A SIMULATION ANALYSIS OF POLICIES FOR THE NORTHERN COLOMBIA BEEF CATTLE INDUSTRY

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ABSTRACT

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The Atlantic Coast of northern Colombia (known as the Costa) supports between 40 and 50 percent of Colombia's cattle population and, with easy access to domestic and world markets, is the most important of Colombia's five beef-producing regions. Because cattle raising is the main economic activity in the Costa and is an extensive operation with low technical efficiency, the region has been a priority target for cattle development programs. In the mid-1960s, with the financial and technical assistance of several international agencies, the Colombian government started a cattle development program aimed at increasing beef production mainly on the Atlantic Coast. In the early 1970s this program was reinforced with a disease control program and then revised and issued as a national cattle development plan. The main instruments of this plan are credit, technical assistance, export subsidies and improved marketing and slaughtering facilities. Its long-term objectives are to increase the protein supply to the Colombian population and to generate foreign exchange earnings.

Alvaro Posada

The primary purpose of this study was to develop a system simulation model to (1) analyze the effects of production incentives on the decision of farmers to adopt new production methods, and (2) estimate the effects of the expanded regional production on the income of farmers, government revenues, Colombian beef consumption and sustained level of exports. Four alternatives to traditional production were considered. Alternative 1 considered the improvement of native and artificial grasses; alternative 2 considered the improvement of artificial grasses and the substitution of artificial for native grasses; alternatives 3 and 4 added the production of forages and silage to the improvement of range lands in alternatives 1 and 2 respectively. At the present stage of the study, however, alternative 2 was the only one comprehensively tested and used as a base run for policy experimentation. The cattle system simulation model has five major components (including a cattle demography model) which (1) allocate land use according to the farmer's perceived profitabilities of cattle and crops subject to land and capital constraints; (2) calculate yield and output of cattle and crops and their respective producer and market prices; (3) provide the instrumental linkages for government revenue, export trade policies, and production campaign policies; and (4) generate the performance criteria necessary to evaluate the impacts of alternative programs on the cattle economy through time.

The five major sets of assumptions investigated were (1) disease control in the traditional herd, (2) alternative cattle industry taxing policies, (3) alternative development credit policies, (4) alternative levels of government production campaign promotion, and (5) alternative cattle pricing and export policies. The results of the cattle policy experiments were discussed in terms of the projected time paths (from 1966 to 1985) of five of the most important performance indices incorporated in the model: (1) regional cattle population, (2) Colombian beef consumption per capita, (3) regional farm income from cattle, (4) capitalized grazing land value per hectare, and (5) annual regional government revenue from cattle. Experiments with disease control and export promotion policies each used two indices instead of the above five: regional cattle population and extraction ratio for the disease control policies and domestic market price of finished males and export margin for the export policies.

In general, the study demonstrated that (1) the projected outcomes with the government disease control campaign were greater than under precampaign practices in the traditional herd; (2) the projected outcomes with government programs easing development loan terms were in all cases greater than the base run which assumed current credit policies; (3) the projected area in improved land and the modern cattle population with government policies benefiting both the traditional and modern operations were in all cases lower than under policies benefiting only the modern

operation; (4) the projected area in improved land with the increased land tax rate was greater than the base run which assumed current land tax rates; (5) the projected outcomes with the removal of special taxes on cattle were lower than the base run which assumed no removal of these taxes; (6) given the assumptions on farmers' decisions and accounting mechanisms in the model, availability of credit for land improvement does not seem to be a serious constraint to land modernization; and (7) the projected outcomes with a flexible exchange rate suggest that this is an effective incentive to export without involving large transfers from public revenues to exporters in the form of subsidies.

The study indicated areas where more research and regional data are needed to improve the model's performance, and discussed possible extensions that could help analyze more fully alternative policy strategies for the Costa's overall development. Finally, the study demonstrated that the system simulation approach with a computerized model of the cattle economy which incorporated information from diverse sources and accounted explicitly for the dynamic interactions and feedbacks that might occur can be a very useful methodological tool for policy analysis.

To

Maria Lucia

and

Clara Lucia

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INTRODUCTION

The Problem

Although planning for development has been practiced in Colombia for over thirty years, it has played a small role in the preparation of economic policy, and the various plans have been conceived more as political than as economic documents.

Plans have been criticized as being essentially technocratic exercises; the general public has contributed little to plan objectives and serious intention to implement has been lacking. As a consequence, development plans have enjoyed minimal general support and have had little or no effect on changing the country's economic, social and political structures [26].

The general systems simulation technique, with its special approach to analyzing the problems of development, could be helpful in solving the issues of feasibility, credibility, and general acceptance of the planning exercise. Yet its effectiveness as a tool for development will depend on the will of Colombian authorities to provide the necessary financial and institutional support for fulfillment of the plan's goals.

In Part I, Chapter 1 discusses the scope and procedure of the study and briefly outlines the "systems approach" used. Chapter 2 is a brief descriptive account of Colombian beef production, distribution and consumption that will help clarify the problems of the cattle industry. Chapter 3 describes the region studied and the characteristics of its agricultural production. Chapter 4 discusses the modeling specifications and procedure.

Part II details the Northern or Costa model. Chapters 5 through 9 cover the land allocation and modernization decisions component, the agricultural production component, the price generation component, policy entry points and the criteria and general accounting component.

Part III looks at testing and validation procedures and results. Chapter 10 discusses data needs and the processes of tuning the model to track time series of recorded behavior. The results and implications of sensitivity tests on model parameters are presented in Chapter 11.

Part IV discusses policy applications of the model, conclusions and areas for further work. Chapter 12 presents the results and analyses of runs experimenting with various cattle development policy options. Experiments include an investigation of the sensitivity of policy results to changes in certain parameter values. Finally, Chapter 13 presents summary and conclusions, and outlines areas for further work in refining, improving and extending the model.

CHAPTER 1

SCOPE AND NATURE OF STUDY

Agriculture in the Colombian Economy

Although agriculture is Colombia's main economic activity, its rate of growth during the last two decades has been lower than that of the gross domestic product (GDP). In 1969 it contributed 30 percent of GDP but its share in the national output has been declining as industrialization has proceeded. Nevertheless, agriculture continues to be the main source of employment with over half the Colombian people directly depending on it for their living.

Within the agricultural sector, livestock production occupies about 87 percent of all agricultural land, accounting for about one-third of agricultural output, or approximately 10 percent of GDP. Beef is the primary product.

But despite the agricultural industry's importance, the production of basic food crops has barely kept pace with a 3 percent population growth rate. Cattle slaughter per 1000 inhabitants has been declining since 1950.

Colombia's economic growth has been responsive to changes in the performance of the export sector and this has been dominated by agricultural exports which accounted for 78 percent of total foreign earnings in 1970. While

coffee has remained the country's major export, its share of the total value of exports has declined from 72 percent in 1960 to 61 percent in 1970. As a proportion of all agricultural exports it has declined from over 90 percent prior to 1965 to 75 percent in 1969 [41]. But Colombia's dependence on agricultural exports which have unstable world markets (e.g., coffee, bananas, sugar and cotton) has undesirable disequilibrating effects which jeopardize development efforts and create the necessity of finding new sources of foreign revenues. The development of the beef industry, for which the outlook in world markets is considered brilliant, will accomplish the aims of increasing the domestic supply of protein for an improved diet and of helping remove both the foreign exchange and instability constraints.

Yet in order to fully exploit the natural comparative advantage Colombia has for cattle raising and make it a leading industry that is competitive in world markets, a great effort has to be made to overcome the traditionalism that has characterized the industry and to supply the necessary inputs for modernization.

In recent years the Colombian government has revised its policies toward the cattle industry and reoriented them toward the attainment of increased beef production. These policies have been associated with credit and technical assistance, disease control, land ownership rights, taxation and export subsidies.

The Colombian government has given priority in the cattle development program to the Atlantic plain of Northern Colombia because of that region's favorable natural conditions, its accessibility to domestic and foreign markets, and the fact that it has the largest share of the country's cattle population. This also supports the decision to focus the present study in this geographical region.

Need for This Study

Since cattle production is not merely an important economic activity but the only practical use for millions of hectares of agricultural land not suitable for crop production because of soil conditions, climate, floodings and/or distance from markets, its performance is and will be an important factor in the success of Colombia's efforts to foster sound economic growth in agriculture.

Because of its size, probably future demands for its products and the need for improved operation, the Atlantic plain beef production system's performance has had and will have a significant impact on Colombia's agricultural economy.

Several studies have been done on various aspects of the Colombian beef production and distribution systems. General descriptions of the industry and analyses of current and proposed policies have been done by Riley [61], the Food and Agriculture Organization (FAO) [66], the Caja Agraria [6], the World Bank [42] and the Instituto Colombiano Agropecuario [31]. Production problems and projections have been recently analyzed by Henning [29], Von Oven [60], and

Atkinson [67]. Bowser [5] attempted to make production projections by regions and establish surplus and deficit areas under two systems of management. Daines [68] is attempting to incorporate the cattle subsector into a broader sector analysis of Colombian agriculture.

More specialized studies on diseases and reproduction problems have been done by the Instituto Colombiano Agropecuario (ICA) and Gomez, respectively [31, 24]. Slaughtering, marketing and opportunities for exporting have been studied by Anderson [2], Booz, Allen and Hamilton [4], Secretaria de Agricultura de Antioquia [64], and Garcia Samper [23].

Profitability studies have been done by the World Bank [42, 43], Federacion Colombiana de Ganaderos (FEDEGAN) [20], and Instituto Colombiano de la Reforma Agraria (INCORA) [34]. More recently, the Centro Internacional de Agricultura Tropical (CIAT) [9] made a survey of the cattle industry in Northern Colombia in an attempt to gather basic information and identify specific problems which are in need of further research.

These have mostly been descriptive studies, and when projections are included they are trend-like, straight forward, algebraic estimates. The credibility of these estimates has always been questioned because of their reliance on time-series data which deserve a low degree of confidence. Yet they have served the purpose of providing background information about the cattle industry and a basis, though weak, for planning its development. But except for the Bowser, FEDEGAN,

and the CIAT studies, no attempt has been made to place the cattle industry in a regional context and assess the effect through time of alternative strategies of development on the attainment of a multiplicity of objectives such as employment, farm income, government revenues, foreign exchange earnings, and others without neglecting the interactions with other subsectors of the agricultural economy.

This dissertation is an attempt to integrate the available information into a computerized model that will provide the policy maker with a more informed basis for planning development strategies for the Colombian beef production system on the basis of the learning experience from the Northern region. The basic parameters and structural relationships estimated in this study can be utilized in the future for modeling the cattle industry in other Colombian regions, and/or for developing a broader regional model of Northern Colombia.

This study has gained from experience with other simulators of cattle population and related activities developed for Nigeria, Korea, Northeast Brazil and Venezuela [53, 62, 51, 55]. The cattle population simulator developed by the World Bank [43] also has provided an invaluable experience.

General Systems Simulation Approach as a Tool for Beef Policy Analysis

In recent years there has been an increasing interest in the utilization of the systems approach for analyzing

complex developmental problems. Computerized techniques have helped automate the hand calculation process and expand the range of alternatives which can be examined. Policy makers and researchers have been placing more confidence and credibility on the general system simulation technique as its methodology and approaches for development have been better understood and developed [25, 46, 47]. Public and private decision makers have been presented with an approach that attempts to build a general model to trace the consequences through time of following alternative courses of action based on at least as wide a range of kinds and sources of data and information as decision makers use without specializing in any one technique to the exclusion of techniques frequently used by decision makers. In addition, the approach carefully avoids premature application of maximization techniques in situations where decision makers realize that the multiplicity of goods sought and bads avoided has not yet been reduced to a common denominator. These characteristics make the generalized, systems-science simulation approach very similar, though more comprehensive and complex, to the descriptive and paper-and-pencil and desk-calculator projections which have maintained a high level of credibility among decision makers [47].

Researchers have been provided with a technique for analyzing the problems of development without the methodological and theoretical restrictions of more specialized techniques such as simultaneous equilibrium equations,

linear programming (LP), benefit/cost ratio analyses, internal rate of return analyses, etc.[1/] And as new concepts and experiences regarding the formulation and implementation of systems approaches have evolved, many of the early objections of statisticians concerning the reliability of the estimates of parameters, criterion variables, and prescriptions by users of the systems analysis are being dissipated. The analogy between the general systems analysis simulation approach and the Bayesian approach to inference has been demonstrated by Ladipo [50], and Johnson [47, 49] has analyzed repeatedly the possibility of empirically validating and verifying the normative concepts involved in simulation models.

Econometric methods with probabilistically estimated parameters rely heavily on time-series and cross-sectional data not always available in developing countries. These techniques also tend to be specialized on linear equations and behavioral assumptions involving maximization in accordance with neoclassical theories of the firm and household; the economic forces that link the various components of an economy are assumed to be self-equilibrating as a consequence of the maximizing activities for entrepreneurs and consumers. However, the validity of these two assumptions has been challenged where the findings of these kinds of studies were to

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[1/] For a more detailed discussion of various specialized techniques see Manetsch, et al., [53]. For particular applications to the Nigerian cocoa industry see Chong [10].

be used for policy analysis and prescriptions [53]. These and other methodological difficulties often result in less reliable parameter estimates than available from alternative kinds and sources of data and information with less sophisticated estimation and approximation techniques.

Linear programming and benefit/cost ratios and internal rates of return are other specialized techniques which have gained considerable prominence in recent years. LP is always used in an optimizing mode in solving the problems of resource allocation and policy analysis. The other two techniques have been used more for project analysis than for analyzing alternative policies and programs. Basically, all these techniques suffer from a need for a common denominator among the goods being sought and the bads being avoided. Moreover, the approach is quite mechanistic and may not allow rigorous analysis or interaction between researchers and policy makers needed for a better understanding and improving of the system.

A consideration of the distinctive attributes of the various approaches employed for studying development alternatives in a variety of less developed settings has led to the present proposal to use the system simulation approach as a tool for development planning and policy analysis of the cattle industry in Northern Colombia.

The general systems simulation approach, following the principles of the scientific method and problem-solving research, is viewed as an iterative problem-solving process

that includes problem formulation, mathematical modeling, refinement and testing of a computerized approximation of the mathematical model, and creative design and execution of simulation experiments intended to provide answers to the questions being asked by the decision makers involved.[1/]

The general system simulation approach has been specially applicable for solving many of the problems of economic development which do not meet the requirements for applying the simple maximizing computations of static production, consumption and welfare economics. As decision makers seek so many different goods and avoid so many different bads in developing the economy, it is very difficult for them or anyone to find a common denominator to be maximized or minimized. Problems of ordering and imperfect knowledge about future consequences of present actions complicate the circumstances in which decisions are made. Yet reaching prescriptive conclusions to solve development problems requires development of positive and normative knowledge. The methodology used in the general system simulation approach allows the system analyst to maintain a philosophic orientation sufficiently flexible to permit analysis of questions involving both the normative and the nonnormative values always present when considering the goals of economic development.

[1/] For more detailed discussion of the philosophy and methodology of the general system simulation approach for problem-solving research, see Manetsch et al., [53], Abkin [1], and Rossmiller et al., [62].

There are four distinguishing features of the general system simulation approach particularly useful for the policy analysis of the Colombian beef economy. First, it is a generalized approach which makes use of a wide range of primary and secondary information from many sources including surveys, government records, experiments, business records, qualitative judgments and insights of subject matter experts, and descriptive work about the beef industry from various disciplines. Also a wide variety of specialized techniques are used from econometrics, linear programming, partial budget, project analysis, etc. Since the research and model-building process is iterative and flexible, new information can be incorporated easily as it becomes available, and the structure of the model modified accordingly.

Second, the system approach can incorporate many types of functional relationships into the model to closely reflect the current or potential real system. These include dynamic interactions, curvilinearities, discontinuities, time lags, probabilities and irreversibilities.

Third, the approach does not have to assume (but does not preclude) any profit or utility maximizing producers and consumers, or any self-equilibrating economic adjustments. It does not necessarily involve a unique set of optimizing solutions based upon a common objective or a predetermined singular goal, which does not exist in reality. In contrast, the approach is more guided by the problem under investigation.

