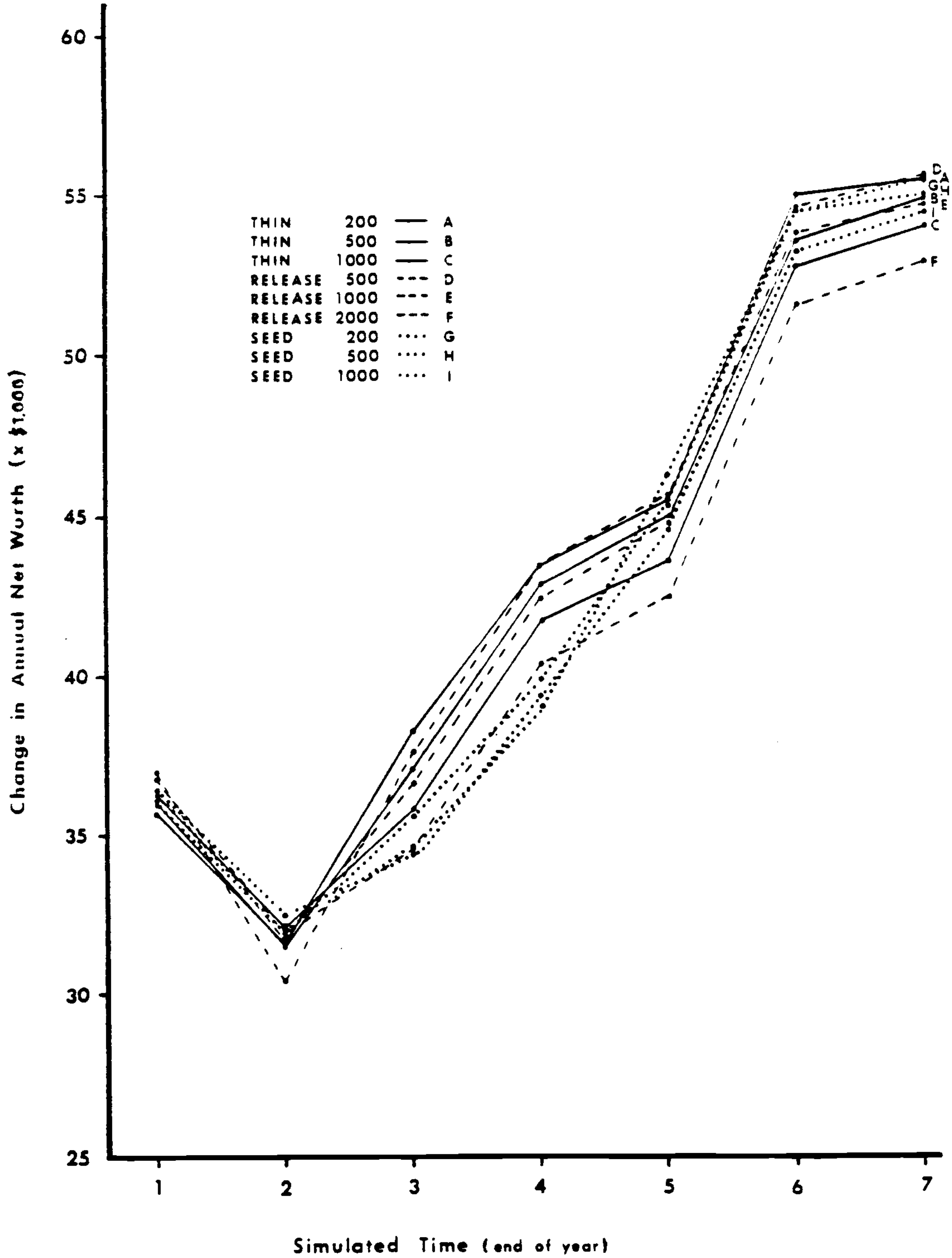

FIGURE 4 -- Comparison of Average Annual Net Worth Changes Within THIN Where The Upper, Middle, and Lower Sets of Lines Represent High, Moderate, and Low Average Cattle Price Sets

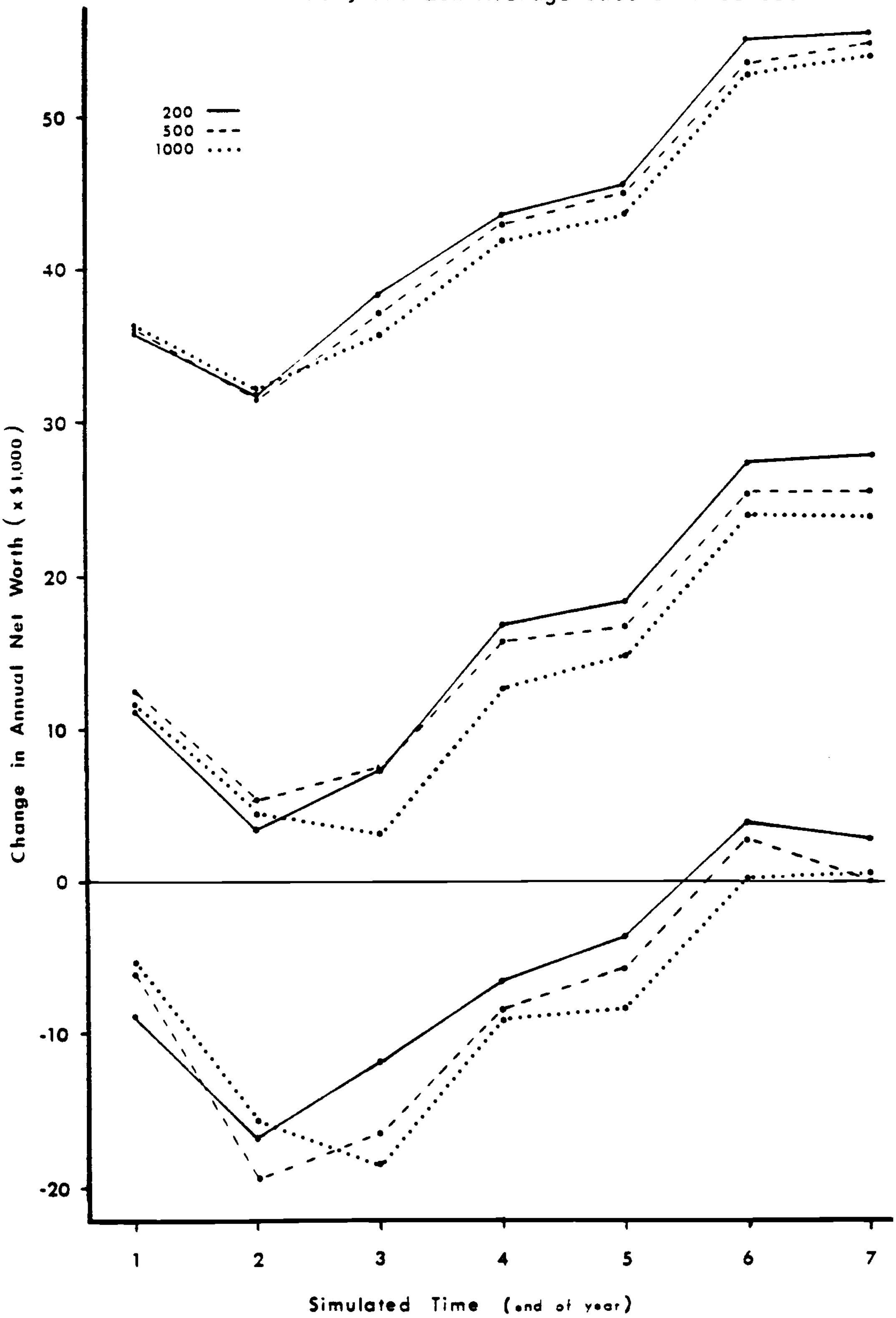

FIGURE 5 -- Comparison of Average Annual Net Worth Changes Within RELEASE Where The Upper, Middle, and Lower Sets of Lines Represent High, Moderate, and Low Average Cattle Price Sets

