A PROPOSED METHODOLOGY FOR STRUCTURING AN ENDOGENOUS GRAZING SECTOR FOR THE CARD-RCA MODEL

by

Burton C. English, and
Pradeep Sircar

CARD Series Paper No. 83-9

For Presentation at a Fort Collins, Colorado
Workshop on Natural Resource Modelling

The CARD-RCA linear programming model of United States agriculture has evolved through more than a decade of detailed research at the Center for Agricultural and Rural Development. At the present time, the model is equipped for endogenous treatment of the production and transportation of the major crops in U.S. agriculture. An optional livestock sector is also available.

The model has been used for analysis of several topics of interest to policy makers, academics, and producers in the private sector. Under contract with the Soil Conservation Service, the model is being further developed in preparation for more extensive use by the government, and several potential avenues to improvement are being explored.

This paper explains the need for including rangeland and permanent pasture use as an endogenous sector in the CARD-RCA model. Also, the problems of modeling rangeland use are discussed, and a methodology for constructing the range sector is examined. This report, therefore, is preliminary in nature and intended for use of CARD, SCS, and FS personnel as they review the needs for the research project at hand. Actual documentation of the grazing sector will be prepared once the sector has been constructed and tested for use in the CARD-RCA models.

The United States Range Resource

One of the most extensive uses of the land area in the United States is livestock grazing. In 1976, approximately 792 million acres of range and forest land were grazed in the 48 contiguous states (USDA Forest Service, 1980), more than twice the acreage used for crops.

The use of range and forest land for grazing provides 16 percent of the roughage needs for livestock production in the nation, approximately equivalent to 86 million tons of nonlegume hay.[1] At current grass hay prices of $50/ton, the value of this production is $4.3 billion.

With increases in demand for red meat, increases in demand can be expected for livestock inputs, including grazing forage. The U.S. Forest Service recently completed an assessment of the forest and rangeland situation in the United States. In this assessment, projections are made concerning the demand for range grazing under alternative assumptions of population and economic growth. These are shown in Table 1. By reviewing even the low demand projections, it can be seen that range grazing is expected to become more important in the future. Using 1976 as a base, a 29 percent increase in demand for animal unit months from range is projected for 1990 under low demand assumptions. A 48 percent increase is projected from 1976 to 2000.

In order to meet these increased demands, changes will need to occur in range management. More land must be grazed, or productivity per unit of land must increase, or both must occur to increase the quantity of animal unit months. These changes, of course, will be closely related with other changes in the structure of agriculture. The fluctuating nature of the cattle market, changes (usually increases) in input costs such as

---

[1] 215 million animal unit months (AUM) converted to nonlegume hay equivalents at a rate of 2.5 AUMs per ton.

feed, capital, and energy, and environmental concerns are some of the more important variables that can be expected to influence range management. Changes in range management may influence such variables as the regional distribution of livestock production, demand for feed grains, and environmental quality.

Table 1. Projected increases in demand for range grazing in the United States to 2030 under alternative assumptions of population and economic growth

Projection Level	Historical Years		Projected Years				
	1970	1976	1990	2000	2010	2020	2030
			(million animal unit months)				
Low	N/A[a]	N/A	280	321	352	380	410
Medium	213	217	284	332	371	408	451
High	N/A	N/A	293	349	397	454	519

[a]N/A indicates this is not applicable.

SOURCE: USDA Forest Service, 1980.

The relationships of range use to the structure of agriculture and environmental quality are, in our judgment, of sufficient importance to merit more thorough treatment in the CARD-RCA model. In this report we briefly describe the status of permanent pasture and rangeland in the current version of the CARD-RCA model. Next, the specific requirements for making an endogenous grazing sector are discussed, and the relevant literature is reviewed. Finally, a methodology is proposed for constructing the range sector.

Current Model Structure

In the current structure of CARD LP models, all noncultivated grazing lands are incorporated into an exogenous roughage land base. This grazing land base includes Conservation Needs Inventory (CNI) acreages of hayland, pasture land, rangeland, and grazed forest land. Federal land leased for grazing by the Bureau of Land Management and Forest Service is also included in the grazing land base.

Yields for the exogenous roughage sector are developed as a function of the hay yields in the producing area, but the details concerning yields are not well documented. Table 2 shows the acres included in this sector, the average yield in tons per acre, and total production projected to 1985. (The only changes programmed into the model are withdrawals of land from the exogenous roughage land base to nonagricultural uses (Meister and Nicol, 1975).)

Table 2. Acres and production of exogenous roughage, 1985

Type	1,000 Acres	1,000 Tons Calculated Production	Tons/Acre Average Yield
Hayland			
dry	21,339	9,270	.43
irrigated	5,522	3,977	.72
Permanent pasture			
dry	95,546	40,775	.43
irrigated	3,469	2,330	.67
Range	377,324	65,962	.17
Forest grazed	134,317	14,824	.11
Public land	308,056	18,201	.06
U.S. total	945,573	155,444	.16

SOURCE: Meister and Nicol (1975).

Objectives for Constructing the Endogenous Grazing Sector

Changes in demand for range use may occur in response to changes in livestock demand, feed grain prices, the cost of harvested forage, transportation costs, environmental policy, and several other variables. Resulting adjustments in range use can occur through different methods. The amount of land used for grazing can be increased or decreased. Also, the productivity of range land may be altered through range improvements and changes in grazing intensity.