Fourth, the system simulation approach provides an experimental setting for exploring the consequences of a wide range of alternative plans or management strategies that ultimately will assist policy makers in determining the best course of action. Decision makers may be shown the consequences of alternative courses of action in terms of what goods or bads will be received by or imposed upon groups of people, when, and in what quantities. After such projections are available, interaction among investigators and policy makers will lead to a better understanding of the trade-offs among the numerous goods and bads involved in the solution of the problem. Developing, extending and refining knowledge on the various goods and bads and learning about the trade-offs is a way of solving the problem of finding an interpersonally valid common denominator. As stated earlier, this problem has contested the usefulness of the approach used by some quantitative techniques of analysis in examining the problems of economic development.

Further, in the iterative process, decision makers and investigators can work interactively to solve the remaining two major theoretical difficulties found in the analysis of development when using some other problem-solving techniques. First, the sequence in which different action programs should be undertaken can be established, thus resolving the problem of how programs and projects (actions) can be ranked. Then, when consequences of alternative decision rules can be projected and studied, it is possible to develop

a basis for choosing the best rule among the alternative courses of action being considered. This solves the planners' problem of choosing a decision-making rule, especially under conditions of imperfect knowledge and uncertainty.

Purpose and Objectives

The purpose of this thesis is to develop a model to help evaluate policy decisions that might be made in expanding the production of beef in Northern Colombia through time. More specifically, the objectives are:

1) To develop a credible simulator that could eventually be extended to other beef producing regions and be further integrated into a national model.

2) To use the simulator

   a) to analyze the effect of new production methods on the output of cattle;

   b) to analyze the effect of production incentives on the decision of farmers to adopt the new methods;

   c) to estimate the effect of the expanded regional production on the income of farmers, government revenues, domestic beef consumption and sustained level of exports.

The procedures used in meeting these objectives will be discussed in Chapter 4.

CHAPTER 2

A GENERAL DESCRIPTION OF THE COLOMBIAN CATTLE INDUSTRY

The characteristics of cattle raising in Colombia described in this chapter will help in understanding the multiple problems affecting the industry.

Stock farming in Colombia is carried on in a variety of climates and ecological zones that give rise to a wide range of problems which limit beef yields and supply. The principal limiting factors are the heavy incidence of animal diseases, malnutrition, deficient marketing and slaughtering systems. Besides the technical factors, government decisions that affect the political, social, and economic environment also have a major effect on the industry's behavior.

Size and Location of Cattle Industry

Of the 114 million hectares in Colombia, only about 40 million are suitable for crop and livestock production; the remainder is under forest or is wasteland. Cropland occupies approximately 5 million hectares, which leaves 35 million hectares under livestock. Even if crop acreage increases at 7 percent per annum during this decade, which would be very rapid growth, there still would be 30 million hectares in 1980 with no practical alternative use but grazing. The nation has the choice of producing cattle on this

land or letting it go idle. Credit and managerial manpower are the only scarce inputs used by the livestock subsector; thus cattle production is not currently a competitor with crops for scarce land.

Although statistical data are not extremely reliable, Colombia supports about 20 million head of cattle, including slightly more than 17 million beef animals. The rate of increase in cattle numbers has been low, about 2 percent per annum over the period 1950 to 1969. Since 1956, the rate has been close to 3 percent [41]. Although Table I.1 shows that herd numbers increased at about 4 percent per annum over the period 1965 to 1969, ICA [31] has projected an average rate of growth of 3 percent annually for the next five years.

The majority of beef cattle are maintained in tropical zones which have been divided into five clearly differentiated producing areas (Figure I.1).[1/]

1) The Atlantic Coast at an altitude of between 0 and 500 meters includes Cordoba, Bolivar, Atlantico, Sucre, Cesar, Magdalena, Guajira, and Northern Antioquia. Average temperature exceeds 24°C and annual rainfall varies between 250 mm and about 2000 mm. Cattle population is approximately 7.6 million head and area in pasture 9.7 million hectares.[2/]

[1/] Max F. Bowser, "Prerequisitos y Potencial para la Exportacion de Carne en Colombia en la Decada de 1970," Agricultura Tropical, XXV (Bogota, Nov., 1969), 679.

[2/] Cattle population and area in pasture for regions 1, 2, and 3 are taken from Caja Agraria [6]; for region 4, from Bowser, ibid., 684; and for region 5 from ICA [31].

FIGURE I.1. Colombia--the five beef cattle producing regions.

2) The Central and Upper Magdalena Valley at an altitude of less than 1000 meters includes Central and Southern Antioquia, Eastern Caldas, Tolima, Huila, the Santanderes, Central and Western Boyaca and Cundinamarca. Average temperature exceeds 24°C and average rainfall varies between 2000 and 4000 mm. Cattle population is approximately 4.3 million head and area in pasture is 5.6 million hectares.

3) The Cauca Valley at an altitude of less than 1100 meters includes Valle, Cauca, and parts of Caldas, Risaralda and Quindio. Average temperature exceeds 24°C and annual rainfall varies between 1000 and 2000 mm. Cattle population is approximately 1.25 million head and area in pasture is 1.2 million hectares.

4) The eastern plains at an altitude between 500 and 1000 meters include Meta, Eastern Cundinamarca, Eastern Boyaca (Casanare), Arauca, Vichada and Guainia. Average temperature exceeds 24°C and annual rainfall varies between 2000 and 4000 mm. Cattle population is approximately 1.5 million head and area in pasture is 16 million hectares.

5) The South, at an altitude of less than 1000 meters includes South Eastern Nariño, Caqueta, Putumayo, Amazonas and Vaupes. Average temperature exceeds 24°C and annual rainfall varies between 1000 mm and 4000 mm. Cattle population is approximately .69 million head and area in pasture is 3.5 million hectares.

Production and Marketing Systems

Cattle production in Colombia is an extensive operation depending almost exclusively upon pastures as a source of feed inputs. Limited amounts of feed concentrates are being used in the more intensive dairy operations, and there are a few cases of confined feeding of steers.

For the nation as a whole, the average carrying capacity is about 0.57 head per hectare, but there are wide differences in capacity among the various classes of pastures

TABLE I.1. Cattle Numbers in the National Herd and Export of Live Animals, 1960-74. (1000 head)

Year	No. of Cattle	Change in Inventory	Registered Exports
1960[a/]	15,329	529.0	
1961	15,679	350.0	
1962	15,979	300.0	
1963	16,279	300.0	
1964	16,584	305.0	3.1[b/]
1965	16,882	298.0	76.0
1966	17,372	490.0	58.4
1967	18,082	710.0	19.8
1968	18,830	748.0	19.1
1969	19,576	746.0	58.3
1970[c/]	19,742	166.0	125.8
1971	20,334	592.0	191.7
1972	20,994	660.0	245.0[d/]
1973	21,573	579.0	282.0
1974	22,328	755.0	329.0

a/ Cattle inventories between 1960 and 1969 are from World Bank Report [41].

b/ Exports between 1964 and 1971 are from Sarmiento [63].

c/ Cattle inventories between 1970 and 1974 are projections by ICA [31].

d/ Exports between 1972 and 1974 are low target projections by Instituto de Comercio Exterior, INCOMEX [35].

and regions. The artificial pastures which make up about one-third to two-fifths of the total pasture area [61, 66] have the greatest carrying capacity: about 2.0 to 2.5 head per hectare under good management. These pastures have a carrying capacity 3.5 to 4.5 times greater than that of natural pastures.

The highest stocking rates are in the Costa departments: 1.35 to 1.45 head per hectare; some of the lowest rates are in the Eastern Plains (Los Llanos) where a breeding cow and her calf are carried on up to 10 hectares. In the Magdalena and Cauca Valley regions the stocking rate varies from 0.74 head to 1.00 head per hectare.

The national beef herd has been derived from "Criollo" breeds which still account for approximately 20 percent of the total. The remainder have been upgraded from "Criollo" by Cebu (mostly U. S. type Brahma) for up to three or four generations. The hybrid vigor of the first crosses and the adaptability of the Cebu to tropical conditions contributed to the popularity of this breeding practice.

The size of producing units varies widely although accurate statistics on herd size distribution do not exist. Large units exist in the Atlantic Coast, Eastern Plains and South regions while in the mountain areas of Central Colombia there are many small units with less than 10 head of cattle per farm. Sixteen departments surveyed by the Departamento Administrativo Nacional de Estadistica (DANE) [14] in 1960 had 98 percent of the cattle in herds of less than 200 head.

As various measures of productivity show, the technical efficiency of the Colombian cattle industry is low. The "extraction rate," which is the proportion of the cattle inventory extracted for domestic slaughter and exportation, is approximately 13 percent annually. This extraction rate compares with 40 percent in the United States, 29 percent in Australia and 24 percent in Argentina.

The calving rate (number of calves born as a percent of females of breeding age) is undoubtedly very low. The estimates of the national average calving rate range from 50 to 70 percent as compared to 80 to 90 percent in countries with well-developed cattle industries.

Death losses are relatively high, averaging at least 8 percent a year for all cattle. Losses are greatest among calves where mortality rates are often 20 to 30 percent or more during the first few months after the calves are born.

The average growth rate is very low; slaughter age is about 4 years, although some of the better growers now market steers at 3 years of age. This is still high compared to the average marketing age of 1.5 to 3 years common for slaughter steers in the United States. Steers from La Costa are slaughtered at about 450 kg. live weight while Los Llanos steers average 390 kg.

Yield per animal slaughtered, in relation to the live weight of the animal, is barely 50 percent, as compared with 58 to 60 percent in countries where types specially bred for the production of beef are prevalent. Beef yields per hectare

and per animal are also low when compared with other countries. Von Oven [60], reported live weight yields per hectare of 62 and 11 kilograms for the Costa and Eastern Plains, respectively, as compared with 90 kilograms for the Buenos Aires province in Argentina. Live weight yields per animal unit were 83, 40 and 117 kilograms for the Costa, the Easter Plains and the Buenos Aires province, respectively.

Mortality and performance at all stages of growth are affected materially by inadequate health control measures. Major diseases or parasites which cause mortality or losses through the falling-off in production among the animals affected are endemic foot-and-mouth (types A and O), rabies, anthrax, brucellosis, septaecemia, ticks and tick-born fevers, black leg, screw worms, and a great variety of internal parasites. Although effective control measures that could be applied in Colombia exist for most of these diseases, treatments are not a common practice.

Since it first appeared in Colombia in 1950, foot-and-mouth disease has caused significant losses that have been estimated by the Instituto Colombiano Agropecaurio--ICA-- at Ps. 332 million annually [31]. These losses are produced by death, reduced weight, retarded maturity, reduced milk production, and culled animals because of severe health injuries. Furthermore, foot-and-mouth disease constitutes an obstacle to trade between affected and immune areas, and precludes livestock and meat exports to countries which are free from the disease or on the way to eradicating it.

Brucellosis, or infectious abortion, is next to foot-and-mouth, among infectious and/or contagious diseases, in causing the heaviest livestock losses. Brucellosis affects about one-fifth of the cow population (1,136,000 head), and about 2 percent of the stud bulls (9,600 head) [31]. Losses in 1967 were estimated at Ps. 177.5 million and consisted of some 136,000 miscarriages, permanent sterility in about 22,700 cows, impossibility of using 9,600 sick bulls, deaths of about 5,500 cows, and permanent loss of milk in the affected cows.

Losses due to parasites are probably equal to or greater than estimated losses due to disease. In many instances an animal may be sufficiently weakened by parasites to readily succumb to identifiable diseases. The incidence of internal parasitosis is enormous, especially among calves; losses may run as high as 15 to 25 percent. External parasitosis is a disease almost entirely confined to animals in the subtropical and tropical zones, where it affects 75 percent of the stock. External parasites cause heavy losses by retarding growth, raising the mortality index and damaging the hides.

Cattle production and yields are also limited by problems of nutrition. Seasonal fodder shortages coupled with deficiencies of minerals and vitamins lead to the diminution of milk and beef yields, to retarded growth and to death in some cases. Furthermore, the reproductive functions are affected, sometimes so seriously that the

animals become infertile or fecundity is reduced; and this in turn greatly lowers the birth rate. Gomez [24] reported up to 20 percent of cows between 2 and over 10 years of age as having permanent infertility, with trophic problems (associated with nutrition) as responsible for 85 percent of the cases.

In addition to seasonal shortages, forage production is aggravated by the underdiversification of pastures and the absence of satisfactory rotation practices. Little attention is devoted to the management and care of pastures and they often deteriorate greatly.

Obsolete and even primitive practices which prevail in many stock farming activities are responsible for the majority of drawbacks and deficiencies found in cattle production. Most stock farmers are slow to adopt new techniques, and absenteeism on the part of landowners aggravates herd mismanagement and intensifies the managers' and herdsmens' tendencies to stick to traditional routine practices.

But husbandry deficiencies are not the only example of poor management. Most ranchers do not keep accounting and production records and have scanty, imperfect knowledge of supply and demand trends as well as of the market situation.

Defective management and extensive methods offer few opportunities for employment and higher salaries. Labor intensity in cattle production is 3 man-days per head-year or 1.71 man-days per hectare-year as compared with 50 to

65 man-days per hectare-year for most annual crops and with 120 to 300 for most vegetable and fruit crops [69].

Daines [70] gives another measure of the low labor intensity and high investment requirements to generate new employment in livestock. In livestock[1/] labor is 1.0 to 4.3 percent of total costs as compared with 20 to 68 percent for most crops. And it takes from 6,300 to 26,255 dollars of investment to generate a new direct man-year of employment in livestock as compared with 300 to 3,270 dollars for most crops.

The failure of the supply of livestock commodities to react to the high demand elasticity by which they are characterized is attributable not only to production difficulties but also to the problems created by current marketing systems. The deficiencies affecting the rounding-up and transport of livestock, as well as slaughter and beef distribution, are manifold.

The marketing system is extremely fragmented; many small buyers and commission agents serve the ranchers, and there are many slaughterhouses, many agents placing meat in slaughterhouses, and many small stores selling meat. Most animals are bought on the farm, and are usually purchased with little consideration of weight or quality. Cattle are shipped directly to "ferias" or stockyards, which are located throughout Colombia. Medellin is the most important market and often sets the price standard for the country.

[1/] Includes wool, eggs, poultry, pork and beef.

The high cost of transporting livestock has been and will continue to be one of the most serious marketing problems confronting the industry. Serious losses of weight occur during on-the-hoof movements. Cattle trailed for long days--from the Llanos for instance--lose up to 15 percent of their weight, in addition to which mortality must be taken into account. Severe weight losses are also registered in animals taken by boat; in some cases the time between the departure from the farms, arrival at the port of loading and transport to the place of destination may be as long as 15 days or longer. Although truck and rail transport cause fewer losses, these means are deficient and costly and the animals are badly mishandled in transit.

Methods of slaughtering and slaughterhouse services are extremely old-fashioned in most municipalities. Conditions are unhygienic, and as a general rule there are no veterinary services for proper inspection of the cattle on the hoof and the meat. One of the chief drawbacks is too many small slaughterhouses where the volume of operations is not large enough to finance the equipment, construction and services which would be required for efficient organization. Only about 5 percent of the slaughterhouses are located in major cities and provide technical and hygienic services.

Among other serious deficiencies in the slaughter of livestock and the handling of meat are the inefficient utilization of slaughter by-products and the lack of

refrigeration facilities, even in torrid climates where meat spoils in a very few hours.

Prices of cattle and beef have been rising with the general inflation that has prevailed in Colombia for several years. Prices of cattle at the ranch, on a liveweight basis, were approximately 5.17 pesos per kilogram in early 1970, equivalent to U. S. $0.28 per kilogram liveweight. Deflated consumer beef prices have increased by 18 percent from 1964 through 1969, while prices at the ranch only increased by 13 percent [41].

In addition to the rising secular trend, beef prices show both seasonal and cyclical variations with cycles averaging about seven years in length. Seasonal price fluctuations are caused directly by the occurrence of dry seasons and the lack of irrigated pastures and forage storage.