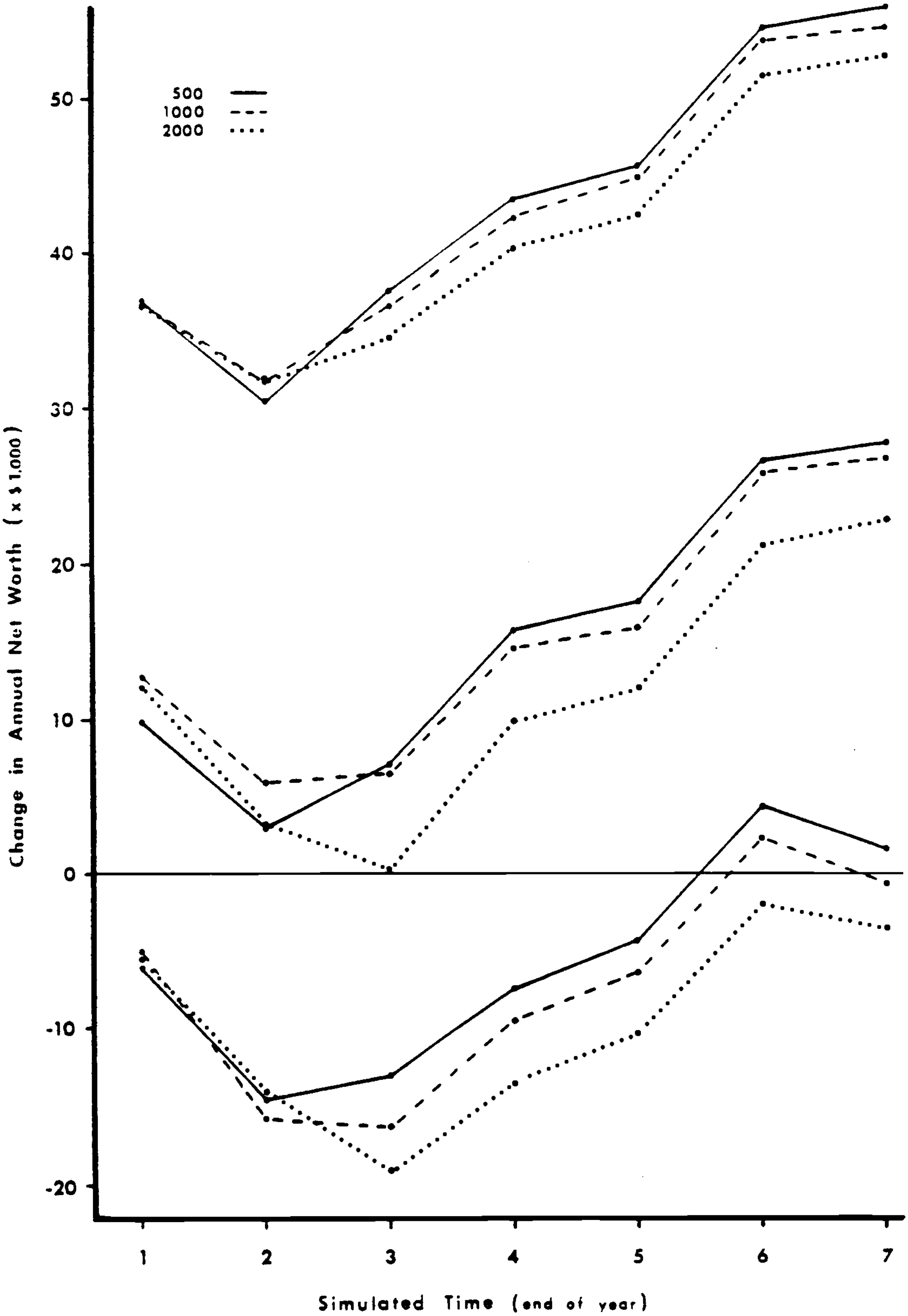

FIGURE 6 -- Comparison of Average Annual Net Worth Changes Within SEED Where The Upper, Middle, and Lower Sets of Lines Represent High, Moderate, and Low Average Cattle Price Sets

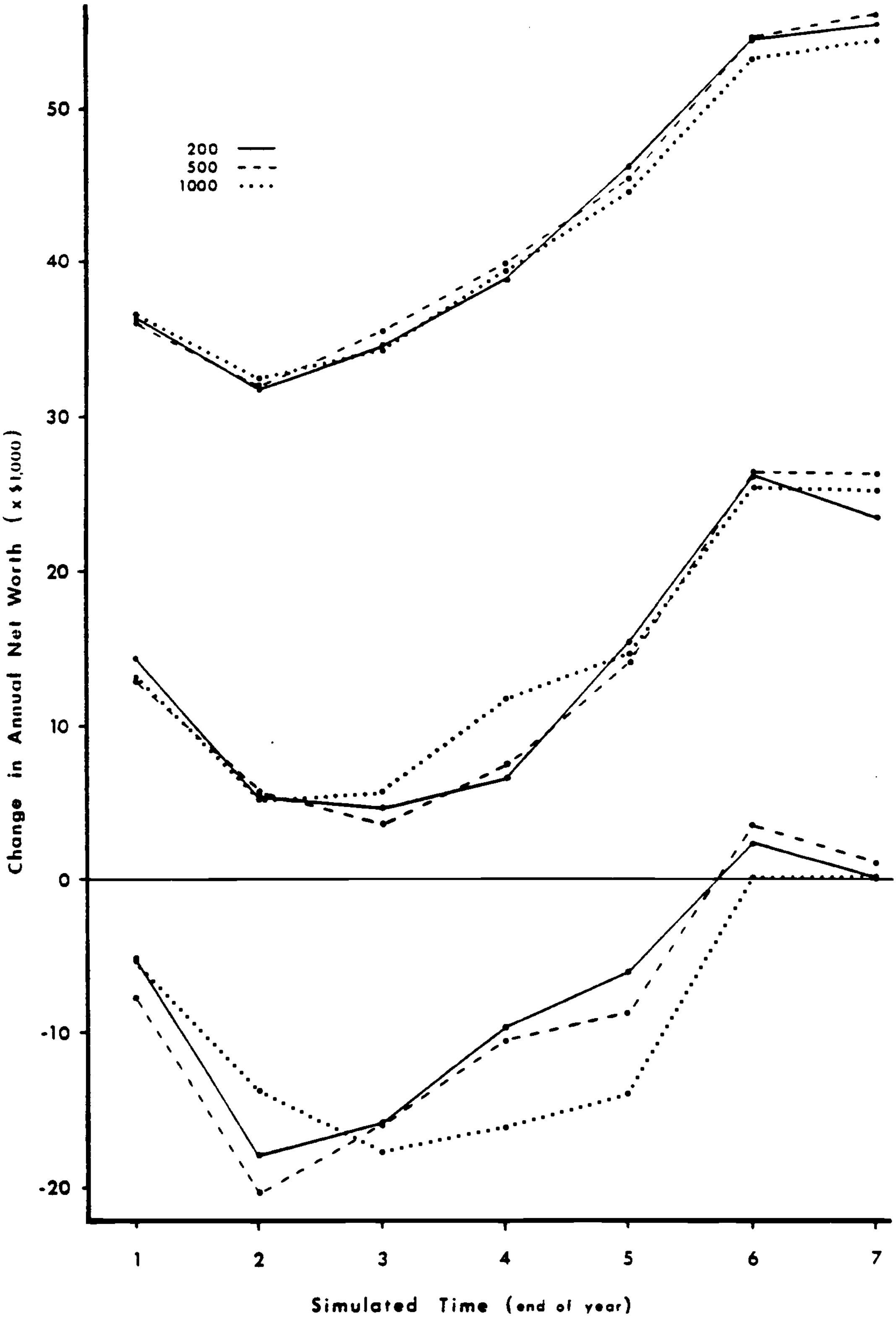

TABLE 12 -- Average Annual Return on Equity (%)