Previously, there was little opportunity to evaluate these potential changes in range use as they relate to the livestock and crop production sectors in the CARD-RCA model. Consequently, some of the major economic and environmental variables associated with U.S. agriculture were not as fully endogenous as may be needed for future analyses. An endogenous range sector, therefore is a major enhancement to the model.

Several objectives should be considered in building an endogenous range sector for the CARD-RCA model. Some of the more important objectives are listed below.

1. A precise definition of grazing land must be developed, and care must be taken not to include land categories that are already included in the cropland sector of the model.
2. Separate resource units (grazing capability classes) should be defined to account for differences in forage type, productivity, and location within the regions of the model.

3. A consistent, up-to-date inventory must be obtained for land in each resource class in each market region of the model. Future changes in this inventory should also be evaluated and provided for in the programs that are used to transform the model for projections into the future.
4. Grazing management activities must be developed to model the alternatives that exist for adjusting the level of grazing intensity and making improvements to increase productivity. For the analysis performed with the CARD-RCA model, the coefficients needed in these activities include: (a) costs, (b) level of forage production made available to the livestock sector, and (c) gross soil loss production.

Literature Review

With these objectives in mind, an extensive literature review was undertaken, and several rounds of correspondence occurred between CARD personnel and experts throughout the United States. Several references were reviewed that concern specific topics of range management, such as forage utilization by livestock, costs of various improvements, soil erosion on rangeland, etc. In this report, only the references that have a significant bearing on the complete task of building a linear programming model for endogenous determination of grazing land management are discussed.

Linear programming as a tool for solving resource allocation problems has been applied only to a limited extent in range management. Heady

(1956) described linear programming as a tool that could be used in identifying range research needs. Heady outlined a ranch profit-maximizing model structure, but no actual data were used to perform an analysis. Brown (1961) reported one of the first applications of linear programming to range management. The model was used in this work to aid in the valuation of improvement practices typical of the Western Range. Nielsen (1964) used linear programming to estimate the economic value of the range resource as measured by livestock production. Several other models have been described for short-term ranch management activities, such as in D'Aquino (1974) and Bartlett (1974). Applications of linear programming to wide land areas and diverse management alternatives, however, have not been widely constructed.

Jansen (1976) developed a model structure and set of computer programs to apply the linear programming technique to the management of up to 200 range resource classes. This program, called the Range Resource Allocation Method (Range RAM), incorporates dynamic techniques to model long-term physical and economic effects of various management practices. Jansen (1974) had previously applied a similar model structure to Northern California. Range RAM, however, is not a model for a specific region. It is a computer "package" that can be used by others who supply the data.

Runnell (1977) describes the basic features of a large linear programming model of rangeland in the United States. The first version of this model, described in U.S. Dept. of Agriculture, Forest Service (1972), was developed through three years of work by the Forest-Range

Task Force and several collaborators throughout the country. The model has been refined and updated for use in making the 1975 and 1980 assessments of renewable resources. Because of the great potential value of this model to the construction of the exogenous grazing sector on the CARD-RCA model, the Forest Service model will be described in detail.

Kaiser et al. (1972) describe the background and computer programming structure of the Forest-Range Environmental Production Analytical System (FREPAS). The Forest-Range Task Force (1972) provides a detailed description of the outputs of the model and an analysis of the range situation similar to those performed for the 1975 and 1980 assessments. An updated version of this original model is known as NIMRIM.

To study range resources in a systematic manner, it is necessary to develop a uniform framework of land base, range management levels, and costs. The basic conceptual framework and procedures used in this study were developed by a team of exports from the USDA Forest Service. Known initially as the Forest-Range Environmental Production Analytical System (FREPAS) (Kaiser et al., 1972), the development of the range resource inventories and outputs is documented by the Forest Service (1977). Different sections of this chapter are devoted to the definitions and rationale used in the development of the range model for this study.

Range Land Base

The term "forest-range", in this study, covers all nonfederal land in the 48 contiguous states, that is in native and natural grasslands and forest lands, if at some stage of their natural succession, or if in response to management, they produce vegetation that is grazable by livestock. Excluded are croplands, publicly owned commercial and non-commercial forest lands and woodlands leased for grazing, transportation system lands, improved pasture, and major waterways. The vegetative cover on the nation's forest and range lands is diverse, and is the result of a complex interaction of climatic factors, topography and soil factors.

The classification system for forest-range land base used in this model is based on vegetation. Closely related plant communities have been aggregated into a single ecosystem. The ecosystem classification and ecological groups are organized by geographical regions of the contiguous United States (Table 3). Detailed description of each ecosystem can be found in "Vegetation and Environmental Features of Forest and Range Ecosystems" (Garrison et al., 1977). Thus each ecosystem is based on potential natural plant communities (PNC). A PNC is defined as the vegetation community that would exist if man were removed from the scene and plant succession was compressed into a single moment. Thus, it reflects the biological potential of a relatively uniform environment and is the basis of the range sector in this study.