Until 1964 the official exports of livestock products were negligible, but have since shown substantial increases. In 1970, these exports reached over U. S. $21 million [63]. In 1974 livestock exports are expected to range between a low target of U. S. $51 and a high target of U. S. $107 million [35].

Exports of beef (frozen, refrigerated and chilled), viscera and processed meat have been increasing in importance. Estimated values for 1971 were U. S. $9.4 million for beef and U. S. $0.17 million for viscera and processed meat as compared with U. S. $2.4 million and U. S. $1.08 thousand in 1965, respectively.

Peru has been the most important market for live cattle followed by the Dutch Antilles, French Guiana and Venezuela. Illegal exports of live animals, predominantly to Venezuela, have been estimated between 100,000 and 300,000 head annually. Spain, Peru, the French Antilles and French Guiana have been the most important markets for beef.

Beef Consumption

Registered or controlled slaughter in 1970 was 2.366 million head, but total slaughter was estimated at 2.603 million head after increasing the former by 10 percent to account for unregistered or clandestine slaughter [63].[1/]

Although the trend in cattle slaughter has been upward, there have been significant variations [23, 61]. From 1954 to 1957 slaughter increased 27.5 percent and then turned downward during 1958 and 1959. From 1960 to 1964 it increased again by 30 percent. From 1965 to 1968 slaughter decreased by 3.3 percent and then turned upward again during the next three years.

Slaughter of male cattle fluctuates less than that of females and averages about 60 percent of total slaughter. Female slaughter averages about 40 percent of total slaughter and has ranged from 34 percent in 1954 to 44 and 43 percent in 1951 and 1965 respectively [16, 61]. Consequently, the year-to-year variations in total cattle slaughter have been

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[1/] This refers to domestic consumption. Official statistics usually include registered exports of beef and live cattle.

largely due to changing policies of farmers who withhold females for breeding purposes. Apparently, accumulation and liquidation phases in the cattle cycle are completed, on the average, every seven years.

The trend in per capita consumption of carcass beef has been slightly downward due to the more rapid rate of growth in the human population than in total beef production. Registered cattle slaughter decreased from 123 head per 1000 inhabitants in 1951 to 110 head in 1970. Per capita consumption decreased from 29.6 kg. in 1951 to 22.4 kg. in 1970,[1/] but when unregistered slaughter is considered, per capita consumption in 1970 increases to 24.6 kg. Yet, unequal distribution of income aggravates the nutritional problem, leaving peasants and low income urban groups with a consumption of 18.0 or less kilograms [31]. Undoubtedly beef consumption by the mass of the population is below the recommended nutritional requirements set at 28.0 kg. [9].

Increases in domestic demand will depend on population growth, per capita income and income and price demand elasticities. Assuming no price changes, domestic demand is expected to grow at approximately 4.8 percent annually [31]. This assumes an income elasticity of .6, and annual rates of growth in population and real income per capita of 3.2 and 3.0 percent respectively [31].

[1/] Estimate based on an overall dressed carcass average of 200 kg.

Riley [61] and ICA [31] have projected domestic consumption in 1975 using different estimates for the average consumption per capita. According to Riley, if per capita consumption remains at 23.75 kg. annually--the average for the 1958-60 period--domestic consumption in 1975 would be 571 thousand tons or a 64 percent increase over the 1958-60 average of 347 thousand tons. If per capita consumption rises to 29.06 kg., domestic consumption would double the base period average. The ICA estimate shows that if per capita consumption is 25.9 kg. annually--the average for 1964--domestic consumption would increase to 640 thousand tons by 1975 or about 85 percent over the base period.

The parameters determining the rate of growth in demand and the estimates of domestic consumption suggest the need for well coordinated government policies if the goals of improved nutrition, production incentives and increased foreign exchange are to be attained. If beef supplies are not increased substantially, the income of the lower income group is not raised, or beef substitutes are not available, large numbers of the population will continue to be undernourished.

National Policies Toward the Cattle Industry

Taxation. Incentives for beef cattle production in Colombia are crucially affected by government policy. Cattle raising is subject to the same income and complementary taxes (net worth and excess profit) as any other economic

activity. But certain special provisions by which costs and income are computed favor the cattle producing taxpayer.

The essence of this tax policy relates to the cost basis on which profits are calculated. For tax purposes, the cost of livestock sold is the purchase price only if acquired during the tax year. If cattle are sold in the year following that of purchase, then the approximate market value at the end of the previous year is taken as the purchase price. The difference between the purchase price and the assessed end-of-the-year market value is treated as an increase in capital and is not subject to income tax.

The tax policy is also designed to encourage ranchers to engage in breeding activities or to hold females rather than males in inventory to build up the national cattle herd. A net worth tax exemption and two taxes support this policy. The first is a slaughter and export tax which differentiates between the sexes: 50 pesos per head for males and 100 pesos per head for females. The second is a selective inventory tax equivalent to the value of 4 kg. liveweight per head which applies only to males over one year of age. The amount of this tax varies from year to year. In 1971 it was 18.40 pesos per head.

A final element in government taxation of the livestock industry is a general inventory tax. Any individual or corporation whose investment in livestock exceeds Ps. 15,000 at the close of any year from 1959 through 1980 is subject to a levy of 1 percent on the net investment.

Taxpayers who elect to subscribe for shares of Banco Ganadero and the Fondos Ganaderos at par, in an amount equal to the total tax due, are exempt from cash payment of the tax. This is in fact the customary form of payment, and it provides an important part of the capital of these credit institutions.

A property tax of 4.2 mills on the assessed value of land is also levied on the cattle subsector. Additional surtaxes of three and two mills are levied on assessed properties in the areas comprising the Corporacion Autonoma Regional de Valle del Cauca (CVC) and the Corporacion Regional de la Sabana (CAR),[1/] respectively.

In 1971 the Colombian Government proposed the use of presumptive techniques for a more effective income taxation of agriculture, and finally in 1972 passed a law for approval by Congress [56]. Now, cadastral value of the land alone serves to assess farm income. Yet only a proportion of the cadastral value is used: (1) 50 percent for permanent crops and cattle raising, (2) 75 percent for temporary crops, and (3) 80 percent for annual crops. The presumed income is 10 percent for all crops and cattle fattening, 4 percent for cattle breeding,[2/] and is also subject to the normal progression of the income tax. The reformed tax law also phases

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[1/] These are regional development corporations with headquarters in Cali and Bogota respectively.

[2/] Javier Ayala, "Nueva Propuesta Sobre Ley Agraria," El Tiempo, (Bogota) January 20, 1972, p. 1.

out the special inventory tax on males and provides tax incentives on reinvestments in the farm. Fifty percent of farm income in excess of the presumed income is exempted from taxation if reinvested during the year following the fiscal year.

Land Reform. Large holdings and extensive methods in cattle raising have made grazing lands an easy target for expropriation and land distribution schemes. Under the provisions of Law 135--the agrarian reform law--most pastoral estates are considered inadequately utilized and could be expropriated at the least favorable terms.

With the increasing need for farm products, and considering that threats of expropriation have discouraged long-term investments and hampered agricultural development, the government in 1971 undertook a major revision of Law 135. The revised law,[1/] now pending approval by Congress, provides for more protection against expropriation of adequately utilized farms and for more favorable compensation terms if expropriation occurs.

The designation of farms as adequately utilized has been tightened; it now includes, among other things, the attainment of minimum levels of productivity, and the improvement of the level of living of the workers employed by the landowner.

Cash payments for adequately utilized farms have been increased to 40 percent of the land value if the value

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[1/] Ibid.

is 500,000 pesos or less, with this proportion decreasing gradually as the total land value increases. The balance will now be paid in five years with interest bearing and negotiable government notes.

Credit. Government direction of agricultural credit is carried on through a complex of official rediscount facilities, reserve requirements and direct legislation. The Monetary Board, appointed in 1963, has legislative control of the banking system and is responsible for setting legal reserve requirements, interest rates and term of loans.

Lending to the agricultural sector has been growing faster than in the economy as a whole. But within the agricultural sector, livestock increased slower than the growth in overall credit in the economy [41]. The livestock portfolio's share of the total has been relatively constant, reaching a low of 18.3 percent in 1966 from a peak of 21.7 percent in 1963. Over the period 1958-1967 the livestock portfolio averaged 19.5 percent of the total portfolio.

Among legislative measures, Law 26 of 1959 has increased the supply of credit to agriculture and strengthened the activities of the Banco Ganadero and Fondos Ganaderos through allocation of the general inventory tax. These credit institutions which specialize in livestock development, must loan not less than 70 percent of their funds for breeding and growing. The law also requires that commercial banks loan not less than 15 percent of their deposits for agricultural purposes.

At present, the Caja Agraria and Banco Ganadero are the two most important sources of credit to livestock producers. In addition, commercial banks are required by law to lend 15 percent of their deposits to agriculture, including loans for livestock development. In 1967, the Caja Agraria held 47.9 percent of the livestock portfolio; the commercial banks 30.0 percent; Banco Ganadero 18.6 percent; and Banco Popular 3.5 percent.

Institutional credit is available to cattle producers at varied interest rates and terms. In general, interest rates charged to small and medium producers range from 8 to 12 percent annually, which are below the current commercial rate of 14 percent. Interest rates charged to large producers are more in line with the commercial rate.

Terms for repayment vary greatly according to the purpose of the loan. For fattening activities terms do not exceed one year, while for breeding and land improvements terms range from three to twelve years. Grace periods from one to four years have been introduced to accommodate better the repayment obligations to the slow return from investments characteristic of the cattle industry.

Special funds from foreign and domestic sources are administered by the Caja Agraria and Banco Ganadero as part of the overall cattle development plan. Small cattle producers within the INCORA-supervised credit programs receive loans, mostly in kind, from the Caja Agraria and Banco Ganadero. The Caja-INCORA scheme is financed by a loan from

AID to INCORA, and funds for the Banco program come from INCORA's Fondo Rotatorio. The Caja also administers a loan from the World Bank for livestock development programs. The Banco Ganadero has been using funds from the Inter-American Development Bank (IDB), the Dutch Government and AID for the same purpose.

Loans from these programs are being devoted mainly to beef production in the Atlantic Coast and the Eastern Plains. Ranchers borrowing from these funds have to participate with 20 percent of the estimated cost, receive technical assistance and invest up to 70 percent of the loan on farm improvements. Interest rates are 14 percent annually, the term of repayment is up to twelve years with a three- to four-year grace period.

Another form of credit quite common in Colombia, known as "cattle-in-partnership," is made available in the form of cattle for which the rancher provides pasture and supervision. Profits are shared when the cattle are sold. The cattle are financed by the private sector and the Fondos Ganaderos (livestock funds), for which financing is provided by departmental and national governments and by the Banco Ganadero and Caja Agraria. A usual profit sharing arrangement is 60 percent rancher, 40 percent financier. While such an arrangement has the advantage of not impairing the rancher's borrowing capacity, it is probably equivalent to a loan with interest between 15 and 20 percent (depending on the profit shared).

Despite the priority given by the government to agricultural credit and the increased channeling of resources to it, there is still an unsatisfied demand for long-term credit. Recent agricultural credit policies have been oriented toward increasing the availability of funds and raising the interest rates to ensure a better utilization of scarce capital resources.

Changes in agricultural credit policies have included:

(1) Increased use of supervised credit. Credit is now considered an effective means of introducing technological change.

(2) Increased terms and interest rate of loans under Law 26. Beginning in August 1969, the Monetary Board increased terms of repayment up to seven years with a grace period of two and one half to three years. Interest rates were changed from 8 and 9 percent annually to a variable rate that is 10 percent the first year and increases every year thereafter by one-half of 1 percent.

(3) Increased and preferential rediscount quotas for loans made by Caja Agraria and Banco Ganadero.

(4) Preferential rediscount rates for Caja Agraria, Banco Ganadero and INCORA.

(5) Obligatory investment by commercial banks for 32 percent of its loan portfolio for development. The latter includes Law 26 loans and other loans of the agricultural sector.

(6) Maintenance of subsidized interest rates for small producers.

(7) New program for credit to land reform beneficiaries organized in cooperative or commercial operations.

(8) New program for personal credit to small farmers based on expected returns on the investments.

Disease Control. With an international commitment to control foot-and-mouth disease (FMD) Colombia has entrusted to ICA the attainment of this goal and the eradication of

brucellosis. To meet its commitment, and with the financial assistance of the Inter-American Development Bank and the technical assistance of the Pan-American Center Against Foot-and-Mouth Disease, ICA prepared a two-stage plan beginning in 1971.

During the 1971-1975 stage the campaign will be concentrated in the Atlantic Coast region where 83 percent of the cattle population will be treated by the end of the period. In the same year the proportion of cattle treated in the rest of the country will be approximately 58 percent.

In the next period--1976-80--control measures will be intensified in all producing zones and the proportion of cattle treated will be very close to 100 percent.

While the control of FMD is restricted to priority areas, the control of brucellosis will be spread over the entire country. The campaign aims at having 100 percent of the female population free of brucellosis by 1974.

Development Plan. In 1972 the Ministry of Agriculture prepared a comprehensive livestock development plan for Colombia.[1/] The objective was to establish livestock production goals for the next decade and then to outline in detail the necessary plan of action to help achieve the desired goals.

The most important policy instruments are: (1) tax incentives for breeding and farm improvements; (2) increased

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1/"El Gobierno Modifica Su Politica Ganadera," El Espectador (Bogota), November 7, 1972, p. 1.

availability of credit and easier credit terms; (3) increased association of credit with technical assistance and subsidized technical assistance for small producers; and (4) protection against land expropriation if certain levels of productivity and use of resources are attained.

Exports. General measures to promote exports are a more flexible exchange rate policy and a 15 percent tax bonus (Certificado de Abono Tributario--CAT) incentive for all exports, except coffee, raw cattle hides, and petroleum. CATs may be traded at a discount or used after one year of issuance for tax payments. More specifically, the government has begun to promote beef exports through a semi-public lending institution, Corporacion Financiera Agropecuaria (COFIAGRO). About 80 percent of COFIAGRO's portfolio is in enterprises engaged in the export of beef, but it also lends to ranchers for fattening operations at one-year terms and at an effective interest rate of 16.28 percent.

The government has recently taken two new measures intended to regulate the domestic and export markets. Beginning July 1972[1/] beef has been banned two days a week from restaurants, hotels and similar public outlets. Beginning January 1973[2/] a quota system regulates exports to avoid

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[1/] Jaime Sotomayor, "Veda de Carne Dos Dias a la Semana," El Espectador, (Bogota), June 30, 1972, p. 1.

[2/] "El Gobierno Fija Cupos de Exportacion de Carne," El Tiempo (Bogota), December 11, 1972.

domestic shortages. This measure requires the gradual phasing out of export of live animals and an increase in beef and processed meat exports.

Domestic marketing of beef is also being improved; the Banco Ganadero in cooperation with USAID has placed special emphasis on financing the modernization of slaughtering facilities.

CHAPTER 3

THE REGIONAL SETTING OF THIS STUDY

The Geopolitical Setting

The states or departments of Atlantico, Bolivar, Cesar, Cordoba, Magdalena, and Sucre considered in this study and known as the Costa, are part of the Atlantic or Caribbean plain which is one of the five geographic regions into which Colombia is divided.[1/] The capitals are Barranquilla, Cartagena, Valledupar, Monteria, Santa Marta and Sincelejo, respectively. In 1964 these six states had a population of about three million within an area of 112,055 square kilometers; these figures were 18 and 10 percent of the total Colombian population and area, respectively [17].

The Atlantic plain is located between the Caribbean sea and the base of the Andean range in the northern part of Colombia. It is characterized by flat and swampy lands in the bottom of the alluvial valleys and the coastal plain, and by slightly undulating to rugged lands in the areas above the valleys floors and in the surrounding mountains. With the

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[1/] The other four are: Andean region, Pacific Coast, Orinoco region and Amazon region. Geographically the department of Cuajira and the Antioquian region of Urabá are included in the Atlantic plain, but for all practical purposes this study will refer to the six departments listed.

exception of the Sierra Nevada de Santa Marta in the northeast, the altitude varies between 0 and 500 meters.