Average Cattle Price Set	Improvement Prescription	Acreage Size		
		Small	Medium	Large
High	THIN	5.40	5.35	5.27
	RELEASE	5.40	5.33	5.20
	SEED	5.33	5.34	5.28
Moderate	THIN	2.94	2.84	2.57
	RELEASE	2.90	2.82	2.72
	SEED	2.69	2.70	2.66
LOW	THIN	-1.01	-1.39	-1.80
	RELEASE	-0.94	-1.41	-2.22
	SEED	-1.43	-1.41	-1.76

TABLE 13 -- Average Increase (Decrease) in Annual Net Worth ($), Years 1 to 10

Average Cattle Price Set	Improvement Prescription	Acreage Size		
		Small	Medium	Large
High	THIN	46300	45700	44800
	RELEASE	46200	45500	44000
	SEED	45500	45600	44900
Moderate	THIN	18400	17700	15700
	RELEASE	18100	17500	13700
	SEED	16600	16700	16400
Low	THIN	(4700)	(6300)	(7900)
	RELEASE	(4400)	(6400)	(9600)
	SEED	(6500)	(6500)	(7800)

TABLE 14 -- Average Increase (Decrease) in Annual Net Worth ($), Years 2 to 5

Average Cattle Price Set	Improvement Prescription	Acreage Size		
		Small	Medium	Large
High	THIN	39700	39100	38300
	RELEASE	39300	38900	37400
	SEED	37900	38300	37700
Moderate	THIN	11500	11300	8800
	RELEASE	10900	10700	6300
	SEED	8000	7800	8800
Low	THIN	(9800)	(12500)	(13000)
	RELEASE	(9900)	(12000)	(14300)
	SEED	(12400)	(13900)	(14900)

IMPLICATIONS AND DISCUSSION

Analysis of the model results indicates the usefulness of the ranch simulation model as a decision-making tool. For this tool to be effective, its results must be interpreted carefully. The statistical analysis indicates the sensitivity of the model to changes in variables. If the model proves to be sensitive to change, then the relative ranking of the alternatives may be useful for decision-making.

Experimental Sensitivity of the Ranch Model

The terminal net worth values for the high average cattle price set (Table 10) were statistically analyzed. Based on the computed F-value, there were no significant differences detected among replications. It can readily be observed from the graph in Appendix C why variation caused by the precipitation index did not result in significant differences among replications. Therefore, it was decided that any future experiments with this model would require fewer replications.

The analysis of variance showed significant differences among both prescriptions and acreages. The model appeared to be more sensitive to changes in acreages than in prescriptions based on F-values of 253.0 and 17.8, respectively. Significant differences were detected if the F-value, with two and thirty-two degrees of freedom, exceeded 5.4 at the 0.01 percent level of significance.

It is important to note here that acreage sizes were completely controllable values whereas improvement prescription heuristics were established and constant. Therefore, the relatively large F-value associated with acreage size may be deceptive when compared to the prescription F-value. Using smaller ranges of size for each prescription would likely reduce the F-value. This study did not test enough coefficient levels to adequately determine model sensitivity to incremental changes in either acreage sizes or average cattle prices.

The implication from objective analysis of the simulation results is that the model could be used by public or private decision-makers for evaluating expected economic impacts on a private enterprise from public range improvement practices. When results are to be used for decision-making, interpretation must be tempered by the fact that the model has not been validated. It is unknown whether the assumptions and coefficient values used for simulation will in actuality remain constant. Given the large number of unknown circumstances that may face any firm over time, validation of a ten year planning model may be impossible.

Nevertheless, the results do represent values obtained by processing the same data set, with changes in appropriate variables, through an identical solution algorithm. Subjectively analyzing these results will show the relative worth among improvement prescription alternatives to the ranch enterprise through time.

Subjective Analysis of Ranch Model Data

Results from the ranch simulation model were intended to be a decision-making aid for efficiently allocating public resources for the benefit of a private ranching enterprise as well as for the local economy. The model results represent the reaction of a single economic component of the county economy to an external stimulus. The usefulness of the results for this purpose is based on the ability of the decision-maker to subjectively analyze the results in light of the assumptions and heuristics that comprise both the ranch model and the tested alternatives. Because the model has not been validated, objectively analyzing results may lead to erroneous conclusions.

In order to demonstrate how the ranch model results can be interpreted, three additional assumptions need to be presented. First, it is assumed that a decision has been made to implement a canopy reducing-forage increasing rangeland improvement prescription in order to balance the year-round forage supply. Second, it is assumed that the array of tested alternatives has been assembled by a public land manager based on criteria such as public benefit-cost ratios, how well each alternative fits into the allotment management, and relevant multiple-use considerations. Third, it is assumed that application of the decision criteria, such as those found in the second assumption, have resulted in essentially equal ratings for the tested alternatives.

It is unimportant whether these assumptions hold for these tested alternatives. These assumptions are presented to give a logical basis for the subjective analysis below. The implication from these assumptions is that the public decision-maker will select the alternative with the highest expected benefits to the private ranch enterprise, all other things being equal. If all other considerations are not equal, the public decision-maker would treat this information as another possible decision variable, but would not likely make the selection on this alone. The private ranch operator, in any case, would surely favor the alternative with the highest expected private benefits. Further, from the private point-of-view, those alternatives with higher returns early would be favored over those with distant returns.

The decision-making process can be rapidly overwhelmed by the amount of data to compare among the various alternatives. In this relatively simple example there were twenty-seven possible combinations to examine. This number can grow rapidly if more variable levels are tested. Strategies must be used to reduce the number of alternatives examined at each stage of the decision-making process. It begins as a scoping process and moves toward actual comparisons among the remaining alternatives.

As an example of how this may be accomplished, consider the data graphed in Figures 1, 2, and 3 representing the twenty-seven possible combinations. Subjective analysis of these would be vastly simplified if some could be eliminated beforehand. The scoping process about to be illustrated is only one of many possible ways of reducing the data to a manageable size. It does represent a logical sequence to follow under the stated assumptions and with the available data.

Graphs of each alternative average cattle price set (Figures 1, 2, and 3) provide the most relevant information for decision-making under the stated assumptions. This information is supplemented and supported by the remaining set of graphs (Figures 4 to 6) and the data in Tables 12, 13, and 14.

The scoping process begins by observing Figures 1, 2, and 3 since they will be the main focus of the analysis. At high average cattle prices (Figure 3) the spread among alternatives at the end of each simulated year is less than when prices are low or moderate (Figures 1 and 2, respectively). This indicates that the model is more sensitive to the alternatives when cattle prices are near the break-even level. This is reinforced by examining the differences among average percent returns on equity (Figure 12).

There are at least two related reasons for this effect. First, when times (prices) are good (as in Figure 3) the choice among alternatives will be less critical than when it is difficult to at least make revenues equal costs. It appears that the economic impacts of a wrong choice may tend to be compensated for by the naturally higher revenues. This leads to the second possible reason -- when prices are near the break-even level (Figures 1 and 2) the firm may not be able to maintain sufficient cash reserves to purchase extra feed following the treatment, as well as to carry on normal business transactions, without needing to borrow short-term capital.

The net effect of these reasons can be observed in the sensitivity of the model at alternative cattle prices discussed earlier. Therefore, in order to base decisions on data that differentiate among alternatives to the greatest extent available, it would be best to restrict further analysis to Figures 1 and 2. In other words, if the best alternative is chosen when times are difficult and times get better, the economic effect of this being the wrong choice for the actual prices should be less than if the situation were reversed. If the choice is made using high cattle prices, when the model is relatively insensitive to the alternatives, and actual prices are near break-even, the wrong choice could make a significant difference in the ranch's relative profitability.

In order to further reduce the number of alternatives for intensive comparisons consider Tables 13 and 14 in relation to Figures 1 and 2. In each figure it appears that most of the differences among alternatives occur by the end of the fifth year. This seems reasonable since the treatment occurred during year two and differences among prescription heuristics were non-existent by the end of year five.

Therefore, Table 13 contains ten year average values while Table 14 contains the average values for years two through five. Although the same general alternatives come out as the best in both tables, comparing tables shows that annual returns to the ranch enterprise will be lower immediately after the treatment is implemented than over the longer run. Because returns will be more critical in the short-run to the firm, Table 14 will be used to select those alternatives for more intensive comparisons.