Within each PNC delineation, the land areas have been further subdivided so that data could be analyzed on a production and condition basis. For the range ecosystems, productivity classes (PC) are expressed in terms of traditional concepts of herbage production. Condition classes (CC) are based on vegetation cover, composition, and vigor, as well as soil factors. For the forest ecosystems, productivity and

Table 3. Ecosystem groups and ecosystems by name

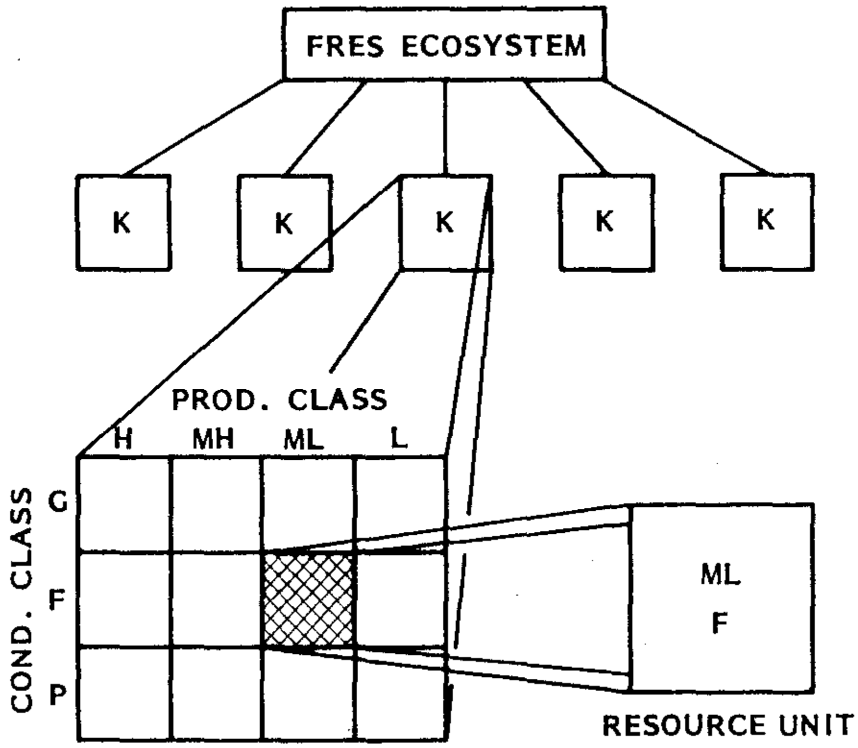
Name	Name
Western Forest	Great Plains
Douglas fir	Shinnery
Ponderosa pine	Texas savana
Western white pine	Plains grasslands
Fir-spruce	Prairie
Hemlock-Sitka spruce	
Larch	Eastern Forest
Lodgepole pine	
Redwood	White-red-jack pine
Hardwoods	Spruce-fir
	Longleaf-slash pine
Western Range	Loblolly-shortleaf pine
	Oak-pine
Sagebrush	Oak-hickory
Desert shrubs	Oak-gum-cypress
Southwestern shrubsteppe	Elm-ash-cottonwood
Chaparrall - mountain shrub	Maple-beech-birch
Pinyon - juniper	Aspen-birch
Mountain grasslands	Wet grasslands
Mountain meadows	
Desert grasslands	
Annual grasslands	
Alpine	

condition classes have been defined in terms of volume of wood produced and timber stand size class. Categories for estimating the productivity of an acre of forest-range ecosystems and for reporting conditions are shown in Table 4.

Table 4. Productivity and condition classes of forest-range ecosystems

Forest ecosystems	Range ecosystems
Productivity	
Wood	Herbage
Cubic feet per acre per year	
120+	First quartile (high)
85 to 119	Second quartile (moderately high)
50 to 84	Third quartile (moderately low)
0 to 49	Fourth quartile (low)
Condition	
Timber	Range
Nonstocked	Good
Seedling, sapling and pole	Fair
Saw timber	Poor

Acreages are compiled by "resource units" (Figure 1). A resource unit identifies the acres of a particular ownership by productivity class (PC), condition class (CC), ecosystem, and region. Thus, the land inventory provides important dual properties: analysis could be



K = Ecosystem

H = High, MH = Moderately High, ML = Moderately Low, L = Low

G = Good, F = Fair, P = Poor

Figure 1. Disaggregation of ecosystems into resource units

accomplished on an ecological basis; and it could be transformed to meaningful geographic units for evaluation and presentation. Complete expansion of the land classification yields 3,852 resource units but only 2000 combinations exist.

Range Management Levels

A range management level is a feasible action or combination of actions a decision maker may elect to implement. A management level is a concept and is independent of location. When implemented in a given location on an individual resource unit (land-vegetation), a set of appropriate practices to meet the level of management is specified and resource output predicted. Implied in the set of management levels defined for range are production goals as implemented through appropriate practices applied to the ground.

Range practices used to develop management strategies

Practices are specified treatments of range lands or mechanical structures necessary to achieve a particular management objective or level. Practices are defined and costs determined for each practice in each potential natural vegetation community (PNC) by resource unit (RU). For range management, 17 practices have been defined. Definitions and background rationale used in this study to develop management strategies include fertilization, irrigation, water control, six methods of vegetation manipulation, debris disposal, mechanical soil treatment, seeding, rodent control, insect and disease control, small and large water developments, fences and timber thinning (Table 5).