The most important rivers are the Sinú in the west, and the Magdelena with its three major tributaries, the San Jorge, the Cauca and the Cesar. The Magdalena, Cauca, San Jorge and Sinú rivers are navigable and serve as important means of transport.

The region has a relatively good network of roads which connect the main urban centers, but access roads to the agricultural areas are few and inadequate, especially during the rainy season.

The railroad connects the port of Santa Marta with Bogotá, Medellín and Cali. Air transportation is available both for passengers and cargo from the airports in the capitals and from air strips throughout the area. The sea ports of Barranquilla, Cartangena and Santa Marta have modern facilities and serve a substantial part of the Colombian export-import trade.

The Population

The Costa population has four major attributes, most of them characteristic of other regions in Colombia. First, the total population in the Costa has been increasing at an increasing rate. The annual average rate of population growth is estimated to be 3.23 percent.[1/] If it continues at this rate, the population will double in approximately 22 years.

[1/] Rate of growth estimated for the period 1938-1964.

Second, the population is unevenly distributed. The department of Atlantico has the greatest density (219 inhabitants per square kilometer) and Cesar the lowest (11 inhabitants per square kilometer). In 1964, about 61 percent of the population was urban, and approximately one-half of this was concentrated in the cities of Monteria, Cartagena, Barranquilla, and Santa Marta.

Third, throughout the region the population has been shifting fairly constantly since 1938. These movements can be classified as: (1) permanent migration from rural areas to major towns of the region (population growth in the four major cities mentioned earlier is estimated to be near 5.0 percent annually); (2) migration from urban and rural areas to the neighboring labor-short Venezuela; (3) seasonal in- and out-migration of the rural labor force to accommodate the demand for harvest labor, especially for cotton, in the region and in the rest of the country; (4) migration from the rest of the country and from the region toward the new rural frontier areas along the Valle del Cesar, the Magdalena, and the low Cauca; and (5) out-migration toward other regions, especially the more developed urban-industrial departments.

Fourth, education, occupational status, and income per capita are unevenly distributed, not only between the urban and rural populations but among the departments in the region. Literacy ranges from 40 percent in the more agricultural departments to 62 percent in the more urbanized

and industrialized department of Atlantico. The proportion of economically active population engaged in agriculture, forestry, hunting and fishing ranges from 60 percent in the departments of Cordoba, Bolivar, Sucre, Cesar and Magdalena to 16 percent in the department of Atlantico [17].

Although the 1964 census lists no figures on income per capita, income is probably higher in the urban than in the rural areas, and higher in the department of Atlantico than in the more agricultural departments. (These estimates are based on information collected by the Departamento Administrativo Nacional de Estadistica [DANE].) In 1970, DANE[1/] examined the family income of urban and rural workers in the Atlantic region, in four other Colombian regions, and the city of Bogotá. For the Atlantic region, DANE estimates that 63 percent of the employed urban population and 84 percent of the employed rural population had a monthly income of 1,000 pesos[2/] or less.

The 1970 DANE sample estimated over unemployment in the Atlantic region to be 10.96 and 7.73 percent of the economically active population for the urban and rural areas, respectively. But unemployment is more serious than these figures suggest. The number of people suffering from shortage of work is probably larger than the observed numbers actively

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[1/] DANE, Encuesta de Hogares 1970, Bogotá, June (1971), pp. 1-59.

[2/] One U. S. dollar equals approximately Ps 20.

seeking work or longer hours, because the unemployed or underemployed not openly seeking work might do so if unemployment decreased.

Ecological Zones

The Atlantic region can be divided into four distinct ecological zones characterized by the climate and natural vegetation: (1) the tropical dry-humid savannah in the littoral, east from the Sinu river outlet; (2) the tropical humid savannah in the center; (3) the tropical dry-humid forest south of the humid savannah; and (4) the tropical humid forest in the extreme south (Figure I.2).[1/] In turn, each zone can be divided into two special natural regions--the flood plains and the uplands--distinguished by their soils and the crops cultivated. These ecological zones are identifiable and reasonably distinct, although the boundaries between them are arbitrary. The three geographical features that determine the agricultural activities in these zones are climate, soil moisture and soil types.

Climate and Natural Vegetation

Rainfall and temperature are the two most important climatic features. The region alternates between two contrasting rainfall patterns: a low rain or dry period from December through March, and a high rainfall period

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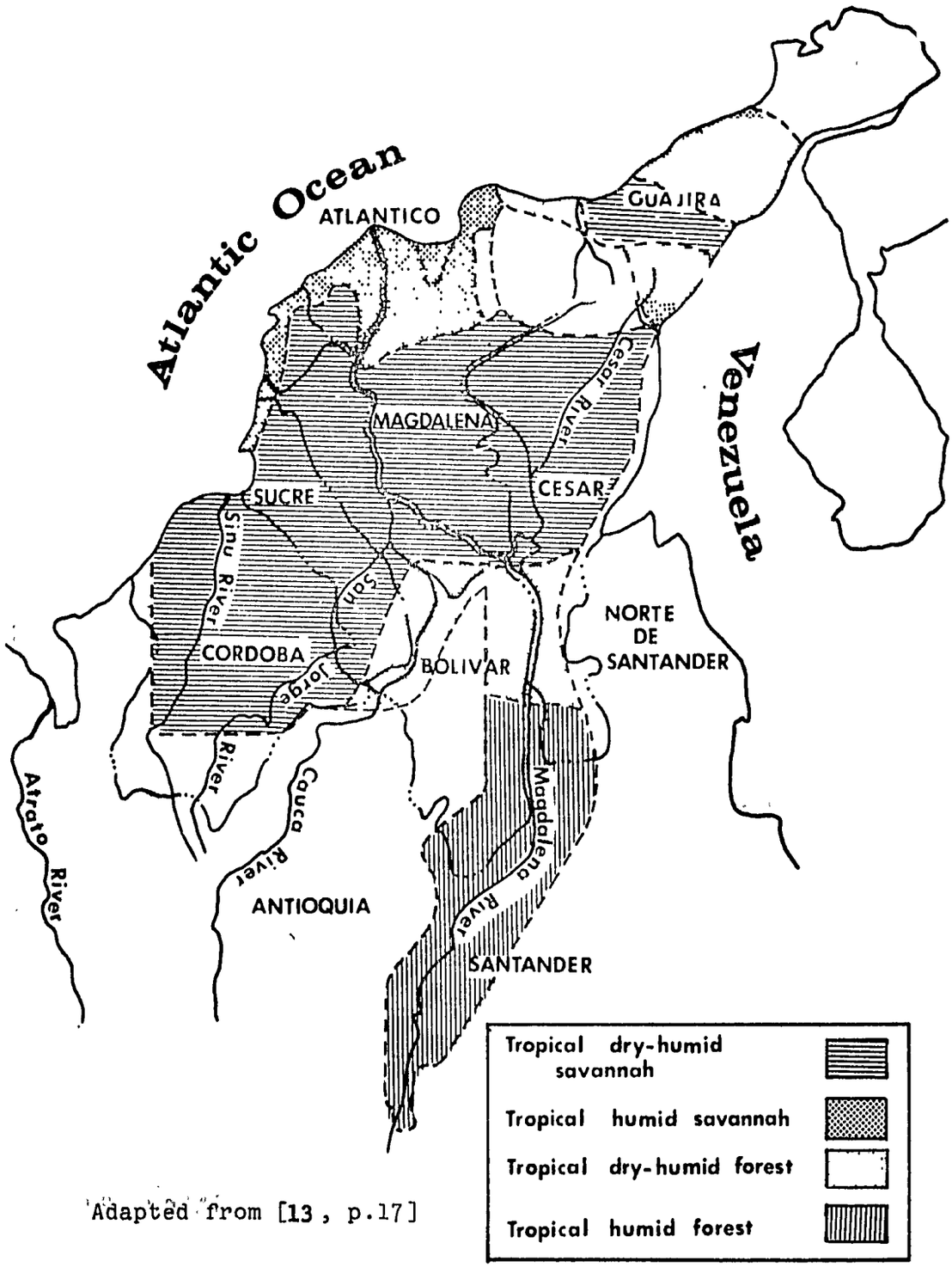
[1/] In this and the following two sections, I have drawn heavily on the Magdalena Mission Report [13].



Adapted from [13, p.17]

FIGURE I.2. Ecological zones of Northern Colombia.

from April through November. In general, rainfall increases and dry periods are shorter from north to south.

In the dry-humid savannah of the north, total annual rainfall averages less than 900 mm. The humid savannah receives between 1000 and 2000 mm. annually, the dry-humid forest about 2000 mm., and the humid forest in the south over 2000 mm. An equally important feature is the seasonal distribution of rain. The littoral receives hardly any precipitation in the dry season, whereas the other zones receive a fairly substantial amount throughout the year (an average of 23 mm. per month during the dry season).

The annual average temperature is about 27°C. Throughout the rainy season, the humidity is over 80 percent. During the dry period, winds flow from the sea causing the temperature and humidity to drop slightly, but this effect decreases with increasing distance from the littoral.

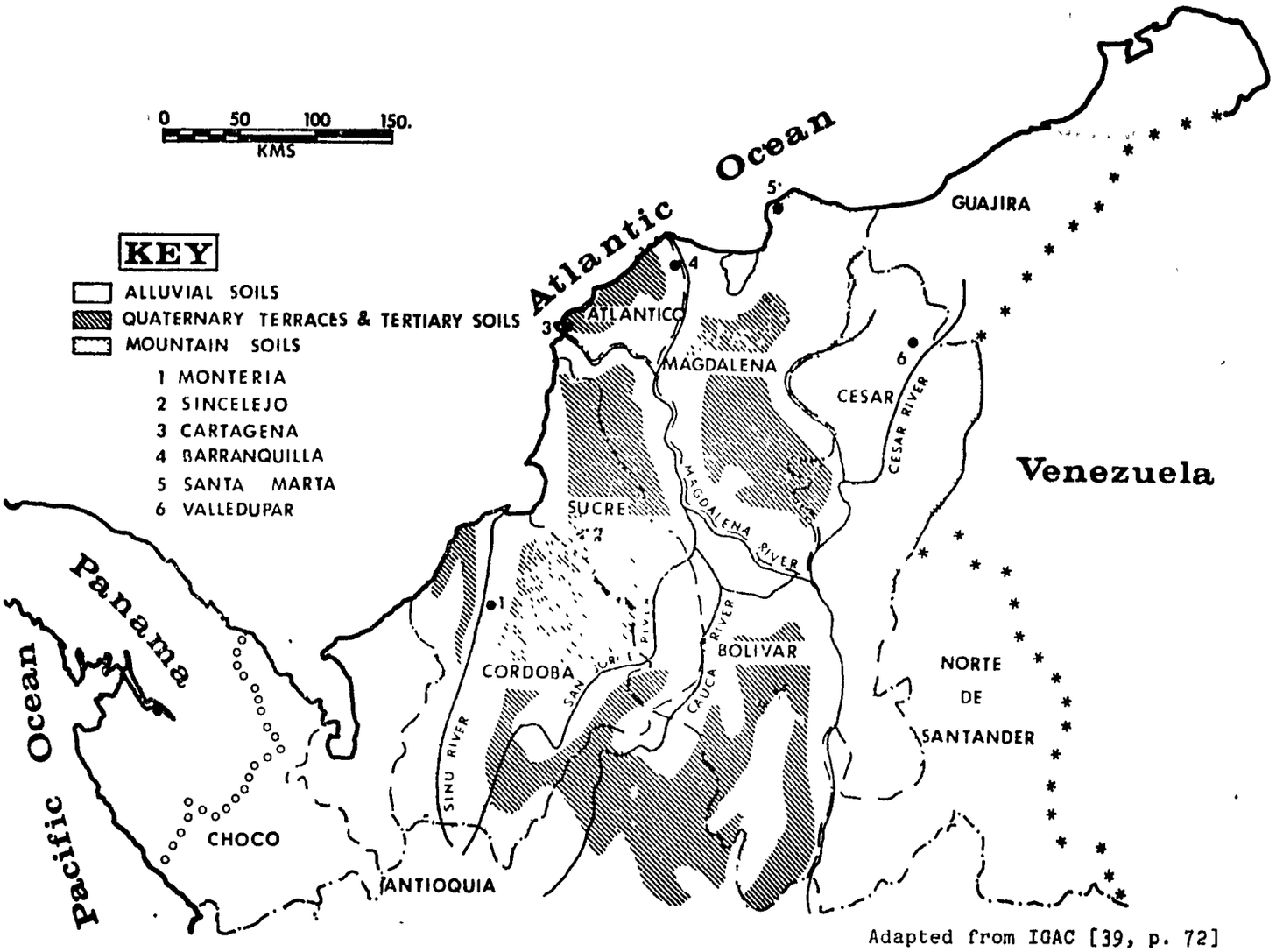
The natural vegetation of the Atlantic region can be divided into three basic categories: (1) the dry-humid savannah in the north characterized by xerophitic and sub-xerophitic vegetation and grasses; (2) the humid savannah in the center characterized by a mixture of natural grasses, scattered shrubs and thin to thick forest in the more wet areas near the rivers and in areas with higher rainfall within the zone; and (3) the rain forest in the south. The distinguishing feature from north to south is the vegetation change from the sparse savannah to the lush rain forest associated with increasing abundance of precipitation.

In general, the four ecological zones provide a good habitat for grazing animals and crops. The dry-humid savannah in the north is more suitable for grazing, although annual crops are grown during the rainy season. Irrigation is required because of the dry periods and to allow for double cropping. The humid savannah, the largest and most important agricultural zone, produces most of the region's cotton. During the rainy season, cropping is safe; with drought-resistant and short-cycle crops such as sorghum, double cropping may be possible. This region also provides most of the grazing land. The dry-humid forest provides lush green pasture all year, but is considered too wet for annual crops other than rice. In the northeast banana belt, which is in the same climatic zone, the land is used mainly for grazing. The humid forest has the same land uses as the dry-humid zone.

Soils

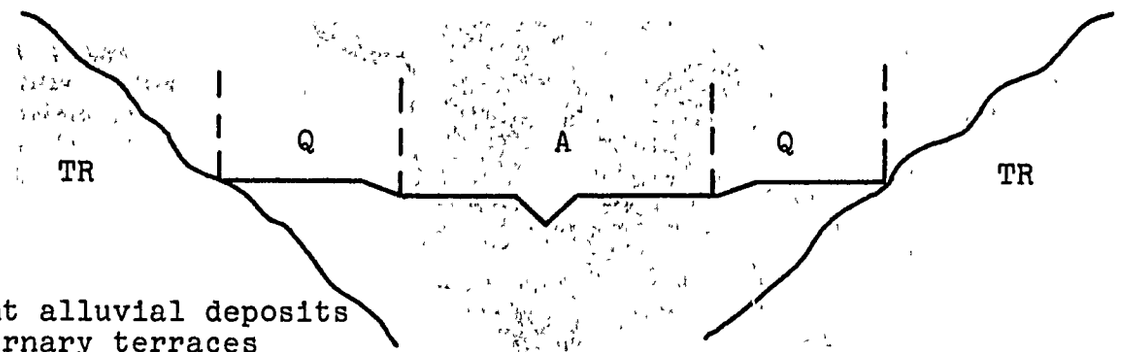
Semi-detailed soil studies of the Costa region have been made by the Instituto Geográfico Agustin Codazzi (IGAC) [38], the Instituto de Fomento Algodonero (Cotton Development Institute) [36, 37], and the Mission for the Study of the Magdalena Valley [13]. These studies also contain information which correlates soil types and phases with potential use.

Soils in the region can be divided into four general groups according to their origin: alluvial or flood plains, quaternary, tertiary and mountain (see Figures I.3 and I.4).



Adapted from IGAC [39, p. 72]

FIGURE I.3. Costa--general soil groups.



A = recent alluvial deposits
Q = quaternary terraces
TR = tertiary soils

FIGURE I.4. Hypothetical cross-section of alluvial valleys in Northern Colombia.