The average values for the high cattle price set again show the lack of model sensitivity to the alternatives. Based on the moderate cattle price set, it would appear that at least five alternatives should be considered further. Likely candidates would be: (1) THIN

200 ac; (2) THIN 500 ac; (3) RELEASE 500 ac; (4) RELEASE 1000 ac, and; (5) SEED 1000 ac. Selection of the THIN and RELEASE prescriptions were based on their average values being clearly in a group above the rest. Selection of SEED 1000 ac was based on a curiosity about why the large size had the highest value within SEED.

This list could be changed when the low cattle price set is considered. Although all of the alternatives show negative average results, two clearly lose less than the others. These are THIN 200 ac and RELEASE 500 ac. It would appear to be a conservative approach to decision-making if only these two are considered further. It also appears that the SEED prescription results are lower due to the additional grazing rest required during the early years since by the end of ten years the differences in averages are much less. Further, when prices are low the additional rest in SEED causes relatively higher losses than the other alternatives as compared to when prices are profitable. Therefore, it would seem worthwhile to at least compare the SEED alternatives among themselves to gain additional information. However, from this it would appear that only THIN 200 ac and RELEASE 500 ac should be seriously considered for selection beyond this point, especially if prices are expected to be below the break-even point. If prices are unknown, at least THIN 500 ac and RELEASE 1000 ac should be added to this list.

This brings the analysis back to Figures 1 and 2 in order to compare these alternatives. As indicated previously, the major emphasis should be on years two through five. However, following the alternatives through the entire period may provide additional information.

The difference between the SEED prescription and the other prescriptions can be seen in Figure 3 and is accentuated in Figures 1 and 2. It appears that total rest until year four causes the SEED alternatives to rank low relative to the other alternatives during that time period. However, by the end of the seventh year the SEED alternatives are fairly competitive with the other alternatives. These figures, therefore, illustrate the way SEED data behave, as alluded to when comparing Tables 13 and 14.

To continue the decision-making example consider lines A and D in both Figures 1 and 2. It can be readily observed in these figures that these alternatives rank the highest in most years following the treatment. Therefore, it would appear that choosing either THIN 200 ac or RELEASE 500 ac would have about the same impact on annual ranch net worth values.

In this case the scoping process eliminated enough data and alternatives to make the final selection relatively easy from Figures 1 and 2. However, if it results in many alternatives remaining for consideration there are other ways to examine the data to differentiate among alternatives.

For example, if THIN 500 ac and RELEASE 1000 ac were considered based on average net worth changes at moderate cattle prices and if all SEED alternatives were also considered, it would be worthwhile to conduct the scoping process within each prescription. That is, compare net worth flows among sizes for each improvement prescription. Figures 4, 5, and 6 were set up for this purpose.

In Figure 4 it can be observed that the 200 ac prescription is, for most years, above either of the other alternatives at each average cattle price set. Obviously this alternative is superior to the other sizes for this prescription. Likewise, in Figure 5 the 500 ac size ranks higher in most years than the other alternatives making it superior to other RELEASE sizes. This tends to support the conclusions made earlier in the scoping process where only THIN 200 ac and RELEASE 500 ac were selected for additional analysis.

Although the scoping process has indicated that the SEED alternatives were inferior to other alternatives based on average changes in net worth, Figure 6 does illustrate how these types of graphs may be useful in decision-making. The response of the model to SEED is not as clear as that experienced with either THIN or RELEASE and, therefore, merits further attention.

At low average cattle prices in Figure 6, except for year two the large size is inferior to the other sizes. Also, the medium size is inferior to the small size in early years while superior in later years. At moderate prices the large size is superior to the others in years three and four with little difference among sizes in years five through seven. Data in Appendix D show that by year nine the large size seems to be relatively inferior. At high prices there is very little difference among alternative sizes. Therefore, the relative impacts from selecting a SEED alternative will be dependent on the average cattle prices received by the firm. Thus, while the firm is in a profit-making position it would appear that SEED at large acreage would give higher expected short-term returns. Further, when the firm is losing value, the large size will have the most negative short-term impact.

The point to this discussion is that each alternative may show markedly different net worth flows as cattle prices change. If the stated assumptions hold true, the ranch enterprise would surely favor those alternatives with higher early returns with the belief that long range future effects can be mitigated by other practices. In any case, the decision-maker should glean as much information from the data as is possible before making a decision.

The scoping process presented represents one possible way of reducing the number of alternatives for intensive comparisons under the stated assumptions. Similarly, comparing graphs of alternatives was a highly subjective process. However, one point brought out by this process remains important. Because average cattle prices can not be known with any certainty, choosing a few "best" alternatives at each average price set for future consideration may be the most reasonable way to approach the problem. If one alternative ranks consistently high at all relevant price sets, it would seem logical to select it. Otherwise, the choice becomes much more difficult.

The most valuable asset of this model may be the manner in which the decision-maker becomes aware of the complexities of a modern day ranching operation. It may also assist public land managers to more fully appreciate the impact that a public decision can have on a private enterprise.

CONCLUSIONS

Conclusions from this study will be divided into two groups -- those related to: (1) the hypotheses stated earlier on expected effects of each tested variable on model results, and (2) the appropriateness of the assumptions used in the design of the experiment. These conclusions suggest both the limitations of the current model version and areas for possible future work to strengthen the model. These suggestions will be presented in the final section.

Hypothesis Fulfillment

The five hypotheses stated earlier were made prior to the simulation experiment. How accurately each hypothesis predicted model behaior will be discussed in the same order the hypotheses were presented. The conclusions presented relate both to the usefulness of the variable for decision-making and to the pseudo-validation of the model.

1. Average cattle price differences had the greatest economic impact on annual net worth changes in ranch value. This effect was previously discussed extensively and reasons will not be repeated here. Because cattle prices are completely uncontrollable by the firm, analysis should consider a range of feasible cattle price sets. The decision-maker should then focus on the relative rankings among alternatives at each relevant cattle price set and make the choice by scoping all rankings together.

2. Although a break-even cattle price set was not determined, it was apparent from the data that the break-even set would be

between the low and moderate price sets. The fact that this break-even price set is within the realistic range of prices actually received, initial coefficient values determined would tend to validate the relationships among model components and the coefficient values used. Therefore, it appears that the model is a reasonably accurate depiction of a real-world ranching enterprise and should be a useful tool for planning.

3. As expected, from the end of year two to the end of year five the differences among alternatives were greater both on a year-by-year and average net worth change basis as compared to the same type of comparisons when the time frame was extended. Therefore, for this experiment it appears that the data over the short-term would provide the most information for differentiating among the economic impacts of each alternative on the ranch enterprise.

4. (A) As expected, the improvement prescription with the most rest (SEED) appeared to be economically inferior to prescriptions with less rest. This was especially evident in the short-term average net worth changes (Table 14) where SEED ranked low at each average cattle price set. Over the long-term the differences were lessened (Table 13) but the rankings remained the same. Therefore, it appears that rest will have definite short-term economic impacts on the firm when compared to expected results from other prescriptions. This effect may persist into the long-term.

4. (B) Although there were exceptions on a year-by-year comparison (Figures 4, 5, and 6), it appears that the larger size of a given prescription had an adverse short-term impact on the changes in net

worth at each average cattle price set compared to expected changes at smaller sizes. The reasons for this are not entirely clear, but it appears that the additional costs for feed in the short-term at larger sizes is causing the lower change in net worth.

4. (C) It was expected that over the life of the simulation, the larger sizes would "catch up" to the smaller sized alternatives for a given prescription. Only the SEED prescription showed this effect at some cattle price sets. Therefore, for the set of assumptions used in the experiment, it would appear that although differences among sizes are less in the long-run than in the short-run, the larger sizes do not recover from the initial financial burden fast enough to reasonably justify their selection. Thus, it appears that benefits (additional forage) from large prescriptions do not compensate for either feed costs in the short-term and additional public grazing costs in the long-term.