Table 5. Range practices included in the management strategies

Range practice	Definition
Fertilization	The application of any soil additive by any means with the objective of improving soil productivity for grazing purposes.
Irrigation	The installation of systems and structures that supply water to the land. This practice is defined in moisture deficient areas.
Water control	The draining of land or some other measure that regulates the water table. Bog or marsh drainage with an objective that improves forage production and livestock accessibility.
Low cost mechanical vegetation manipulation	The manipulation or control of vegetation by bush hogging, mowing, light disking, etc.
High cost mechanical vegetation manipulation	The use of heavy machinery such as dozing, chaining, plowing, shearing, etc., to control or manipulate woody vegetation.
Chemical vegetation manipulation	The use of herbicides as a primary agent in controlling undesired brush species. Application is done through aerial or surface techniques.
Biological vegetation manipulation	The use of insects, fungi, virus, etc., in controlling unwanted brush species.
Manipulation of vegetation by fire	The use of prescribed burning in the destruction of rough herbiceous residue.
Mechanical soil treatment	The physical disturbance of the soil through chiseling, pitting, contour furrowing, etc. with an objective of either seed bed preparation, water infiltration, erosion control, and micro-climate improvement.

(continued)

Table 5.(continued)

Range practice	Definition
Seeding	Planting by drilling, broadcasting, etc. in conjunction with other treatments.
Rodent control	Methods applied when seeding designed to reduce the rodent population density so that range productivity is improved.
Insect and disease control	The controlling of insect infestation and diseases which are detrimental to forage and range resources.
Small water development	The development of a single stock watering site through small dams, pits, minor spring development, shallow wells, and small water "catchments."
Large water developments	The development of deep wells, trick tanks, springs, large dams, seeps, and ditches having water storage and distribution systems.
Fences	The placement of fence on the range
Timber thinning	The reduction of the tree canopy that has the effect of increasing forage production.

Management Strategies

From the almost infinite number of management alternatives, five management strategies are defined. Intensities vary from no livestock to maximum livestock production and are defined below.

Strategy A--Environmental management without livestock[1]

Livestock are excluded by fencing, riding, public education, and by incentive payments. The environment is preserved from natural or other man-caused disasters. Resource damage is corrected to maintain a stewardship base. The total cost of applying this strategy is borne by other functions (for example, watershed, recreation, timber management).

Strategy B--Environmental management with livestock

Livestock is permitted at present capacity of the range environment. Investments for range management are minimal and only to the extent required to maintain the environment at a stewardship level in the presence of grazing. Costs of correcting resource damage resulting from past abuse are charged to other functions. Resources are protected from natural catastrophies.

Strategy C--Extensive management of environment and livestock

The goal is to maintain full plant vigor and to achieve full utilization of grazable forage. Techniques such as fencing and water developments

---

[1]Management Strategy A is not considered in the present study because it does not include livestock production.

are applied as needed to obtain improved grazing systems and range conditions. Relatively uniform livestock distribution and plant use are considered. No attempt is made to maximize forage production by cultural practices such as seeding and fertilization.

Strategy D--Intensive management of range environment and livestock

All available technology and practices for range and livestock management are considered and used as they may be cost efficient to improve livestock production, quality and utilization. Production of forage is maximized subject to the constraints of multiple use of range resources and maintaining the environment. Existing vegetation may be replaced with improved forage species. Better growing conditions and structural modifications can be made to accommodate complex livestock management and practices. Advanced livestock management practices are commonplace.

Strategy E--Environmental management and livestock production maximized

The goal is to maximize production of livestock while maintaining soil and water resources. Improved forage species may be introduced. This level requires large investments for construction and implementation of improvements, cultural practices, and animal husbandry; but all practices used must be cost efficient. Multiple range resource used is not a constraint.

The production outputs, management practices and management strategies required have been assumed to be the same for a resource unit (RU) (which is PNC-PC-CC combination) no matter which forage supply region it is located in. Presently, the PNC data are being aggregated to an Ecosystem level. Thus, instead of 107 different areas, there would be 34.

Costs

Cost information[1] has been developed for each management practice after the assessment teams came up with the acreage production data. The following table (Table 6) shows what information was gathered for range and timber resources. Certain calculations are performed while merging the cost data with practice numbers[2] and amount of practice used for different vegetation types, productivity classes, condition classes, and ownerships.[3] For cost calculation, practice numbers are organized into two categories.

(1) practice numbers 1-13, 17, and

(2) practice numbers 14-16.

---

[1]A full description of cost rationale, tables of practice and investment costs are included in Duran and Kaiser (1972).

[2]Practice numbers are in order with the number against each practice defined previously in this chapter.

[3]In the present study, only nonfederal ownership is considered.

Table 6. Direct costs of forest-range practices[a]

Items	Costs	
	Range	Timber
Skilled hours (of labor)	X	
Unskilled hours (of labor)	X	
Skilled dollars	X	
Unskilled dollars	X	
Equipment	X	
Material	X	
Equipment and material cost	X	X
Annual maintenance	X	X
Preparation and overhead		X
Total direct cost	X	
Practice life (number of years	X	X

[a]Costs related to range practices used in rangelands under non-federal ownership are only considered in this study.