Topography, fertility and use are closely related to these soil groups. Alluvial soils are characterized by slopes of 0 to 3 percent; soil textures vary from light to medium and heavy, with deep topsoil and drainage varying from well-drained to imperfectly and poorly drained. Often these lands have a high nutrient content with the exception of soluble nitrogen, which is low. Soil pH ranges between 6.3 to 7.3; it is lower in the poorly drained soils and higher in soils with some degree of salinity.

Quarternary soils or terraces are old alluvial deposits characterized by slopes of 0 to 3 percent, and a hard or clay pan at varying depths. Soil textures are light and drainage is imperfect. Soil pH ranges between 5.0 and 6.0 and the nutrient content is low.

Tertiary soils have undulating slopes ranging widely from moderately steep to steep (7 percent to 50 percent). Soil textures vary from light to heavy, and most soils are susceptible to erosion. Soil pH ranges between 5.5 to less than 6.0, and the nutrient content is low.

The mountain soils in the region are characterized by steep to very steep slopes. Because of the excessive relief, most of them are erodible. They are formed chiefly from igneous and metamorphic rocks. Though the high nutrient content of some of these soils would ordinarily make them suitable for coffee and other permanent crops, because of their erodability their best recommended use is in forest.

Based on studies by the IGAC [38], the Magdalena Mission [12], and the Cotton Development Institute [36, 37], an inventory of the soil resource base by department was made (Table I.2). This inventory includes the acreage of total land, soil classification according to origin, and land use. Table I.2 also shows the region's natural endowment for raising cattle.

The Agricultural Economy

The Costa economy is basically agricultural, with cattle the predominant activity, whereas manufacturing is low and concentrated in the cities of Barranquilla and Cartagena. Agriculture employs 50 percent of the economically active population.

The Costa agriculture is characterized by the same problems that affect agriculture in all of Colombia: (1) slow rate of growth; (2) low productivity and high cost per unit of production; and (3) unequal distribution of wealth.

Private ownership is the predominant characteristic of land tenure in the region. A 1964 survey showed that 60 percent of farms were privately owned and included seven-eights of the agricultural land [12]. Other striking features of the Costa's land tenure are the high degree of concentration and absenteeism. As Table I.3 shows, approximately two-thirds of the farms are less than ten hectares, while about 1 percent of the farms are over

TABLE I.2. Costa-Land Classes and Recommended Use by Departments. ('000 has.)

Land Class \ Region and Use	Atlantico	Bolivar and Sucre	Cordoba	Magdalena and Cesar	Total	Recommended Land Use
1-Well drained	21.60	90.60	38.50	183.70	334.40	Crops and cattle (533.30)
2-Nonflooded imperfectly drained	59.00	20.00	3.30	116.60	198.90	
3-Periodically flooded & poorly drained:						
a-Water logging		103.14	155.63	66.20	324.97	Cattle, crops occasionally
b-One-month floodings	5.64	141.82	37.80	226.09	411.35	Cattle (2,813.00)
c-Four-month floodings	7.63	317.84	82.48	154.32	562.27	
d-More than four-month floodings	20.00	1,452.90	133.30	86.88	1,693.08	
4-Saline	17.20	52.30	15.20	61.60	146.30	
Total Land	131.07	2,178.00	466.21	895.39	3,671.27	
5-Lakes	25.00	47.10	25.20	129.82	227.12	
Total Area	156.07	2,225.70	491.41	1,025.21	3,898.39	
6-Quaternary terraces	0.50	65.90	218.10	381.40	665.90	Cattle, cash crops occasionally, food crops (1,822.40)
7-Tertiary soils						
a-Slope ≤ 25%	22.00	315.20	422.40	396.90	1,156.50	
b-Slope > 25%	52.00	573.00	310.00	761.00	1,696.00	
8-Sandy soils and dunes:						Cattle (2,042.66)
3% < slope ≤ 25%	33.36			313.30	346.66	
Total Land	107.96	954.10	950.50	1,852.60	3,865.06	
9-Eroded and Mountain Soils	62.10	511.70	1,075.60	1,791.70	3,441.10	Forest
Grand Total	326.03	3,691.50	2,517.51	4,669.51	11,204.55	

Adapted from [13, 36, 37, 38], and personal information from the Geographic Institute (IGAC).

TABLE I.3. Costa--Distribution of Farms According to Size, 1960

Size Categories (has.)	No.	Percent	Area Occupied by Farms		
			Has. (000)	Percent	Average (Has.)
Less than 10	120,793	67.5	241	3.4	2.0
From 10 to 100	43,741	24.4	1,491	21.3	34.1
From 100 to 500	12,225	6.8	2,348	33.5	192.1
Over 500	2,356	1.3	2,928	41.8	1,242.8
TOTAL	179,115	100.0	7,008	100.0	39.1

Source: CIDA [12, p. 72]

500 hectares and occupy 42 percent of the land in farms. According to DANE[1/] 6,706 administrators operate one-third of the total agricultural land, or an average of 370 hectares each (mostly pastoral states). The majority of landlords visit these haciendas infrequently--rarely on a weekly basis and in some cases only once or twice a year.

Although crops have been increasing in importance, land use is dominated by pasture. While in 1959 crops occupied only 7.5 percent of all land and 12 percent of land in farms, pasture accounted for approximately two-fifths of all land or approximately three-fifths of land on farms [14, 15]. Artificial grasses are a low proportion of total

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[1/] DANE, Censo Agropecuario 1960, Resumen Nacional, Bogotá, February (1964), p. 21.

grasslands; 20 percent according to DANE [18], and 45 percent according to FAO [66].

Cotton is the most important commercial crop; in 1969 the region had 137,000 hectares in cotton and produced 62 percent of the total Colombian production [7]. Sesame and rice are also important crops, accounting for 59 percent and 23 percent, respectively, of the total Colombian production in 1969 [7]. Sorghum has become increasingly important, particularly as a double crop with cotton; at the same time, the land devoted to raising bananas for export has declined from 20,000 hectares in the mid-sixties to approximately 5,000 hectares in the seventies. Sugarcane, tobacco, and coffee are also grown but to a lesser extent.

The most important staple crops are cassava and corn, both in terms of the number of producers and the number of hectares. In 1969 [7] 79,000 hectares were planted in cassava and the production accounted for 40 percent of the total Colombian production. About 203,000 hectares were planted in corn which accounted for 26 percent of the total Colombian production. Plantain followed in importance (30,000 hectares), and still less land was used for beans and fruits.

Although the introduction of commercial crops to the region during the past two decades has changed a number of traditional agricultural practices, average yields are still fairly low. Yet the potential for high yields clearly exists as has been demonstrated in properly managed commercial and

experimental farms. In the former, yields of cotton-seed, irrigated rice and sorghum have been doubled and that of corn tripled, while experimental yields for corn and irrigated rice have been 6 and 2.5 times as high, respectively [41].[1/]

Low yields have been attributed to: (1) a large proportion of small holders producing under traditional methods;[2/] (2) a lack of adaptive research and extension; (3) inadequate distribution and high cost of modern inputs; and (4) a lack of price incentives.

Soil conservation practices are ignored and the continual tillage of steep, erodible slopes with clean-cultivated crops is accelerating soil depletion.

As pointed out, cattle raising is the most important economic activity in the Costa where the same general characteristics and problems affecting the Colombian cattle industry also apply. The major production problems in the region can be summarized as follows:

(1) Management and economics

(a) Lack of farm accounting and record keeping to establish cost relationships and operational efficiency

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[1/] Average yields (M.Ts/Ha) in the Costa for the period 1965-1969 have been: cotton-seed 1.4, corn 1.11, irrigated rice 2.3, sesame .66, and sorghum 1.8 [7].

[2/] In 1960 according to DANE [15], 98 percent of sesame, 83 percent of cotton, 95 percent of rice, and 96 percent of corn were produced in plots less than 10 hectares.

(b) Lack of basic knowledge on returns to the different factors of production needed for an efficient allocation of resources and for considering organization alternatives

(c) Inefficient markets for both products and inputs, including capital

(2) Human

(a) Low level of education

(b) Lack of skills and training

(c) Poor health

(3) Technological

(a) Inadequate soils and range management

(b) Inadequate breeding, pest and disease control practices

(4) Environmental

(a) Poor use of natural resources

(b) Downgraded quality of rural life

Cattle Production

Although there are not reliable time series estimates of the cattle population in Colombia, it seems that the Costa supports between 40 and 50 percent of the total Colombian cattle population. Table I.4 shows the age and sex distribution of cattle in the Costa and the rest of Colombia according to the 1968 sample survey [18], but care should be taken when considering these figures. This survey, the sample surveys of 1964, and 1965, and the 1960 agricultural census made by DANE seemed to have underestimated the total cattle population by 2.5 million head [29].

TABLE I.4. Cattle Numbers in the Costa and Non-Costa Herd, 1968. ('000 head)

Region	Less than 2 years		Two and more Years		TOTAL
	Males	Females	Males	Females	
Costa:					
Atlantico	34.95	52.86	14.90	133.18	235.89
Bolivar and Sucre	481.81	487.12	172.40	1,167.15	2,308.48
Cordoba	381.76	349.50	418.82	1,059.27	2,209.35
Magdalena and Cesar	464.46	471.27	394.50	1,018.06	2,348.29
TOTAL COSTA	1,362.98	1,360.75	1,000.62	3,377.66	7,102.01
Non-Costa	1,965.77	2,438.40	1,634.84	4,559.16	10,598.17
TOTAL	3,328.75	3,799.15	2,635.46	7,936.82	17,700.18

Source: DANE [18, p. 1]

The Costa is specialized in beef production from herds formed predominately by the cross-breeding of Cebu cattle with the native cattle. Within this type of cattle operation there are three productive phases which are performed separately as specialized activities or in conjunction with each other on individual farms. These are: (a) breeding--cows and calves; (b) growing--males and females, 1 to 4 years of age; and (c) fattening--males, 3 to 6 years of age and females discarded from the breeding herds.

The dual production of beef and milk has been a common practice among small and medium sized cow herds. The 1971 CIAT survey [9] showed that 62 percent of the cattle farms have breeding and milk production as their main economic activities. In 1968 DANE [18] reported one-third of the cows (females over 2 years) were milked, but this proportion seems to have been increasing with improved access to markets and increased demand. Yet yield of milk per cow is low, ranging between 3.06 liters daily during the rainy season and 2.54 liters during the dry season, with lactating periods varying from 90 to 250 days a year depending on the quality of management. Despite low yields, milk production is an important source of income for ranchers and a contribution to improved nutrition in the region.

As Table I.5 shows, the Costa is a major surplus area, and the major deficit area is Western Colombia. The Eastern Plains (excluding Meta) and the South, not shown in this table, are minor surplus areas. Yet, comparing

TABLE I.5. Surplus and Deficit Relationships in Beef Production Among Regions, Colombia, 1969-1972

Region	Year	Production (Tons)*	Domestic Consumption (Tons)	Difference Between Production and Consumption
Atlantic Plain[a]	1969	198,082	62,231	+135,851
	1970	213,669	64,720	+148,949
	1971	240,325	67,309	+173,016
	1972	260,080	70,001	+190,079
Western Colombia[b]	1969	88,525	183,533	- 95,008
	1970	96,423	189,224	- 92,801
	1971	105,763	195,092	- 89,329
	1972	115,360	201,141	- 85,781
Central Colombia[c]	1969	74,574	125,955	- 51,381
	1970	79,666	130,490	- 59,824
	1971	86,036	135,187	- 49,151
	1972	92,380	140,054	- 47,674
North Eastern Colombia[d]	1969	66,669	60,680	+ 5,989
	1970	71,178	62,136	+ 9,042
	1971	76,829	63,628	+ 13,201
	1972	82,443	65,155	+ 17,288

a/ Includes Atlantico, Bolivar, Cesar, Cordoba, Magdalena, Sucre, Guajira.

b/ Includes Valle, Cauca, Risaralda, Quindio, Nariño, Antioquia, and Caldas.

c/ Includes Cundinamarca, Tolima, Huila, Bogotá, Meta.

d/ Includes Boyacá, Norte de Santander, Santander.

*Figures are in metric tons.

Source: Adapted from Max F. Bowser. Prerequisitos y Potencial para la Exportacion de Carne en Colombia en la Decada de 1970. Agricultura Tropical, XXV (Bogota, November, 1969), 704-708.

regional estimates of beef production and consumption to identify surplus-deficit areas does not provide an adequate measure of total cattle produced by regions and interregional movements in terms of number of animals, since much of this movement involves feeders. It has been estimated that the Costa provides approximately two-thirds of the cattle that move in interregional trade [61].

The surplus cattle movements from the Costa include finished, stocker and feeder animals which move south mainly through the markets of Medellin and Bucaramanga. In some instances the cattle move southward to the central and upper Magdalena Valley region by means of the Magdalena River and the railroads. Cattle for export is handled through the Caribbean ports of Coveñas, Barranquilla, Cartagena and Santa Marta. Cattle are moved to Venezuela as well, but estimates of this flow are not available.

The results from the 1960 census provide a detailed breakdown of cattle operations by farm size and by number of head (summarized in Table I.6). As this table shows, the size of the cattle farms follows a skewed distribution.

Only one-fourth of the farms had cattle at the time of the census, but these farms included approximately three-fourths of all land in farms. The average number of cattle per farm was 68 with a range that included 182 ranches with an average of 1900 head each. Cattle inventories were concentrated on a relatively small percentage of farms of more than 500 hectares each. Conversely, the smaller farms make

TABLE I.6. Costa--Cattle Distribution According to Size of Ranch, 1960

Size Categories (has.)	Units		Cattle in Farms		
	No.	Percent	Head (000)	Percent	Average (head)
Less than 10	11,382	25.0	99.8	3.0	9
From 10 to 100	22,478	49.0	681.0	22.0	30
From 100 to 500	9,598	21.0	1,053.7	34.0	110
Over 500	2,195	5.0	1,256.2	41.0	572
TOTAL	45,653	100.0	3,090.7	100.0	68

Source: Adapted from DANE [15].

up a high percentage of farms having cattle but control a small percentage of total cattle inventories; three-fourths of the farms were less than 100 hectares and controlled one-fourth of the cattle with an average inventory of less than 50 head of cattle.

Agricultural Services

Although the agricultural service structure of the Costa appears to be rather complete from the standpoint of physical facilities, it seems in many instances they are not performing efficiently considering the needs of the region.

Research is undertaken by the Instituto Colombiano Agropecuario (ICA) in three experiment stations and eight centers for the study and diagnosis of cattle diseases. In

addition to ICA, the Land Reform Institute (INCORA) maintains experimental farms in some of its irrigation projects. Beginning in 1969, the Centro Internacional de Agricultura Tropical (CIAT) started a training and research program in animal sanitation and farm management.

Extension activities are mainly undertaken by ICA, but technical assistance, usually in conjunction with supervised credit, is also provided through INCORA and the banking system. Extension-type services are also provided by the national federations of cotton, rice, cereals, and cattle growers, and by various firms selling plant protection products, herbicides and fertilizers.

Institutional credit is supplied by INCORA, the commercial and the development banks. Another common source of credit for the cattle subsector are the cattle-in-partnership agreements. These are found in both the private and public sectors. The latter are Departmental Organizations, called Fondos Ganaderos, which devote most of their efforts to breeding programs. Under the partnership arrangement, the rancher provides supervision of the cattle and pasture in exchange for a share of the profits when the cattle are sold.

Although agricultural credit programs are available within a wide range of interest rates and terms, the general consensus is that such credit is in short supply and is unevenly distributed. The CIAT survey showed an excess demand for credit (for buying stock) at the prevailing rates of interest.

Modern inputs are marketed through various channels: private supply stores, the INCORA cooperatives, grower federations, and the Caja Agraria. But despite this diversity of outlets, the region suffers from distribution problems: shortages and unavailability are common in the more isolated areas. Since production and distribution do not perform efficiently, prices are too high and incentives for increased use are lacking.

With the exception of cotton and bananas for export, for which there are very well organized marketing channels, the marketing of farm products performs poorly. This is characterized by an excess of middlemen, a shortage of medium- and long-term credit, lack of storage facilities, and inadequate means of transportation. The Institute for Crop and Livestock Marketing (IDEMA) is taking an active role in improving the marketing performance through minimum support prices and by providing storage facilities and credit. INCORA has also been contributing to the coordination of the market through establishment of farmers' cooperatives.