5. The sensitivity analysis conducted on data from the high average cattle price experiment showed that varying forage production by using precipitation indices did not cause significant differences among replications. At least for this model version, the total effect of the precipitation index was insignificant in relation to the differences in net worth change caused by other variables. Thus, because the cost of using the computer must be weighed against expected results, it appears that replicating based on random forage fluctuations is not worth the expense.

Appropriateness of Experimental Assumptions

The assumptions under consideration are distinct from those used in the subjective analysis. For clarity, the assumptions to be discussed will be formally stated. Therefore, it was assumed that: (1) an average eastern Oregon cattle ranch could by hypothetically formulated, (2) the firm would maintain a constant herd size, and (3) the firm's reaction to less forage short-falls was to feed either grown or purchased hay.

It should be evident to those working in agriculture that no two enterprises are alike in all respects. Thus, the data used were gathered from a variety of sources and do represent values within an expected range. Therefore, although the initial ranch situation used in the experiment does not represent any particular operation, it does represent an efficient business enterprise that could possibly exist in eastern Oregon.

The constant herd size assumption proved to be highly influential on the results and their interpretations. The effect of the constant herd size was discussed previously in terms of the hypotheses and will not be repeated. The reasons for this assumption were relatively straight-forward. First, if herd size was allowed to be reduced at the time of project implementation, the firm would have to rebuild the herd later by either holding back more calves from sale or buying calves or cows. Second, if herd size was allowed to go above the original level the firm would have to provide year round feed and forage for these additional animals. Because neither of these options was desirable in terms of evaluating the effects of canopy reducing-forage increasing alternatives on the firm, constant herd size was assumed.

Feeding grown or purchased hay during forage shortages was assumed to limit the number of possible options to those normally expected to be selected in eastern Oregon. Although the possibility may exist for leasing additional pasture, this was not considered to be a normal reaction.

LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Most of the limitations of the model and suggestions for future research have been implied in the previous discussion. The limitations form the basis for identifying future research needs. There appear to be two major limitations: (1) there was a lack of site-specific forage production coefficient values for the improvement prescriptions and (2) the model has not been validated by its ability to predict results. The former problem may be solved by establishing methods for collecting data that will be in a form useful for modeling. Although indications of model validity can be inferred from the data, the latter problem can only be resolved by continuously testing the model through time.

In the absence of adequate data, decision-makers must rely on available data as adjusted to fit their needs -- in essence, using professional judgement. For example, instead of knowing how much of the vegetation should be reserved for cattle forage, wildlife forage, erosion protection, and any other use throughout the year at various points in the climatic cycle, the decision-maker must use a total average yearly production estimate and allocate so much to each use. Obviously, without data to document their choices, the allocation must be based on their subjective evaluation of the situation.

Interpretation of results from a simulation study should be approached with the same type of professional judgement. Just as the model is an abstraction of a real-world operation, coefficient values based on research and/or judgement are, at best, statistical estimates of a population parameter. Each coefficient value, as well as each interrelationship among coefficients, has an individual error term. This being the case, results obtained from the model will surely have an error caused by combining all these individual errors.

The manner in which these errors compile through a simulation model (summing, multiplying, etc.) is undeterminable. Thus, it is impossible to make any kind of realistic confidence statement on the results. Until the model can be validated with specific ranches the reliability of the model will remain unknown. Therefore, interpretation of results for decision-making should be based on relative differences among alternatives.

The assumptions and limitations of the model form the basis for identifying future research needs. These suggestions relate to: (1) data collection requirements and (2) alternative model assumptions. Data collection should relate forage response on a homogeneous land type to each improvement prescription through time. This may be accomplished by: (1) determining which plant species in any given association are forage plants, (2) determining the relative palatabilities of each species in every plant community at various times of the year, and (3) determining the time path of the vegetation response to the improvement prescription.

There appear to be an infinite number of possible changes that could be made, both in the model and in coefficient levels, to further adapt the simulation process to the decision-making process. Some examples for change: (1) any set of improvement prescription heuristics can be adapted into the model, (2) additional levels of coefficient values could be used for acreage sizes, (3) assumptions could be relaxed to allow changes in year-round herd size, or (4) the enterprise could go into a cow-calf-yearling operation allowing the firm to hold calves until yearling age in order to use the additional summer forage (a short-term annual increase in herd size).

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APPENDICES

APPENDIX A

1. Literature Review: Computer Simulation

Systems simulation was selected as the tool to use in evaluating economic responses of a firm (ranch operation) to changes in selected variables. Because the use of computer simulation as a tool for range or ranch management is relatively new (especially at Oregon State University), it seemed appropriate to discuss at some length what system simulation is and how to apply it to modeling a ranch enterprise. The field of simulation is very broad, therefore, this discussion will be limited to those areas directly related to studies such as this. Before discussing the design of a computer simulation study, some basic definitions that were used must be presented.

A system was defined as an aggregation of components united by some regular interaction or interdependence to perform a specified function (Gordon 1969, Shannon 1975). Each component (subsystem) will affect the total system, as well as affect the properties of other components (Naylor *et al*. 1966, Sonntag and Klein 1977). When dealing with economic systems, from the firm on up, the human mind has difficulty in comprehending its complexities when viewing the whole rather than its parts (Naylor *et al*. 1966). However, system behavior will not likely be deducible from an examination of its parts; thus, methods were required to estimate the effects on the whole (Naylor *et al*. 1966, Sonntag and Klein 1977).

Computer studies of systems can be divided into two types: system analysis and system postulation (Naylor *et al*. 1966). Systems analysis was concerned with understanding how an existing or proposed system operates both in terms of structure and performance (Gordon 1969). The primary purpose of this analysis was to examine components, variables, parameters, functional relationships, constraints, and criterion function of the system (Dent and Anderson 1971, Shannon 1975, Zeigler 1976).

System postulation was described as being characteristic of the way simulation has been employed in economic studies, where system behavior was reasonably known but the processes that produced the behavior were not known (Gordon 1969). Postulation involved making hypotheses on a likely set of activities that can explain the system behavior and conducting experiments to test these hypotheses (Naylor *et al*. 1966).

A system model was defined as the body of information gathered to represent its components and their interactions (Gordon 1969). Models of economic systems typically take the form of mathematical relationships necessary to specify components, variables, parameters, and functional relationships (Naylor *et al*. 1966).

Finally, simulation has been defined as the process of designing a model of a real system and conducting experiments with the model for the purpose of systems analysis or postulation (Gordon 1969, Shannon 1975). In many instances, the ability to follow detailed workings of the system as well as tracing implications of input or decision changes on the output may be more important than the ability to find an optimal solution to a problem modified to fit a specific solution algorithm (Dent and Anderson 1971, Sonntag and Klein 1977).

System simulation appeared to be a logical choice as a tool for modeling the complex interrelationships found in range and ranch production (Gordon 1969, Dent and Anderson 1971, Shannon 1975, Zeigler 1976, Sonntag and Klein 1977).

These definitions have provided the basis upon which the current study was predicated. Several authors listed steps for planning and conducting simulation studies (Naylor et al. 1966, Gordon 1969, Shannon 1975). Steps adapted from Gordon (1969) are listed below. The following discussion will focus only on those steps relevant to this study. The steps presented were (Gordon 1969):

1. Defining the problem,
2. Planning the study,
3. Formulating a mathematical model,
4. Constructing a computer program for the model,
5. Validating the model,
6. Designing experiments,
7. Executing simulation runs, and
8. Analyzing results.

The first three steps were completed by Sonntag and Klein (1977). The fourth step was also developed by Sonntag and Klein (1977) but was modified for use in eastern Oregon by Whitley (1979). The work upon which this thesis was based occurred in steps four through eight.

Naylor et al. (1966) proposed a multistage verification procedure. First, hypotheses were formulated describing system behavior. Next, an attempt to "verify" the hypotheses was made with the model. Finally, the model's ability to predict system behavior was tested.

In this sense, the ranch model has not been validated for use on eastern Oregon cattle ranches. This study only partially addressed the first two stages described by Naylor et al. (1966). Attempts to predict real system behavior have not been conducted with this model in eastern Oregon.