A value called "Extent of practice" (EOP) has been calculated depending on the practice number category. If the practice number falls into category 1, then EOP = practice amount (this value from form 4) ÷ practice life (this value from cost data) ÷ 100. If the practice number falls into category 2, then

$$EOP = (\text{practice amount} \div \text{practice life}) \div 100{,}000 .$$

Following the EOP calculation, an adjusted annual maintenance cost has been calculated by multiplying the original annual maintenance cost by EOP and that figure has been multiplied by cost practice life. Also, the first seven costs listed above on the table have been adjusted by multiplying them by EOP. Finally, a total direct cost has been calculated by summing skilled dollars, unskilled dollars and equipment and material costs.

Costs have been annualized because some strategies required a higher proportion of short-lived practices than others, and interest has been added to reflect the social cost of selecting those practices that tie up capital. For each strategy, the annual investment and maintenance costs for selected practices have been calculated. Management and supervision expenditures have been added. Average values have been presented for a given resource unit. Costs for practices also have been assumed to be the same across regions within a resource unit (RU).

Knowledge of resources, resource capability, resource limitations, demands for numerous outputs, and the related costs is not meaningful in itself. It needs to analyzed in a rational manner, and evaluated in relation to the needs of the society.

The study by Sircar, English, and Heady (1983) sought ways in which commodities, resources, impacts and trade-offs could be considered in a logical quantitative manner. The research method of this study was based upon the theory of comparative advantage and employed the mathematics of linear programming. This model is developed on the basic framework of large scale interregional linear programming models eveolved from several years of research at the Center for Agricultural and Rural Development (CARD). The national interregional linear programming model used in this study was developed recently at the Center (CARD) in conjunction with the Resources Conservation Act (RCA) effort. Two models used especially as background for this study are reported in English et al. (1982) and Meister and Nicol (1975). Except for the range sector, these studies provide much of the modeling background used in this study.

The CARD-RCA Model: A General Description

A schematic diagram of the CARD Rca Linear Programming Model is presented in Figure 2. It represents three quantitative components of a linear programming problem: an objective function, alternative methods or processes (activities) for attaining the objective, and resource and other restrictions.

Constraints	Dry rotations	Irrigated rotations	Range resource units	Water: Surface buy	Water: Ground buy	Water: Transfer	Water: Release of irrigated hay	Nitrogen buy	Dry irrigated conv.	Irrigated dry dev.	Crop trans.	Livestock prod.	Livestock trans.	Forage (AUM)-~~NLH~~ conv.	Grazing-cropland conv.	RHS
Objective function	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}		X_{17}	X_{18}	X_{19}		X_{111}	X_{112}	X_{113}		X_{115}	
Dryland	1								1	-1					-1	$\leq R_2$
Irrigated land		1							-1	1						$\leq R_3$
Grazing land			1												1	$\leq R_4$
Crop prod.	X_{51}	X_{52}									± 1	$-X_{512}$				$\geq R_5$
~~NLH prod~~d. Nutrients	X_{61}						$-X_{67}$					$-X_{612}$		X_{614}		$\geq R_6$
Forage prod. (AUM)			X_{73}											$-X_{714}$		$\geq R_7$
Livestock prod.												X_{812}	± 1			$\geq R_8$
Nat. timber prod.			X_{93}													$\geq R_9$
Water (PA)	$-X_{101}$			X_{104}	X_{105}		X_{107}					$-X_{1012}$				≥ 0
Water (ASA)				X_{114}	X_{115}	± 1										$\leq R_{11}$
Nitrogen	$-X_{121}$	$-X_{122}$						1				X_{1212}				$\leq R_{12}$
Soil loss (crop)	X_{131}	X_{132}														
Soil loss (range)			X_{143}													
Bounds			B_3	B_4	B_5		B_7		B_9						B_{15}	

Figure 2. Schematic diagram of the CARD RCA linear programming model

The restraints (expressed as rows) are listed vertically. The types of activities (expressed as columns) are listed horizontally. The X_{ij} notations within the tableau represent sets of input-output or technical coefficients that must be determined. The X_{1j}s represent the objective function row indicating the per unit cost associated with each activity. The X_{ij}s in the commodity rows reflect yield, consumption, and transportation coefficients, while the X_{ij}s in the resource rows represent the fixed amount of resource used by each activity. Some activities are defined as transfer activities and have no objective function value. Each soil-loss row in this model is unconstrained and acts as an accounting row. The soil-loss coefficients $X_{13,1}$, $X_{13,2}$ and $X_{14,3}$ reflect the severity of erosion for the conditions that prevail for the defined land use activities.

The vector R_is, expressed as right hand sides (RHS), represent resource availability and specified commodity demands that must be met by the system. The bound vector (B_js) indicates the economic and institutional restraints imposed on resource availability. In the following sections of this chapter, each component of the model and the development of coefficients is discussed.

Limitation of the model

The study recognizes the limited scope of the model because of the complexity of the natural ecosystems and lack of understanding of numerous interactions thereof. Further, the conventional linear programming model assumes a timeless, static environment and ignores the effects of a decision's impact on opportunities and choices during subsequent time periods. Therefore, the conclusions derived from the model are conditional statements about the future, based on assumptions inherent to the model. The results are projected, so the interpretations of the solutions are subject to the knowledge of the assumptions from which they are derived.