Cattle Marketing

Farmers sell most of their cattle to country dealers or ship directly to "ferias" or stockyards located within the region and as far as Medellin. The CIAT survey showed that five-sixths of the producers sell their cattle to the country dealers who come to the farms to bargain. The cattle are then transported to local slaughterhouses and ferias or

shipped to more distant markets. These dealers also act as intermediaries on feeder cattle transactions.

Cattle are usually purchased on the basis of estimated live weight or by the head. Delivery and transportation arrangements are agreed upon. In almost all cases buyers furnish transportation and assume all costs and risks involved in moving the cattle from the farm or ranch. Contract sales in conjunction with credit have been introduced in the region with the development of the beef export market. These contracts are arranged with the packing houses and for the finishing period.

Most of the cattle in the region are moved by truck, but cattle still move long distances on foot. Some of this movement involves the transfer of feeder cattle from breeding areas to fattening areas. Fat cattle and feeder animals also must be moved on foot to highway, rail, or river shipping points.

Severe weight losses occur during these hauling and on-foot movements. CIAT [9] reports losses up to 40 kilograms per head for finished males after a ten-hour haul to the market.

Live animal prices are affected by both seasonal and long-term cycles. The long-term cycles have averaged about seven years in length. Although the origin of the long-term cycles has not yet been clearly understood, prices, biological timetable of cattle reproduction and nutrition equilibrium seem to be some of the underlying causal forces.

Seasonal price fluctuations are caused directly by the occurance of dry seasons and the lack of irrigated pastures or forage storage. During the dry season, cattle are sold as available forage is used, and prices are driven down. The opposite occurs during the rainy season when pastures are abundant.

Estimatates of the marketing margins for beef vary. A recent estimate made by Sarmiento [63] shows that the rancher receives between 80 and 85 percent of the final value. From the standpoint of the producer's share, the beef market seems to be performing well.

Slaughtering of livestock and the handling of meat have the same serious deficiencies described in Chapter 2. Most slaughter facilities are small rural community or village operations, but modern slaughterhouses are in operation in Barranquilla, Cartagena, Santa Marta and La Gloria--a Magdalena river port 300 kilometers south of Santa Marta. These plants are operated mainly to supply the needs of the export market.

CHAPTER 4

GENERAL SPECIFICATIONS AND PROCEDURE

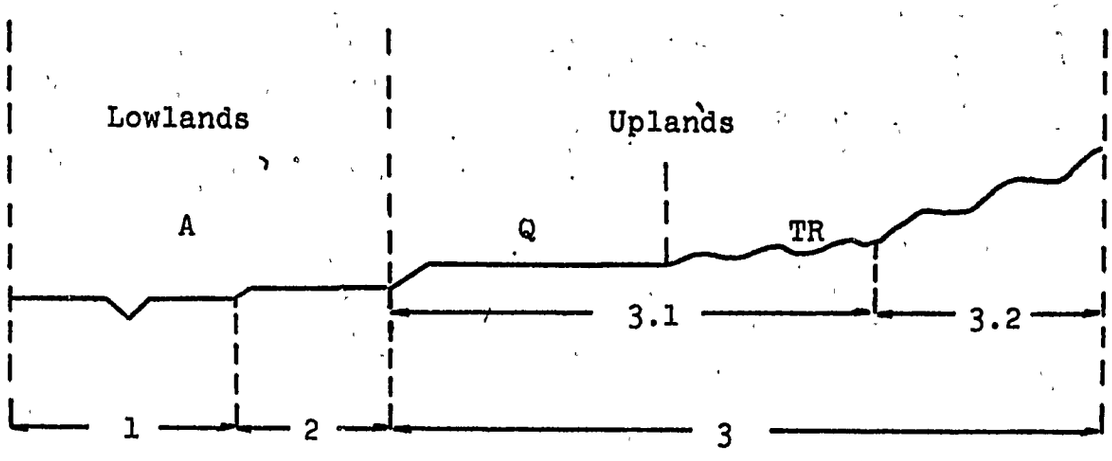
Given the variety of land classes, climatic zones and types of cattle operations that exist within the region, and considering the multiplicity of changing variables that make up its social and economic environment, some simplifying assumptions and/or restrictions are needed to confine the study to workable proportions.

Area of Study

The study will be confined to the Departments of Cordoba, Bolivar, Atlantico, Sucre, Cesar and Magdalena which carry the largest cattle population in the Atlantic plain. The area has a vast potential for successful beef production, easy access to domestic and foreign markets, and expanding facilities for modern slaughter and meat processing.

Farming Sectors

Although there are four distinctly separated ecological zones in the Costa (see Chapter 3), the model is broadly disaggregated into two farming sectors, three agricultural regions and two subregions of competing farming activities based on land use capability (disregarding climatic conditions). Figure I.5 is a hypothetical cross section of these sectors.



Lowland
1. grass only region
2. cash-crops, food-crops, grass region

Uplands
3. cash-crops, food-crops, grass region
   .1 cash-crops, food-crops, grass subregion
   .2 grass-food crops subregion

A = alluvial deposits
Q = quaternary terraces
TR = tertiary soils

FIGURE I.5. Agricultural regions of Northern Colombia.

Sector 1 or lowland is the flat land area in the valley floor formed by recent alluvial deposits. Of the two agricultural regions identified in this sector, region 1 includes lands which are permanently flooded or are subject to seasonal floodings and are used only for grazing. Region 2 is the flood-free area where cash and food crops compete with cattle for land and capital. Region 2 can expand into region 1 as the latter is drained and becomes available for cropping but cannot expand beyond the natural limit of lowlands.

Sector 2, or upland, is the nearly flat to rolling land above the valley floor. It is formed of quarternary terraces and tertiary soils with slopes of 1 percent and over. This sector comprises agricultural region 3 and subregions 1 and 2 where farming is mixed, and includes cash and food crops and cattle production. Subregions 1 and 2 are roughly determined by topographic conditions; subregion 1 is suitable for mechanized cropping and is the area where cash and food crops compete with cattle for land and capital. Subregion 2 is characterized by a more rough and complex topography and is suitable for food crops and grasses which also compete for land and capital. Region 3 cannot expand beyond the natural limit of uplands, but in subregion 1, land in cash crops can contract and expand within its natural limit.

These farming regions are not entirely internally homogeneous with respect to climate and cropping potentials. They occur within the four ecological zones but compromises were made to delineate these regions as homogeneous areas.

The primary reasons for this are twofold. First, despite climate variations, the pattern of farming is very similar in all ecological zones, and behavioral characteristics of farmers who control land use and modernization decisions are assumed to be identical throughout the four zones. Secondly, at the present state of aggregation of the model we are not interested in performing a separate accounting for each ecological zone.

Ranching Practices

While ranching in these sectors is of a mixed type, cattle breeding and growing is predominant in the uplands and fattening is done in the lowlands. But the cattle from the two sectors are aggregated into one herd when simulating the animal demography and computing the major outputs of the model. When the new alternatives of production are introduced, the cattle population of the Costa is disaggregated into two populations, one traditional and one using modern techniques (see Figure I.6). The "traditional" cattle population is assumed to subsist on the flood-free (lowland and upland) areas during the rainy season. During the dry season, crop residues and additional grazing land which becomes available as the flood waters recede during dry months also add to the nutrient supply. It has been estimated that about 400,000 head from Sucre alone are moved from the uplands to the lowlands in search of water and forage as the dry season advances and food becomes scarce.[1/]

[1/]Personal information.

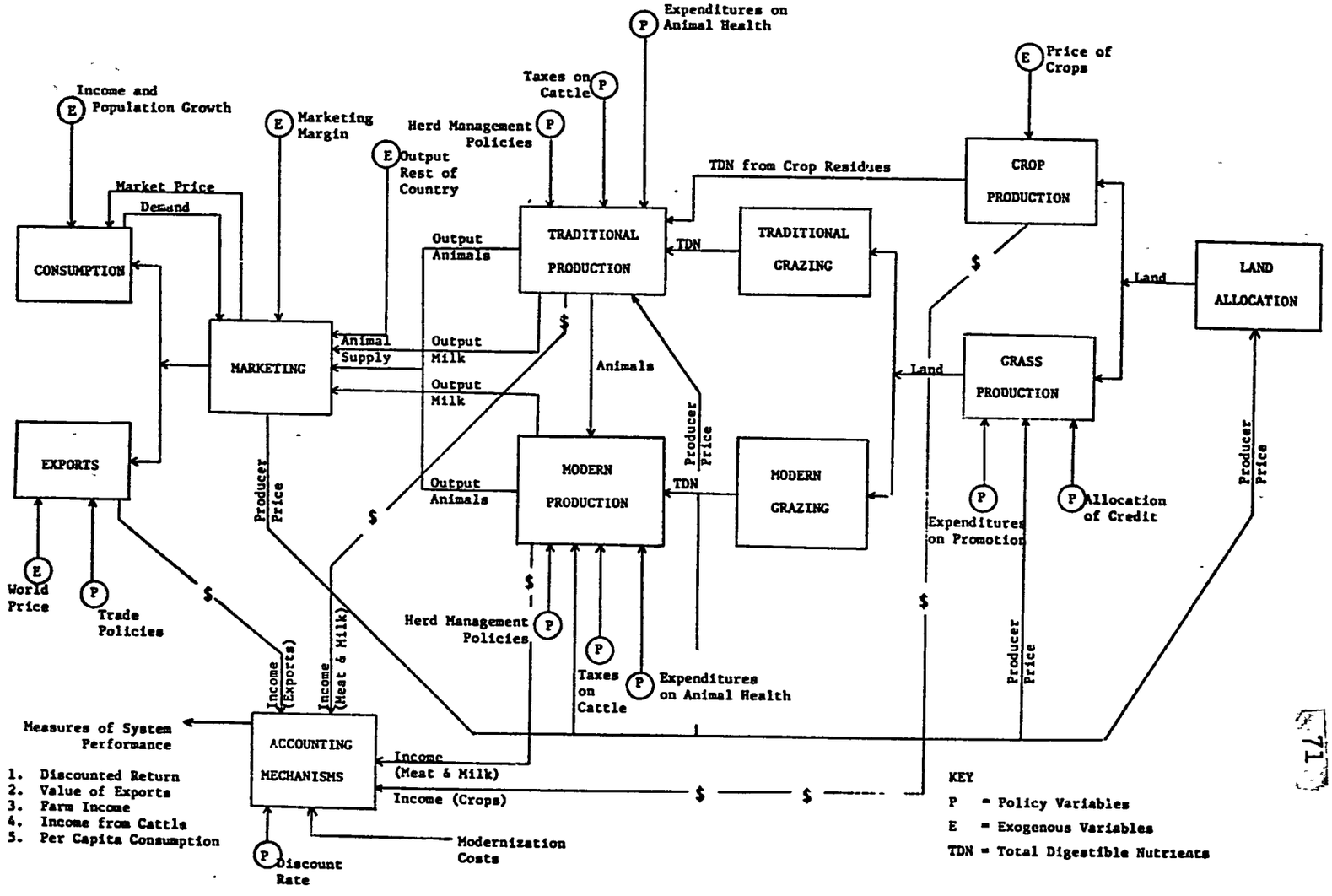


FIGURE I.6. A functional flow diagram of cattle production.

Animals in the "modern" sector are assumed to be situated on the flood-free pasture lands where adequate nutrition is available from properly managed grassland and supplemental feed obtained from land devoted specifically to forage production. The level of husbandry is also assumed to be upgraded: diseases and parasites are controlled and improved breeding techniques are used.

Modern Alternatives

In considering the alternatives to traditional cattle production care has been taken to select those which embody a rather simple technology and are deemed to be both feasible and easily transferable given the resources at hand and the behavioral characteristics of ranchers in the Costa. Thus the alternatives considered are focused on investments in relatively simple improvements that will advance management and increase output. Outlays are spent on the most elementary of inputs: fences and stock water supply to permit the beginnings of managerial control; yards and corrals to offer the beginnings of health protection measures; seeds and fertilizers to begin to increase fodder production.

Since a major problem for cattle in the region is a lack of adequate dry season nutrition resulting in substantial weight losses, lower calving rates, higher death rates, and "delayed" maturation, the alternatives emphasize methods of increasing pasture production and growing and storing forage. These not only improve nutrition but also step up

the average carrying capacity, allowing either for a larger or a constant cattle population in the face of expanding crops and shrinking pasture area.

The modern alternatives evaluated in the model are:

(1) Pasture lands are kept with the grass species already present. Fences, stock water supply and corrals are established to pursue the beginnings of managerial control and health protection measures. Proper grazing rate and pasture rotation are introduced to increase fodder production and improve nutrition.

(2) The same ranching practices as in Alternative 1 with artificial pastures substituting for natural pastures.

(3) The same as in Alternative 1 with forage crops being used to provide feed during the dry season.

(4) The same as in Alternative 2 with forage crops being used to provide feed during the dry season.

At the present stage of development of the model, the modern alternatives are not competing among each other for land and capital; they are evaluated in separate computer runs, each one at a time.

Static Restrictions

Handling all the variables in unrestricted dynamics requires a team effort which is beyond the scope of this study. Thus, analytical restrictions are imposed that keep some of the variables fixed. Patterns of consumption and of ownership of resources, and hence an implied distribution of private real income is assumed fixed; the regional population is assumed constant, and the institutional set-up of the economy is assumed fixed. The implication of these assumptions

for the outcome of the study will be discussed in the last chapter.

Another restriction imposed on this study is that its primary focus is on the beef production process with only general considerations of the related crop subsector, and rudimentary considerations of the marketing element of the beef subsector.

Procedure

To accomplish the objectives of this study, a multi-component but non-maximizing model of a micro-macroeconomic nature has been developed. The computer simulation model is composed of five basic components or building blocks (see Figure I.7) which are closely interrelated as the outputs from one block serve as inputs of others. Information-feedback mechanisms build into the system add to the dynamic interaction of variables within and among the various components.