Naylor _et al_. (1966) described experimental design for simulation studies as selecting factor levels and combinations of levels to test while endeavoring to ensure that results were reasonably free from random error. Gordon (1969) added that consideration should also be given to computer time required; in other words, the costs of expanding an experiment with more factors or factor levels and making more computer runs.

Analyzing simulation results consisted of computing test statistics and interpreting them in terms of the original hypotheses (Naylor _et al_. 1966, Gordon 1969). Naylor _et al_. (1966) suggested that analysis of variance methodologies were appropriate for data analysis.

2. Literature Review: Initialized Ranch Coefficients

Initial values for model coefficients used in the study were presented in the text. These values represented expected averages and were derived from: previous work at Oregon State University; discussions with area ranchers and agency and university personnel; and through a search of the literature. Because "average" values were used, it was often difficult to cite a single source. In fact, many values were used unchanged from previous undocumented work at Oregon State (Whitley 1979) when it was felt that it was within the range suggested by those living in the target area. Values in Tables 6, 7, 8, and 9 not specifically referred to below were used unchanged from Whitley (1979). Essentially what follows is the rationale used in selecting coefficient levels when they differed from the previous work.

It was estimated that nearly one-half of the brood cows in Grant County, Oregon, were owned by moderate sized ranches -- those with 200 to 499 brood cows (Schmisseur 1979). Sixty percent of these ranches were managed for spring calving (Schmisseur 1979). Forty-three percent were managed as cow-calf operations (Schmisseur 1979). A herd size of 400 brood cows with appropriate replacement heifers and bulls was selected. The cow-calf option was selected, although the yearling option could easily have been justified.

Once herd size was selected, feed sources were matched to the operation. All ranchers used dryland range and sixty-two percent grew irrigated hay (Schmisseur 1979). The moderate sized ranches produced sufficient hay to balance herd needs and were the only size of ranch which grew grain (Schmisseur 1979). Therefore, in an average range production year, feed produced was equated to that required.

Beef herd coefficient values (Table 7) used in the experiment represented values that could be expected under an intensive herd management program. Diet options were selected from the input form to use as much pasture or hay as was seasonally reasonable (Sonntag and Klein 1977). All other values used were at a high level in order to represent an efficient herd management program.

Forage and feed coefficient values (Table 8) were used with few changes from work by Whitley (1979). Hay yields were based on work by Gomm (1979) and represented high average yields. Percent crude protein content of the seasonal pastures was based on work by Cook and Harris (1977).

All financial aspects were used from Whitley (1979) when subsequent discussions with area ranchers placed them within a reasonable range experienced by them during the period from 1967 to 1977. The total cost for federal grazing represented the permit fee of $2.68 per animal unit month and $8.00 per animal unit month for all other costs associated with using the allotment.

3. Literature Review: Possible Output From the Model

The simulation study conducted only considered changes in annual net worth values and, to some extent, average percent return on equity values. The Beef-Forage-Grain Production Model developed by Sonntag and Klein (1977) was certainly capable of tracking many more outputs. The number of these selected will directly impact the cost of an experiment. Sonntag and Klein (1977) divided output tables into yearly detailed tables and final summary tables.

The detailed tables included (Sonntag and Klein 1977):

1) Beginning inventory (items, age, capacity, remaining value),
2) Ending inventory (same as above),
3) Resource flows by 2-week periods (cattle labor, crop labor, other labor, pasture production, pasture requirements, pasture balance, forage fed),
4) Cash receipt and expense flow by 2-week periods (cattle and crop receipts, cattle and crop expenses, miscellaneous receipts and expenses, cash balance),
5) Grain and hay production, use, purchases, and balance,
6) Pasture production (acres, yield, use rate, total use).

The final summary tables for each year of the analysis included (Sonntag and Klein 1977):

1) Farm plan summary (area of grains, oilseeds, hay, number of cows, beef-production options employed),
2) Financial summary at year end (assets, debts, net worth, net farm income situation),
3) Ending value and change in investment of selected capital items,
4) Pasture improvement and herd expansion levels,
5) Product sales and selected input use,
6) Diets of various classes of animals,
7) Receipts and expense summary (receipts, expenses, debt situation, personal expenses),
8) Crop options employed.

4. Appendix Bibliography

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APPENDIX B -- Factorial analysis for the analysis of variance of the high price set data

Sum of Squares for Replications

Replication 1 = 9478021
Replication 2 = 9480656
Replication 3 = 9473152
Replication 4 = 9480227
Replication 5 = 9469781

Average = 9476367
Sum of Squares = 9,971,384

Sum of Squares for Prescriptions

THIN = 15827044
RELEASE = 15771255
SEED = 15783538

Average = 15793946
Sum of Squares = 114,579,037

Sum of Squares for Acreages

Small = 15886204
Medium = 15824320
Large = 15671313

Average = 15793946
Sum of Squares = 1,631,531,409

Sum of Squares of

THIN 200 = 5310899
THIN 500 = 5279263
THIN 1000 = 5236882
RELEASE 500 = 5305627
RELEASE 1000 = 5271760

APPENDIX B -- Continued

RELEASE 2000 = 5193868
SEED 200 = 5269678
SEED 500 = 5273297
SEED 1000 = 5240563

Average = 5264649
Sum of Squares = 2,108,712,938

Sum of Squares -- Total

$\Sigma x^2 = 4.9891966 \times 10^{13}$
$(\Sigma x)^2/n = 4.9889744 \times 10^{13}$

Total Sum of Squares = 2,221,846,320

ANALYSIS OF VARIANCE	Degrees of Freedom		Sum of Squares	Mean Square	F-value
Replications	4		9971384	2492846	0.77
Treatments	8		2108712938	263589117	81.76
Prescription		2	114579037	57289519	17.77
Acreage		2	1631531409	815765705	253.04
P x A		4	362602492	90650623	28.12
Error	32		103162139	3223817=EMS	
Total	44		2221846461		

FIGURE 7 -- Comparison Among Replications of RELEASE 500 ac Using High Average Cattle Prices