Regions of the model

Four sets of regions are used: (1) the data collection regions used in the development of the model's data base; (2) the regions or producing areas (PA) within which crop production activities and crop land conversion activities of the model are defined; (3) the market regions (MR) within which the demands for commodities are defined; and (4) the reporting regions (major zones) within which the results are summarized.

The data regions

Two major kinds of data regions are used in this model. The forest-range data[1] are collected by resource unit (RU) within each potential natural plant community (PNC) by the Forest-Range Task Force (Forest Service, 1972). These basic RUs vary in area depending on the location of the geographical region of the ecosystem and range conditions. As, for example, a RU in a desert ecosystem is different in size from grassland ecosystems. Output data vary for each PNC. Therefore, the

[1]The complete data tapes have been provided by the Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, Fort Collins, Colorado.

assessment teams have estimated production figures for each RU within each PNC, using the management scenario and rationale. The range data base is documented in Forest Service (1977). The nonfederal forest-range land base of the model is defined within ecosystem regions. The PNC data are aggregated to ecosystem. The range production data are distributed to the corresponding MR which make up the ecosystem.

The crop sector data regions, shown in Figure 3, are built on county approximations of the major land resource areas used for data collection by the Soil Conservation Service (SCS), U.S. Department of Agriculture. Further adjustments are made to generate crop production coefficients that are needed in defining the model. Besides these two major data collection regions, the data regions also include the county and states of the continental United States from which census and commodity production data are tabulated.

The producing areas (PA)

The 105 producing areas or regions (PA) shown in Figure 4 are derived from the Water Resource Council's 99 aggregated subareas (ASAS). The crop production sector and the cropland base of the model and the cropland conversion activities are defined within these regions. Water supplies for the western United States are defined for producing areas 48 to 105.