The first, the land allocation and modernization decisions component allocates land between crops and cattle in the regions of competing farming activities. Land use in food crops in all regions and cash crops in region 2 are exogenously determined, but in subregion 1 land use decisions are based on perceived relative profitabilities of the cattle and cash crops enterprises. Cattle modernization decisions are based on perceived relative profitabilities and the availability of credit, investment capital, and information either from farmer-to-farmer in a diffusion process or from extension agents as part of modernization promotion efforts. Then,

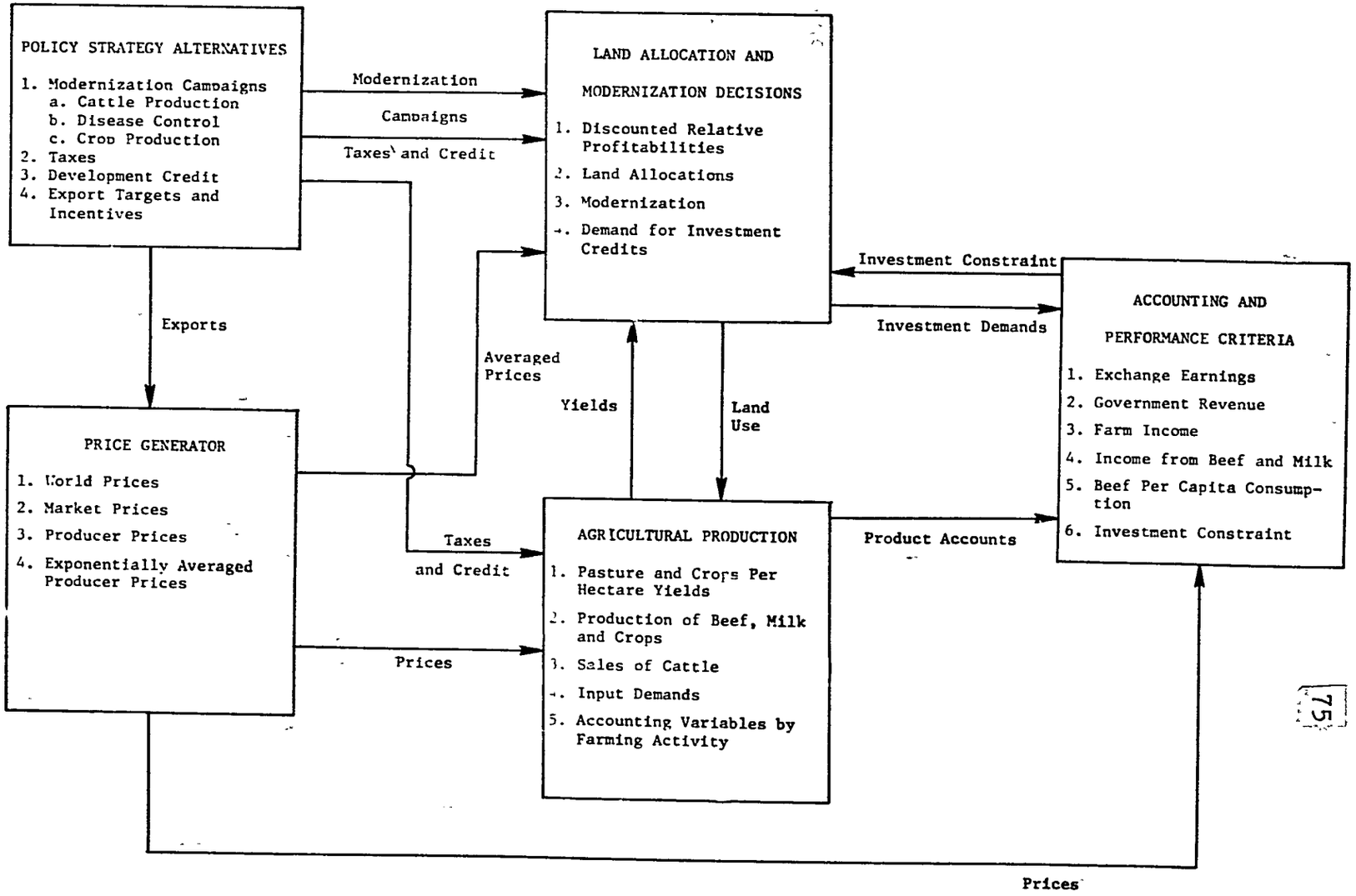


FIGURE I.7. Building blocks of the Costa beef model.

expansion of total cultivated land and/or of modern cattle operations may occur as a result of these economic decisions.

The second principal component takes the allocation of land from the land allocation component and, given prices, costs and yields, computes agricultural production and farm income. The principal element of this component is the cattle demography which is computed endogenously for the region and exogeneously for the rest of Colombia.

A third unit of the model (the price generator) generates world, market and producer prices for cattle, and producer prices for crops. Although market prices for cattle are based on total demand and supply, prices for crops are exogeneously determined. Since we are concerned with farmer decision makers, the streams of future revenues and costs (Equations 5.35) used in the profitability calculations should reflect the farmers' expectations. Thus, the producer prices used here are five-year exponential averages of recent prices. In the production component, however, current prices are used to determine short-run supply responses of cattle.

The remaining two components are the primary entry and exit points of the system. As policy entry points, cattle production campaigns (land, herd and management improvement, and animal health) are specified and conducted and credit, taxes, subsidies and export policies are set. Finally, in the criteria and general accounting component, several alternative criteria functions which might influence a policy maker's choice of development programs are calculated

at both interim and final stages of the simulation experiment. Farm incomes derived from meat, milk, and crops are computed, as are capital investment and operating costs incurred through implementing various modernization policies. Thus, several relative benefit/cost relationships for experimental modernization policies are summarized by computed performance functions which include discounted net income from cattle, cattle and crop incomes, foreign exchange balances, beef output, and government revenues. The ability of the industry to meet the increase in demand for beef is determined by computing the domestic consumption when projected exports are achieved.

Each of these five building blocks of the Costa cattle model will be described in some detail in Chapters 5 through 9.

P A R T II

MODEL DESCRIPTION

Introduction

The computer simulation model of the cattle economy of northern Colombia is composed of the five basic components or building blocks summarized in Chapter 4: the land allocation and modernization decisions component, the agricultural production component, the price generation component, policy entry points, and the criteria and general accounting component. These building blocks, composed of interrelated functional relationships and linkages between them (an output from one either being an input to another or a performance variable), are an attempt to represent the physical, biological, economic, social, political, and cultural relationahips within and among the major segments of the Costa's cattle economy.

Most of the equations describing these components are applicable to all four modern alternatives considered. But, in cases where there are structural differences arising from the underlying assumptions, specific formulations are shown and discussed. Moreover, the efficiency and economy of the computer model is increased with the use of subroutines written in the FORTRAN programming language.

These subroutines permit simulation of the behavior of the various alternatives and their components over time with one general model.

Each of the five building blocks of the Costa model will be described in some detail in Chapters 5 through 9. A copy of the computer program displaying all equations, value of parameters and initial conditions used in these components and their related subroutines is shown in the Appendix.

CHAPTER 5

LAND ALLOCATION AND MODERNIZATION DECISIONS-- CROPS/CATTLE (LAMDAC)

Component LAMDAC of the simulation model allocates land to the production of cash crops, food crops and grasses in each of the farming sectors and three agricultural regions described in detail in Chapter 4 (see Figure I.5). Briefly, region 1 is subject to seasonal or permanent floodings and is kept under traditional grazing practices; region 2 is the flood-free area in the alluvial valleys, and region 3 is the area of quarternary terraces and tertiary soils above the valley floor. In making these allocations, LAMDAC simulates farmers' choices among the alternative uses for their land based on economic and cultural factors. Modernization of current cattle practices is an alternative as is transferring land into the production of crops or cattle.

Land Uses

In general, the land uses in the agricultural regions include grasses, annuals, perennials, and wood lots. Since crops are of secondary concern in this study it was not considered necessary to design a detailed land allocation mechanism for the various crops. Instead they are handled as constant weighted averages of the major commodities grown in the region. Although this assumption has the advantage

of simplifying model computations at this stage, it prevents increases in average values--caused by a rapid expansion of crops with high profitabilities--affecting the pasture/crops allocation decisions. Cash crops in the lowlands are defined as a weighted composite of the major commercial crops grown in the Costa: sesame, cotton, corn, sorghum and rice. Bananas for export are grown in the banana belt north of Magdalena and are computed separately. Cash crops in the uplands include the same group of crops as in the lowlands with the exception of rice and commercial bananas. Further, it is assumed that 47.5 percent of sesame, 63 percent of cotton, 28 percent of corn, and 48 percent of sorghum are grown in the lowlands.

Food crops in all regions are defined as a weighted composite of the major staples grown and consumed in the Costa: plantain and cassava.[1/] Although corn is also an important staple and it is grown mainly in small or subsistence plots, it was included here as a cash crop because of government interest in promoting its production with the aim of generating an exportable surplus [57].

[1/] The weights used are as follows: (a) cash crops in lowlands: sesame--.04; cotton--.265; corn--.244; sorghum--.017; and rice--.433; (b) cash crops in upland: sesame--.054; cotton--.18; corn--.74; and sorghum--.021; (c) food crops: plantain--.34; and cassava--.66. These weights are derived from hectares in production as reported in [7].

Pastures are defined as a weighted composite of artificial and native grasses, each having a different yield and nutritional value. Differences in pasture yield and nutritional value also arise from the four range and herd management improving alternatives considered in the model.

Availability of Agricultural Land

Farming area in each region has expanded into the land in forest as the latter has been cleared due to price incentives, population growth, etc. Without detailed information on how these factors have influenced such expansion, as an initial approximation the model exogenously computes increases in the agricultural land base through time using first order, delay equations. These equations simulate the gradual addition of new land to the agricultural land base until the latter reaches the maximum area potentially available in each case [21, 52, 54]. A more elaborate computation would make land expansion a function of endogenous decisions and would likely make use of higher-order distributed delays to simulate more realistically the time response of these decisions.

$$TLAVL(t) = TLAVL(t-DT) + \frac{DT}{DEL15}*(TLAVL0 - TLAVL(t-DT)) \quad (5.1a)$$

$$TLAVU1(t) = TLAVU1(t-DT) + \frac{DT}{DEL16}*(TLAVU01 - TLAVU1(t-DT)) \quad (5.1b)$$

$$TLAVU2(t) = TLAVU2(t-DT) + \frac{DT}{DEL17}*(TLAVU02 - TLAVU2(t-DT)) \quad (5.1c)$$

$$TGLSF1(t) = TGLSF1(t-DT) + \frac{DT}{DEL18}*(TGLSF0 - TGLSF1(t-DT)) \quad (5.1d)$$

where:

TLAVL = flood-free agricultural land actually available in region 2 (has)

TLAVL0 = flood-free agricultural land potentially available at time zero in region 2 (has)

TLAVU1 = agricultural land actually available in subregion 1 (has)

TLAVU01 = agricultural land potentially available at time zero in subregion 1 (has)

TLAVU2 = agricultural land actually available in subregion 2 (has)

TLAVU02 = agricultural land potentially available at time zero in subregion 2 (has)

TGLSF1 = grazing land actually available in region 1 (has)

TGLSF0 = total potential grazing land in region 1 at time zero (has)

DEL15,16,17,18 = lag parameters (years).

Additions to the cropping area in region 2 due to the performance of flood control and drainage projects (RLDRN) are exogenously determined by Equation 5.2. Irrigation and drainage schemes are accompanied by land distribution and are undertaken and administered by the government through INCORA.

Administrative and construction time lags occur in this process which cause the drained land to be immediately unavailable for cultivation. These time lags are introduced by means of the third order distributed delay of Fquation 5.9. Changes in the rate at which land is drained (RLDRN) and in the time required for the completion of a project (DEL11) will allow testing the effect of various policies toward land reclamation on the total grazing area.

TLDRN(t) = min(TLDRN(t-DT) + DT*AUX10(t-DT), TLDRNL0) (5.2)

CALL DELAY(RLDRN(t-DT), AUX10, CROUT11, DEL11, DT, K11) (5.3)

where:

TLDRN = total grassland drained and added to cropping area (has)

TLDRNL0 = total flooded land capable of drainage and flood control at the beginning of simulation (has)

RLDRN = unlagged rate at which flooded land is drained (has/yr)

AUX10 = actual (lagged) rate at which drained land becomes productive (has/yr)

DELAY = is a FORDYN subroutine which introduces distributed delays with various properties

CROUT11 = an array of intermediate rates necessary in simulation of the drainage delay

DEL11 = average length of time in the drainage process (years)

K11 = the order of the delay (=3 in this case)

DT = time increment of the model (years).

Food Crops

Food land is land on which either subsistence or cash food is actually in production. It is assumed there is no competition among food crops and that they remain at a constant relative proportion. Justification for this assumption and its likely effects in the model's output have been discussed in the section on land uses. Exogenously promoted yield increases are allowed as part of the modernization of agriculture, but there is no disaggregation between traditional and modern production.

Food crop land is assumed to grow exponentially with time and population growth as determined by the following equations:

$$RLFC(t) = AL2*TLFC0*EXP(AL2*t) \quad (5.4)$$

$$TLFC(t) = TLFC(t-DT) + DT*RLFC(t-DT) \quad (5.5)$$

where:

RLFC	=	rate of change of land in food crops (has/yr)
TLFC0	=	land in food crops at time zero (the start of the model) (has)
TLFC	=	total land in food crops (has)
AL2	=	a model parameter (very nearly the annual population growth rate)
EXP(AL2*t)	=	this is an exponential function defined as equivalent to e^{at} where a = AL2
DT	=	time increment of the model (years)
	=	time in years.

Food land in the uplands is given by:

$$TLFCU(t) = C249 * TLFC(t) \quad (5.6)$$

$$TLFCU1(t) = \min(CFD1 * TLFCU(t), TLAVU1) \quad (5.7)$$

$$TLFCU2(t) = \min((1-CFD1) * TLFCU(t), TLAVU2(t)) \quad (5.8)$$

where:

- TLFCU = total land in food crops in upland sector (has)
- TLFCU1 = total land in food crops in subregion 1 (has)
- TLFCU2 = total land in food crops in subregion 2 (has)
- TLAVU1 = agricultural land available in subregion 1 --Equation 5.1b (has)
- TLAVU2 = agricultural land available in subregion 2 --Equation 5.1c (has)
- CFD1 = a model parameter allocating food crops to subregion 1
- C249 = a model parameter allocating food crops to the uplands (region 3)
- min[a,b] = a function equal to the minimum of terms within the brackets.

Food land in the lowlands is given by:

$$TLFCL(t) = \min(TLFC(t) - TLFCU(t), TLAVL0 + TLDRN(t)) \quad (5.9)$$

where:

- TLFCL = total land in food crops in region 2 (lowlands) (has)
- TLAVL0 = flood-free agricultural land available at time zero in region 2 (has)
- TLDRN = total land drained and added to cropping area in the lowlands--Equation 5.2 (has)

Cash Crops

Cash crop land is land on which commercial crops are actually in production. As for food crops, cash crops enter the model at a constant relative proportion without competing for land among themselves. Exogenously promoted yield increases are allowed also, but there is no disaggregation between traditional and modern production.

The expansion of cash crops in region 2 is exogenously determined by a constant rate near the historical trend (RLCRL). In subregion 1 of region 3 this expansion is determined endogenously and is discussed below in conjunction with the allocation of pasture. The general assumption is made that cash and food crops compete for a limited amount of land available for cropping (TLAVL, TLAVU1) in each region.

Cash crop land in region 2 (lowlands) is given by the following equations:

$$ALNDL(t) = TLAVL(t) + TLDRN(t) - TLFCL(t) - TLBAN(t) \quad (5.10)$$

$$TLCRL(t) = \min(TLCRL(t-DT) + DT*RLCRL, ALNDL(t)) \quad (5.11)$$

$$TLCRLR(t) = TLCRL(t) + TLBAN(t) \quad (5.12)$$

where:

ALNDL = allocatable land (cash crops and pasture) in region 2 (has)

TLBAN = total land in commercial banana (has)

TLCRL = total land in cash crops--excluding commercial banana--in region 2 (has)

TLCRLR = total land in cash crops in region 2 (has)

RLCRL = rate of change of land in cash crops (banana excluded) in region 2 (has/yr).

Total land in bananas for export is determined from time series data as reported by Caja Agraria [7, 8] and assumed to remain after 1970 at its present area of 5,000 hectares which is the hurricane-free, adequately irrigated region within the banana belt:

$$\text{TLBAN}(t) = \begin{cases} 20{,}000 & 0 \leq t \leq 6 \\ 18{,}520;\ 8{,}950;\ 7{,}860 & 6 < t \leq 9 \\ 5{,}000 & t \geq 10 \end{cases} \qquad (5.13)$$

Pasture and Cattle

Pasture land is land on which cattle are actually in production. The area in pasture is computed separately for each region and then aggregated to obtain the total for the Costa. In region 2 and in subregion 2 the assumption is made that cattle are a less profitable activity than growing crops and no decision mechanism is considered; therefore, pasture land is computed as a residual after subtracting land in crops from the total available land in each region. This simplification is based on the empirical evidence that in the more productive lowlands the profitability of cash crops outweighs that of cattle. Likewise, in small farms where food crops are grown in both region 2 and subregion 2 cattle production is not considered as a profitable alternative. In regions 1 and 2 it is also assumed that once land is drained it is placed into a more intensive use and subtracted from

grazing. The allocation of land in subregion 1 is based on the relative returns to land from the cash crops and cattle activities. It is thus responsive to exogenously determined crop prices and cattle prices determined endogenously by the model.

Pasture or grazing land in the seasonally flooded and in the flood-free areas (regions 1 and 2) is computed as:

$$TGLSF(t) = TGLSF1(t) - TLDRN(t) \tag{5.14}$$

$$TGLL(t) = \max(TLAVL(t) - TLFCL(t) - TLCRLR(t), 0) \tag{5.15}$$

where:

TGLSF1 = as defined in Equation 5.1d

TGLSF = total pasture land in region 1 (has)

TGLL = total grazing land in region 2, the flood-free area (has)

max[a,b] = a function equal to the maximum of terms within the brackets.