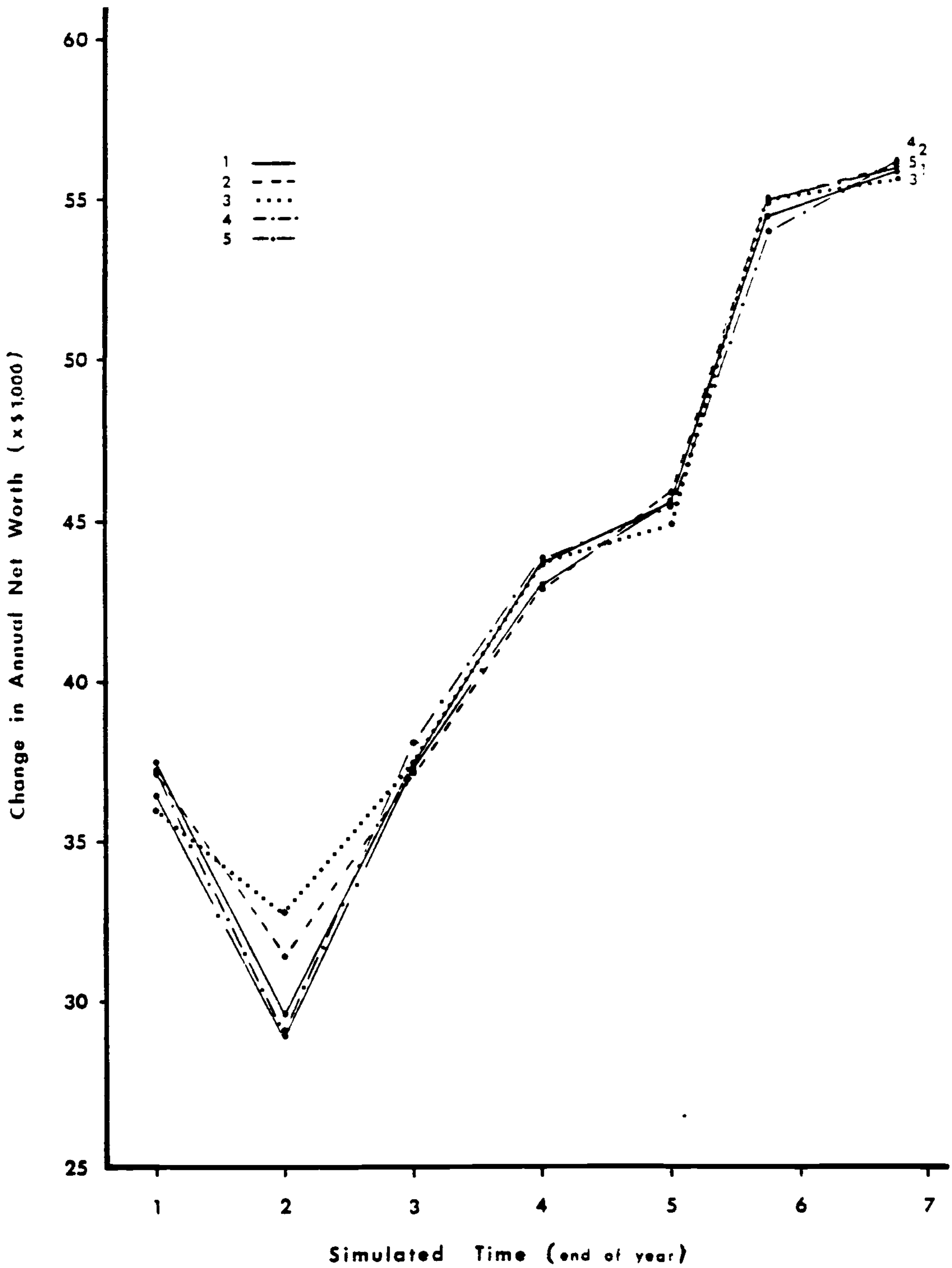


FIGURE 8 -- Comparison Among Replications of RELEASE 1000 ac Using High Average Cattle Prices

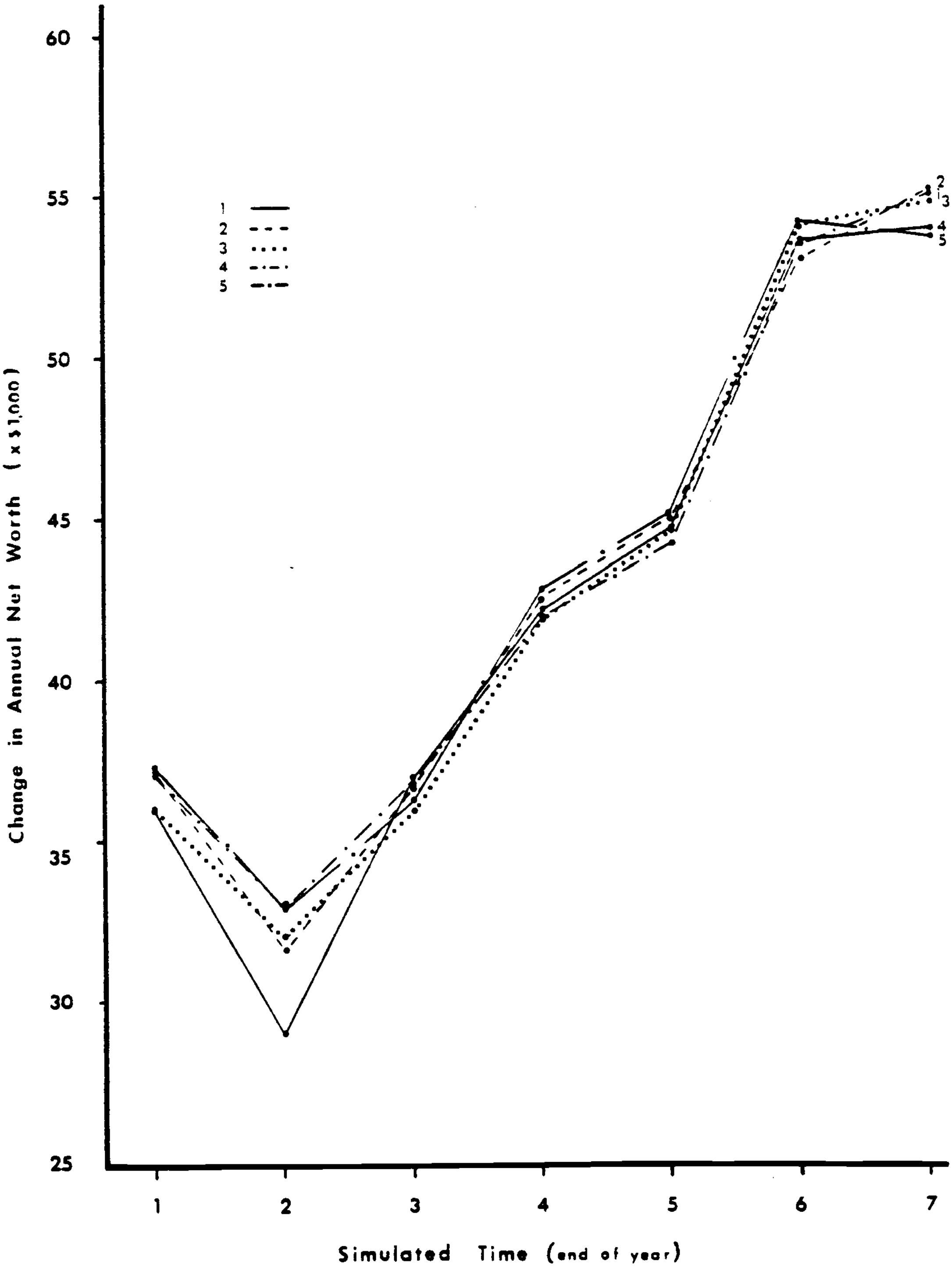
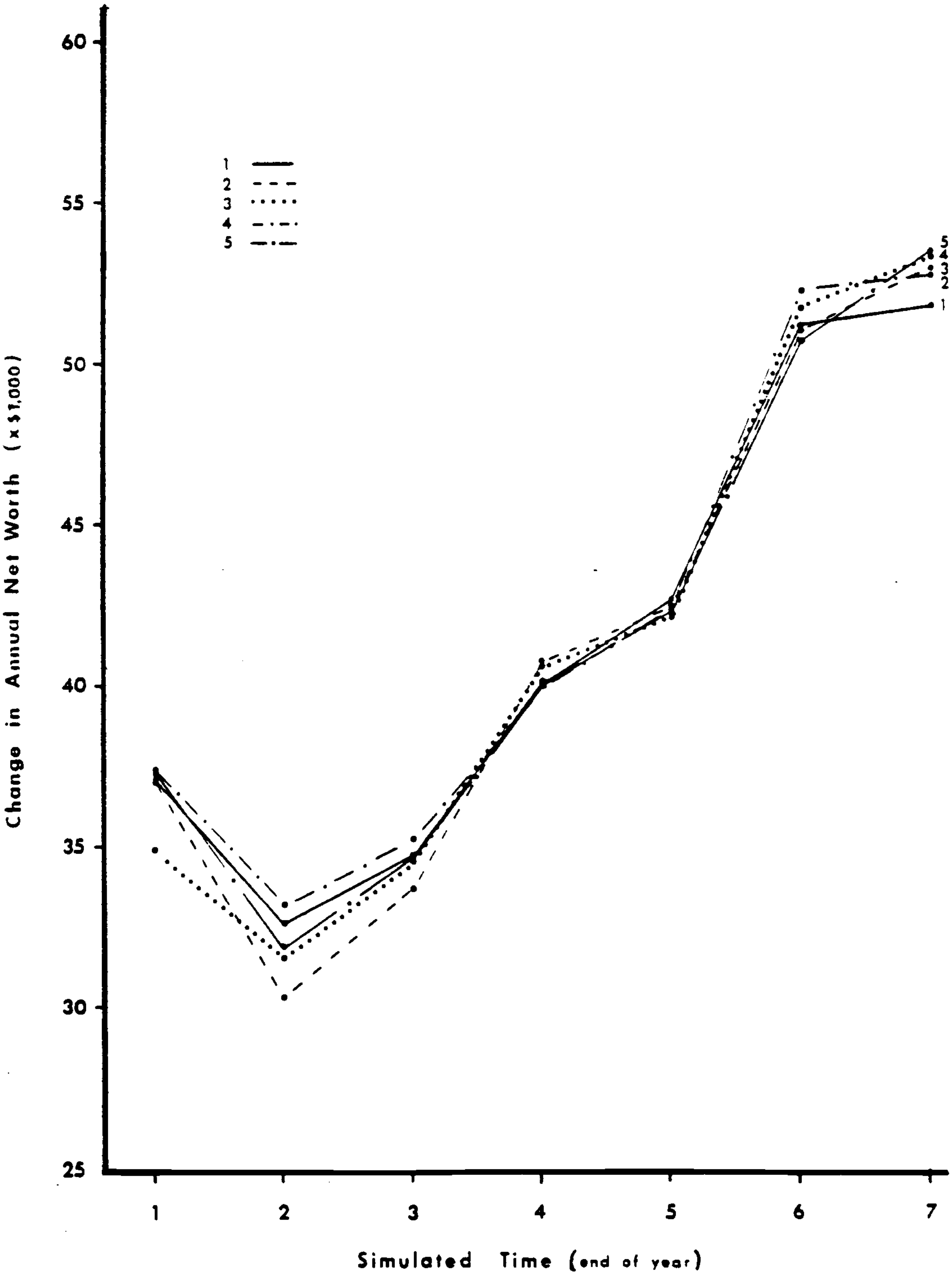