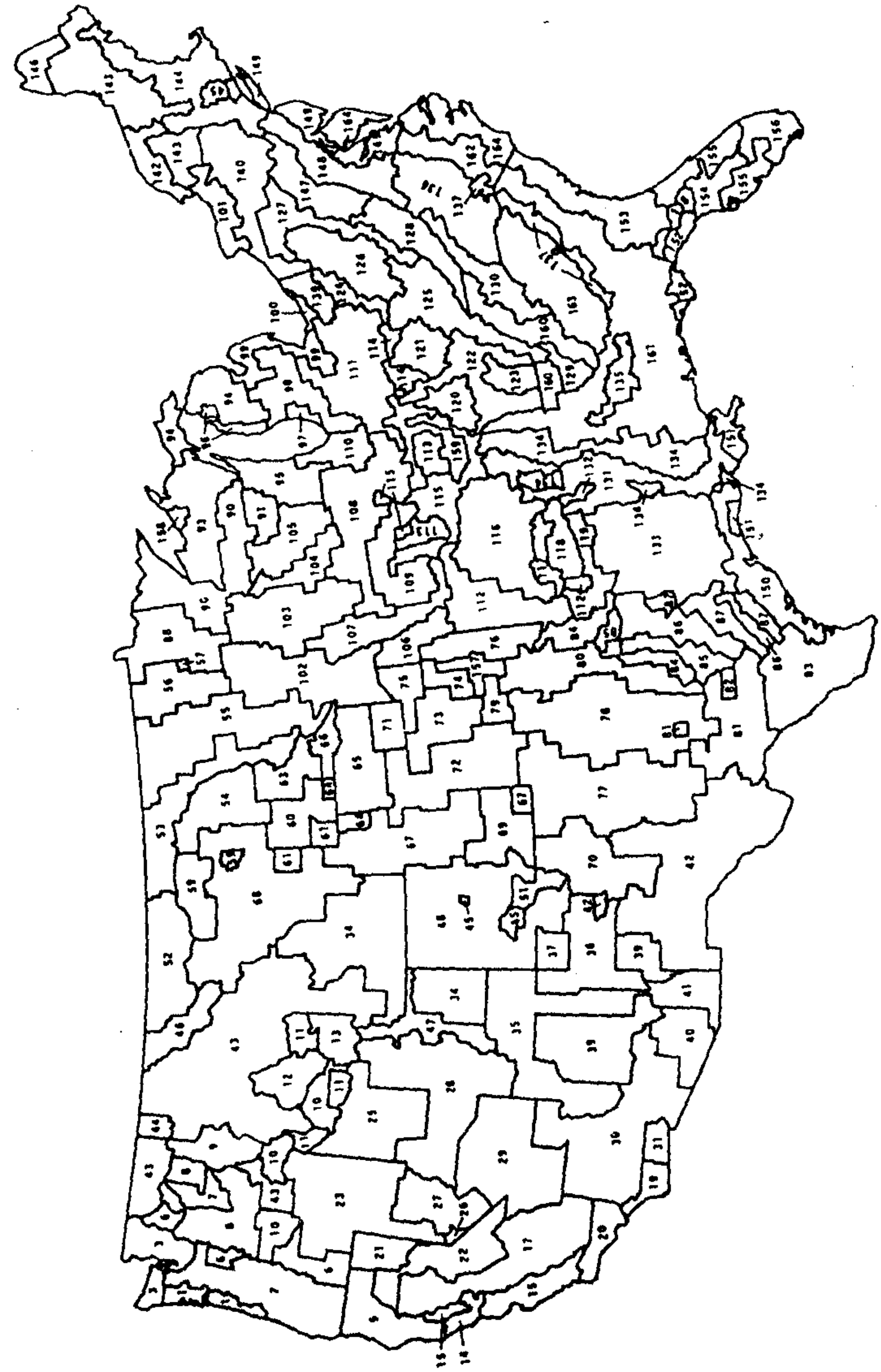


Figure 3. The SCS data collection areas

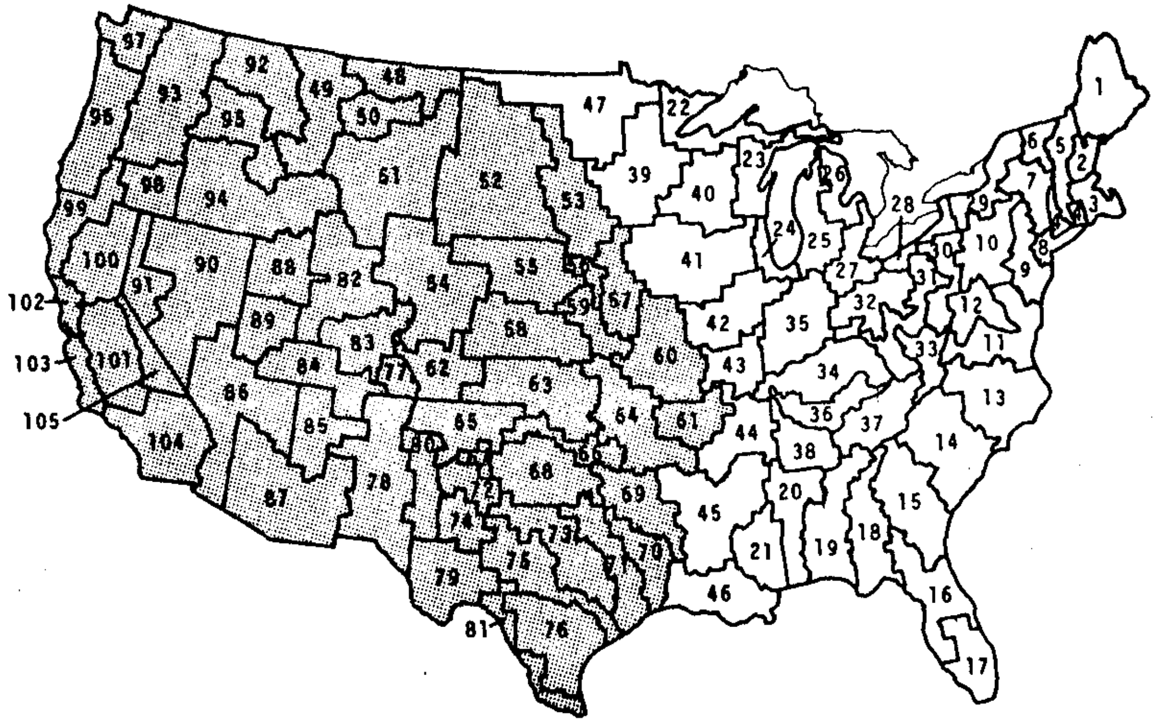


Figure 4. Producing areas with irrigated lands (shaded areas)

Figure 5. 31 market regions

The market regions (MR)

The 31 market regions, shown in Figure 5, are the aggregation of the 105 PAs. The MRs serve two purposes. First, each market region functions in the model as a demand and transportation center. Commodity demands, range products, and transportation activities are defined within these regions. The metropolitan center identified within each MR acts as a trading post. It is through the spatial linkages that the relative comparative advantages and changes in production patterns are determined among the regions of the model in fulfilling the demand restraints. Second, the endogenous livestock, range forage production, and nitrogen purchasing activities are defined in these market regions.

The reporting regions

The final set of regions (major zones) are defined by aggregating the adjacent market regions and producing areas. The nine major reporting regions (zones) are shown in Figure 6.