FIGURE 9 -- Comparison Among Replications of RELEASE 2000 ac Using High Average Cattle Prices



APPENDIX D-1 -- Average Annual Net Worth Values, Low Average Cattle Prices

Net Worth Gain (Loss) (x $100)

Improvement Prescription	Size (ac)	At End of Year 1	2	3	4	5	6	7	8	9	10
THIN	200	(90)	(167)	(120)	(66)	(37)	39	28	(61)	29	(28)
	500	(61)	(194)	(164)	(85)	(58)	28	0	(81)	5	(21)
	1000	(53)	(156)	(186)	(92)	(84)	2	5	(113)	(30)	(85)
RELEASE	500	(61)	(146)	(131)	(74)	(44)	44	17	(75)	33	(5)
	1000	(50)	(157)	(163)	(95)	(63)	23	(6)	(86)	(1)	(41)
	2000	(54)	(141)	(191)	(135)	(104)	(20)	(36)	(150)	(46)	(79)
SEED .	200	(52)	(180)	(159)	(97)	(61)	24	0	(82)	(11)	(28)
	500	(77)	(204)	(160)	(105)	(88)	36	11	(64)	30	(27)
	1000	(53)	(138)	(177)	(161)	(119)	1	1	(86)	(16)	(35)

APPENDIX D-2 -- Average Annual Net Worth Values, Moderate Average Cattle Prices

Improvement Prescription	Size (ac)	Net Worth Gain (x $100) At End of Year 1	2	3	4	5	6	7	8	9	10
THIN	200	112	34	73	168	183	274	278	172	292	253
	500	125	53	74	158	167	254	253	177	270	239
	1000	116	45	31	127	148	240	238	155	250	220
RELEASE	500	99	30	71	158	176	267	278	188	285	257
	1000	128	59	65	146	159	260	269	170	267	230
	2000	122	31	3	99	120	212	229	130	227	193
SEED	200	124	54	47	66	154	262	235	175	293	246
	500	129	57	36	75	142	264	263	176	272	251
	1000	132	51	57	118	127	255	252	159	256	229

APPENDIX D-3 -- Average Annual Net Worth Values, High Average Cattle Prices

Improvement Prescription	Size (ac)	Net Worth Gain (x $100) At End of Year 1	2	3	4	5	6	7	8	9	10
THIN	200	358	316	383	435	455	550	555	466	574	539
	500	360	315	371	429	450	536	549	456	565	536
	1000	362	321	358	418	436	528	540	449	553	520
RELEASE	500	369	304	376	435	456	574	560	464	570	539
	1000	368	317	366	424	448	538	547	453	563	530
	2000	368	319	346	404	425	515	429	436	543	511
SEED	200	362	319	346	389	463	545	555	463	574	532
	500	362	320	356	399	455	546	550	463	569	537
	1000	364	325	344	394	446	532	545	451	561	527

APPENDIX E

The computer program and subfiles used in this project are on file at the Department of Rangeland Resources on magnetic tape. Also on file is the input form used. The program was written in FORTRAN and was operable on Oregon State University's CDC (Cyber) computer as of January, 1982. The following sequence of commands will operate the program. All editing must follow the sequence on reading the program from magnetic tape.

Computer control commands will be shown in the left column in each of the following sections. Commands in all capital letters must be typed as shown. File names are underlined and may be any permissible name. Commands of small letters must be replaced by the user and are defined in the right column. In addition, the right column will contain explanations for each command.

1. Reading the Ranch Model Program and Data from the Magnetic Tape

Login procedure	Standard logging in procedure to obtain computer access.
SETTL,n	Sets a time limit for each run. n=maximum time limit allowed on the account number.
LABEL,TAPE,VSN=RANCH,PO=R. TEMPm/PW=p	Assigns the tape labeled RANCH to a tape drive and puts it in read mode. Commands must be on one line. m=temporary volume serial number assigned at tape check-in. p=password assigned at same time.
DEFINE,BFG	Establishes a direct access file.

COPYBF,TAPE,BFG	Copies the program from the tape to file BFG. There should be 204 sectors in this file which can be checked with the command XCAT.
COPYBF,TAPE,DATA3 COPYBF,TAPE,DATAC COPYBF,TAPE,PRICE	Copies the default values and production possibilities file from tape to local file DATA3, user input to local file DATAC, and bi-weekly average cattle prices (1968-1978) to local file PRICE. PRICE was not used in this study, but the prices are on file for future reference.
SAVE,DATA3,DATAC	Saves the local files as permanent files which can be verified by using the XCAT command.
RETURN,TAPE	Dismounts the tape.

2. Compiling the Program and Data

ATTACH,BFG/R	Direct access file BFG is called from your catalog and rewound to the beginning.
GET,DATA3,DATAC/R	Indirect access files DATA3 and DATAC are called and rewound.
SETTL,n	As above.
DEFINE,BIN	Creates space for saving the binary compilation.
FTN,I=BFG,B=BIN,L=LIST,...	Compiles the program from FORTRAN to binary. The three parameters -- I,B,L -- must be used. Other parameters may be added, consult a manual. At this point the file LIST will contain the program in BFG. Unless hard copy of the program is desired or parameters are being used (error tracing) which require hard copy, the command CLEAR should be used. Otherwise, skip the next command.

CLEAR	Clears all local files (i.e., LIST).

3. Running the Compiled Program

TITLE(LIST)your name/identifier	Establishes the heading for hard copy output. LIST will contain all output from the program. The "/" starts a new line and can be used to title each run -- the first line is used by the computer center to distribute output.
SETTL,n	As above.
ATTACH,BIN/R	Direct access file BIN is called and rewound.
GET,DATA3,DATAC/R	As above.
BIN(DATAC,LIST)	Program is actually run. The computer responds by showing run time, a value greater than this must be used in SETTL.
REWIND,LIST ROUTE(LIST,DC=LP)	Sends all output stored in LIST to the line printer to be picked up.
CLEAR	Clears all local files in order to make additional runs in the same session.

4. Additional Information

At this point the user has the option of making input changes and running the program with this new data set, or of logging off the system. All changes in input must be confined to the file called DATAC above. If changes are made in other files, the whole simulation experiment must be started over since the solution algorithm will have been changed.

Data in DATAC is arranged corresponding to the altered input form on file in the department. Changes may be made using the EDIT mode of the NOS system on a CRT display screen. Once editing is completed, a new run can be made starting over with the commands in (3) above.

Logging off the computer must be done according to the manual instructions at the end of each session.