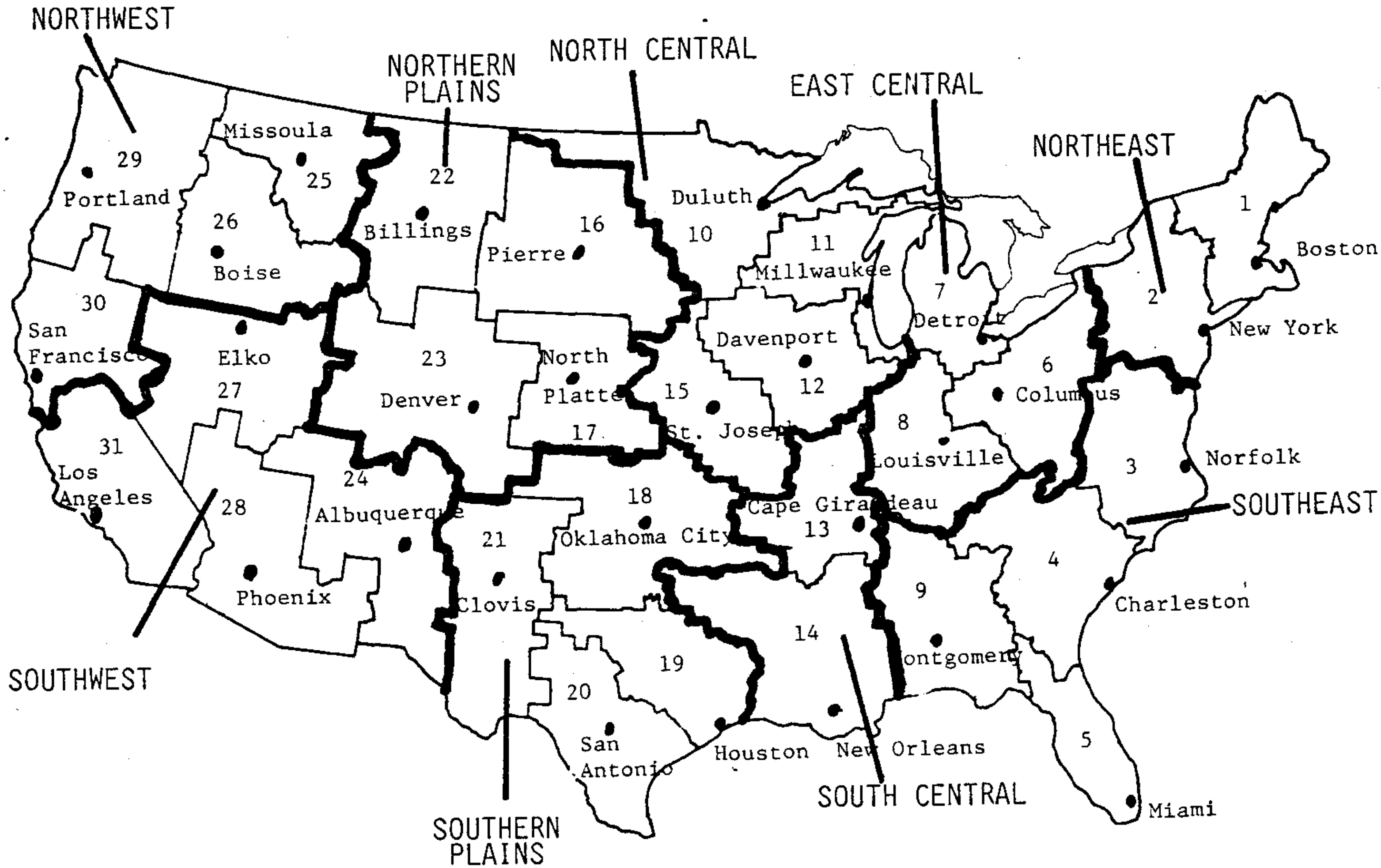


Figure 6. Major Zones

References Cited

Brown, W. G.

1961 Estimation of rates of return from investment in range improvement practices by linear programming. Oregon Agric. Exp. Sta. Tech. Paper 1383, 13 p.

Duran, Gilbert and H. F. Kaiser

1972 Range management practices: investment costs, 1970. U.S. Dept. of Ag. Agriculture Handbook No. 435.

English, B. C., K. Alt, and E. O. Heady

1981 A documentation of the Rural Conservation Act's assessment model of regional agricultural production, land and water use, and soil loss. Miscellaneous CARD Report. Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa.

Forest Range Task Force

1972 The nation's range resources—a forest-range environmental study. Forest Service. U.S. Dept. of Agr. Forest Resource Report No. 19.

Forest Service

1977 RPA-79 assessment: Book of procedures. U.S. Dept. Agric., Washington, D.C.

Forest Service

1980 Review draft of an assessment of the forest and rangeland situation in the United States, supporting technical document to the report to Congress on the nation's renewable resources. U.S. Department of Agriculture.

Garrison, Goerge A., Ardell U. Bjugstad, Don A. Duncan, Mont E. Lewis, and Dixie R. Smith

1977 Vegetation and environmental features of forest and range ecosystems. U.S. Dept. of Agr. Agriculture Handbook No. 475.

Heady, Earl O.

1956 Economic concepts in directing and designing research for programming use of range resources. Journal of Farm Economics 38(5):1604-1616.

Jansen, Henricus C.

1976 Range RAM . . . a long-term planning method for managing grazing lands. U.S. Dept. of Agr. Forest Service Research Paper PSW-120.

Kaiser, H. Fred, Kenneth DeBower, Ronald Lockard, and John W. Putman
1972 Forest-range environmental production analytical system FREPAS. U.S. Dept. of Agr. Agriculture Handbook No. 430.

Kuchler, A.W.
1964 Potential natural vegetation of the conterminous United States. American Geographical Society. Special Publication No. 36.

Meister, Anton D. and Kenneth J. Nicol
1975 A documentation of the national water assessment model of regional agricultural production, land and water use, and environmental interaction. Center for Agricultural and Rural Development, Iowa State University, Miscellaneous Report.

Neilsen, D. B.
1964 Estimating the economic value of the range resource from livestock production. In: Measuring the economic value of products from the range resource. Committee on economics of range use and development of the Western Agric. Econ. Council. Report No. 6, p. 83-111.

Runnell, Robert S.
1977 A systems approach to range assessment from: forests for people, Proc. Society of Am. For. Nat'l. Conv., 1977 Albuquerque, N.M. p. 120-124.