The rate of change in grazing land in region 2, the flood-free area of the lowlands is computed as:

$$RTGLL(t-DT) = \frac{TGLL(t) - TGLL(t-DT)}{DT} \tag{5.16}$$

where:

RTCLL = rate of change of total grazing land in region 2 (has/yr).

Pasture land in subregion 2 of the upland is simply computed as:

$$TGLU2(t) = TLAVU2(t) - TLFCU2(t) \quad (5.17)$$

where:

TGLU2 = total grazing land in subregion 2 (has).

The rate of change in grazing land in subregion 2 is given by:

$$RTGLU2(t-DT) = \frac{TGLU2(t) - TGLU2(t-DT)}{DT} \quad (5.18)$$

where:

RTGLU2 = rate of change of total grazing land in subregion 2 (has/yr).

The mechanism for allocating land to cash crops and pasture (traditional and modern) in subregion 1 is more complex than the one described for the other regions. This part of the model gradually shifts land to the activity with the greatest return per unit of land. First, the model allocates farming land to food crops as shown in Equations 5.4 through 5.7. The remaining area is then allocated to the land in the most profitable of the two other cash earners --cash crop and pasture.

The following equations apply:

$$ALNDU1(t) = TLAVU1(t) - TLFCU1(t) \quad (5.19)$$

$$DLFCU1(t) = TLFCU1(t) - TLFCU1(t-DT) \quad (5.20)$$

where:

ALNDU1 = allocatable land in subregion 1 (has)

DLFCU1 = change in food crops land in subregion 1 (has).

Land shifts to the more profitable activity at a rate that is proportional to:

1) the percent difference in cash returns per unit of land that exists between the two activities,

2) the amount of land currently allocated to the less profitable activity, and

3) a model parameter, CL1, which can be varied to match prevailing farmer behavior.

The rate of land transfer is given by:

$$RLCRU(t) = \frac{CL1*XTLU(t)*(DCRU(t) - DRLAV(t))}{|DCRU(t)|} \qquad (5.21)$$

where:

RLCRU = rate of change of cash crops land in subregion 1 (has/yr)

DCRU = discounted sum of returns over the planning horizon for cash crops in subregion 1--Equation 5.34 (Ps/ha)

DRLAV = discounted sum of returns over the planning horizon for cattle production. This is an average of traditional and modern production --Equation 5.33 (Ps/ha)

XTLU = total grazing land if DCRU > DRLAV

= total land in cash crops if DCRU $\leq$ DRLAV (has)

CL1 = a model parameter that controls the speed of land adjustment

|...| = the absolute value.

Positive rates of transfer mean shifts from pasture and cattle grazing to cash crops; negative rates mean shifts from cash crops to pasture.

Land transferred from grasses to cash crops is immediately available for crop production, but the rate at which land transfers from cash crops to grasses is delayed to account for the time needed for grasses to become well established and to begin production at full grazing capacity.

This time lag is simulated by the following distributed delay:

CALL DELAY(AUX1(t-DT), AUX2, CROUT4, DEL4, DT, K4) (5.22)

where:

AUX1 = unlagged rate of transfer of cash crop land to grazing land: < 0 if DRLAV > DCRU

= 0 if DRLAV < DCRU (has/yr)

AUX2 = lagged rate of transfer of cash crop land

CROUT4, DEL4, DT, K4
= elements of the DELAY subroutine defined earlier (p. 84).

Additions to food land in subregion 1 can come either from land in the least profitable of the remaining activities or from both cash crop and grazing land in specified proportions. Land also could be allocated to food from grazing land even if the latter is more profitable than cash crops.

Such allocation is performed in the model by means of the variable AUX4 and the parameter CL2. If cash crops are more profitable than cattle, the rate of change of land in cash crops is positive (RLCRU > 0) and all the increase in food land comes from land in grasses.

If cattle are more profitable than cash crops, the rate of change of land in cash crops is negative (RLCRU < 0) and the increase in food land comes from land in cash crops and/or land in grasses depending on the value of the model parameter CL2($0 \leq CL2 \leq 1$):

If CL2 = 0 all new land in food crops comes from land in grasses, modern and traditional

If CL2 = 1 all new land in food crops comes from land in cash crops.

The variable AUX4 is then computed as:

$$AUX4(t) = \begin{cases} CL2*DLFCU1(t), & DRLAV \geq DCRU \quad (5.23a) \\ 0, & DRLAV < DCRU \quad (5.23b) \end{cases}$$

where:

AUX4 = transfer of land from cash crops to food (has)

CL2 = a model parameter that allocates the change in food land between cash crop land and grassland.

Given the above allocation mechanism, total land in cash crops in subregion 1 is:

$$TLCRU(t) = \max[\min(TLCRU(t-DT) - AUX4(t) + DT*(AUX2(t-DT) + AUX3(t-DT), ALNDU1(t))), 0] \quad (5.24)$$

where:

TLCRU = total land in cash crops in subregion 1 (has)

AUX3 = rate of transfer of grazing land to cash crops land (= RLCRU) if DRLAV < DCRU

= 0 if DRLAV > DCRU (has/yr).

Equation 5.24 essentially computes the time integral of the total rate of change of cash crop land limited to preclude the possibility of negative land and expansion beyond the allowable land limits (ALNDU1--Equation 5.19).

Given total allocatable land from Equation 5.19 and total land in cash crops from Equation 5.24, the model computes total grazing land (in subregion 1) as:

$$TGLU1(t) = ALNDU1(t) - TLCRU(t) \qquad (5.25)$$

where:

TGLU1 = total grazing land in subregion 1 (has).

The rate of change in grazing land in subregion 1 is given by:

$$RTGLU1(t-DT) = \frac{TGLU1(t) - TGLU1(t-DT)}{DT} \qquad (5.26)$$

where:

RTGLU1 = rate of change of total grazing land in subregion 1 (has/yr).

The total grazing land in the Costa is simply the sum of grazing land in each of the farming sectors and is given by the following equations:

$$TGLU(t) = TGLU1(t) + TGLU2(t) \qquad (5.27)$$

$$TGL(t) = TGLL(t) + TGLU(t) \qquad (5.28)$$

$$TGLR(t) = TGL(t) + TGLSF(t)*C9 \qquad (5.29)$$

where:

TGLU = total grazing land in upland sector (region 3) (has)

TGLU1 = total grazing land in subregion 1 (has)

TGL = total (flood free) grazing land in regions 2 and 3 (has)

TGLR = total grazing land in the Costa region (has)

C9 = a model parameter that adjusts seasonally flooded grasslands to permanent grazing land.

Grazing land in region 1 is subject to periods of flooding that last from a few weeks to six months and longer. Since we are interested in the permanent stocking capacity of grasslands, seasonally flooded grazing land is adjusted in the model to a permanent grazing land equivalent. This is done by the model parameter C9 of Equation 5.29 which is a weighted composite of area and length of flooding.

Alternatives

In principle, every current land use is a conceivable alternative to every other present use in the same farming sector. In practice, however, certain assumptions can be made which will reduce the multitude of alternatives and will simplify the model. Since the model is focused primarily on cattle production, only alternatives concerned with the introduction of technological changes in this activity will be considered in detail. The alternatives to traditional cattle production included in this study are those described in Chapter 4 and considered as feasible in every agricultural region with the exception of region 1.

Pasture land in this region remains under traditional management throughout the simulation.

Implicit in the allocation of land in region 2 and subregion 2 is the assumption that both food and cash crops are more profitable than cattle. Here, the allocation of land to food production has priority in order to meet the nutritional requirements and consumption preferences of the population. The remaining land is then first allocated to cash crops and finally to pasture. In subregion 1 a more complex allocation mechanism has been described; land is first allocated to food production and then to cash crops and cattle based on their relative profitabilities.

Although the present structure of the model restricts consideration of cattle production alternatives to one each simulation, future expansion could include competition among modern grazing alternatives. The model also could be expanded to include competition among crops and a more realistic, though more complex, decision-making mechanism for the allocation of land between individual crops and pasture in all regions.

Cattle Modernization Decisions

Land use decisions between cattle and cash crops have been discussed above in Equations 5.19 to 5.23. In this section we are mainly concerned with the more complex decision mechanism of cattle modernization. The rate at which cattle modernization takes place depends on the relative profitability

of each alternative, on modernization promotion efforts, on diffusion effects, on the availability of capital, and on the behavioral characteristics of the farmers making decisions. These considerations will be discussed in detail below.

Profitabilities

Farmers' decisions among the alternative uses for their land are based upon their perceptions of the relative profitabilities of the available alternatives. These decisions have been restricted to the allocation of land between pasture and crops in subregion 1, and between traditional and modern cattle in all regions but region 1. In the first case, the relative profitability is given in Equation 5.21 above. The relative profitability of the modern cattle production alternatives is given by:

$$PDR(t) = \frac{DRLAM(t) - DRLAT(t)}{|DRLAT(t)|} \qquad (5.30)$$

where:

PDR = the relative profitability differential (dimensionless)

DRLAM = discounted sum of returns over the planning horizon for modern cattle production--Equation 5.31 (Ps/ha)

DRLAT = discounted sum of returns over the planning horizon for traditional cattle production--Equation 5.32 (Ps/ha).

Land use profitabilities are defined as the present value of the stream of net income farmers expect to receive over some relevant planning horizon. The model computes

the sum of the discounted present value of returns to a land use from the present to the planning horizon. This discounted sum is the "profitability" of that land use. But while expected revenues and costs from modern cattle vary over the planning horizon, those from traditional cattle and cash crops are assumed to remain constant. Equation 5.31 computes the profitability of modern cattle:

$$DRLAM(t) = \sum_{i=1}^{n} \frac{(TRLAM_i(t) - TCLAM_i(t))}{(1 + DIR)^i} \qquad (5.31)$$

where:

DRLAM = is defined in Equation 5.30

TRLAM = total revenue from modern cattle--Equation 5.35c (Ps/ha-yr)

TCLAM = total costs of modern cattle--Equation 5.35d (Ps/ha-yr)

DIR = the relevant discount rate (proportion/year)

i = indexes the n years of the planning horizon.

The profitability of traditional cattle is given by;

$$DRLAT(t) = (TRLAT(t) - TCLATL(t)) * \sum_{i=1}^{n} \frac{1}{(1 + DIR)^i} \qquad (5.32)$$

where:

DRLAT = as defined in Equation 5.30

TRLAT = total revenue from traditional cattle--Equation 5.35a (Ps/ha-yr)

TCLATL = exponential average of total costs of traditional cattle--Equation 5.35b (Ps/ha-yr)

DIR = as defined in Equation 5.31

i = indexes the n years of the planning horizon.

The average profitability of all cattle used in Equation 5.21 is given by:

$$DRLAV(t) = \frac{(DRLAT(t)*TTGLR(t) + DRLAM(t)*(TLMOD(t) + TRSL(t))}{TGLR(t)} \qquad (5.33)$$

where:

DRLAV = averaged discounted sum of returns over the planning horizon for cattle production (Ps/ha)

TTGLR = total traditional grazing land in the Costa region--Equation 5.51 (has)

TLMOD = total grazing land in modern production--Equation 5.48 (has)

TRSL = total land in transition from traditional to modern cattle production--Equation 5.46 (has)

TGLR = total grazing land in the Costa region--Equation 5.29 (has).

The profitability of cash crops in the uplands is computed as:

$$DCRU(t) = (TRCRU(t) - TCCRUL(t))* \sum_{i=1}^{n} \frac{1}{(1 + DIR)^i} \qquad (5.34)$$

where:

DCRU = discounted sum of returns over the planning horizon for cash crops production in the uplands (Ps/ha)

TRCRU = total revenue from cash crops--Equation 5.35e (Ps/ha-yr)

TCCRUL = exponential average of total costs of cash crops--Equation 5.35f (Ps/ha-yr)

DIR = as defined in Equation 5.31.

With the purpose of making all discounted present values comparable, the profitabilities are computed using a planning horizon common to all. In this case, this period of time is 12 years, the planning horizon selected for modern cattle. The discount rates used to compute the present value of future returns are behavioral parameters in the model. They reflect farmers' rates of time preference and the varying risks of each alternative. In general, the more risky and unfamiliar the alternative, the higher the discount rate.

Since we are concerned with farmer decision makers, the streams of future revenues and costs (Equations 5.35) used in the profitability calculations should reflect farmers' expectations. These expectations are assumed to be reflected in five-year exponential averages of recent producer prices. Prices of cattle are determined endogenously (Equation 7.2) but prices of crops are determined exogenously and projected into the future with the same trend as costs. The form and computation of producer price averages and trends are discussed in detail later in the description of the price generating component (Chapter 7).

Similarly, the stream of crop yields farmers expect are the yields they currently experience rather than the potential production reported by experiment stations. Increased yields are considered later in Chapter 12 as part of the policy experiments. Additions to expected revenues are any cash and/or price subsidies which may be

offered as part of a modernization program, and the payment of development credits.

The cost side includes taxes on land and cattle, biological, chemical, labor, and capital input requirements over the planning period. Associated input prices are exogenous in the model and are projected into the future according to rate of increase in farm costs. Production costs of crops are averaged and lumped in one figure while those of cattle are computed separately; but all costs are also exponentially averaged when they enter in the computation of profitabilities. Exponential averages of past costs are used here to reflect farmers' expectations of future cost streams. The computation of costs is discussed more fully in Chapter 6.

Total revenue and total cost of traditional cattle are computed as:

$$TRLAT(t) = \frac{(EPAP(t)*ESLSPT(t) + PRMT*EQMT(t))}{TTGLR(t)} + AGSUBT(t) \qquad (5.35a)$$

$$TCLATL(t) = TCLATL(t-DT) + \frac{DT}{DEL19}*(TCLAT(t-DT) - TLCLATL(t-DT)) \qquad (5.35b)$$

where:

EPAP = the expected producer price of finished males--Equation 7.5a (Ps/animal)

ESLSPT = the expected animal sales--(animals/year)[1/]

EQMT = the expected production of milk--Equation 6.21b (liters/year)

PRMT = the price of milk (Ps/liter)

AGSUBT = subsidies paid to traditional cattle (Ps/ha-year)

TTGLR = as defined in Equation 5.33

TCLAT = total traditional cattle costs (unlagged) (Ps/ha-year)[1/]

DT = time increment of the model (years)

DEL19 = lag parameter (years).

The stream of revenues and costs over the planning horizon for modern cattle production reflect different expectations according to the alternative adopted. Changing expectations throughout the planning horizon are simulated by a set of coefficient arrays (SINCR, TMINCR) that increase output and costs over traditional cattle as perceived by farmers. Values of these coefficients for each of the four modern alternatives are shown in Table II.4 in Chapter 6. Total revenue and total cost over the planning horizon, i=1, ..., n, are computed as:

$$TRLAM_i(t) = (SINCR_i * EPAP(t) * ESLSPT(t) + EPAP(t) * BINCR_i * AUXL12(t) + TMINCR_i * PRMT * EQMT(t))/TTGLR(t) + ELOAN_i(t) + AGSUBM_i(t) \quad (5.35c)$$

[1/] For detailed computation of these variables see subroutine AGACC in the Appendix.

$$TCLAM_i(t) = EOPCLM_i(t) + EOCLNM_i(t) + ETCEC_i(t) + EDBSER_i(t) + ETXC_i(t) + EVLDTX_i(t)*ECADEM_i \quad (5.35d)$$

where:

SINCR = expected increase in sales over the planning horizon from the modern herd (dimensionless)

TMINCR = expected increase in milk production over the planning horizon (dimensionless)

BINCR = expected increase in inventory over the planning horizon (animals/year)

AUXL12 = finished male equivalent of cattle prices (proportion)[1/]

AGSUBM = subsidies paid to modern cattle producers (Ps/ha-year)

ELOAN = expected payments of development loans--Equation 6.40g (Ps/ha-year)

EOPCLM = expected operation costs of modern cattle --Equation 6.40a (Ps/ha-year)

EOCLNM = expected operation costs of modern grazing land--Equation 6.40b (Ps/ha-year)

ETCEC = expected total cash establishment costs--Equation 6.40f (Ps/ha-year)

EDBSER = expected debt service of development credits--(Ps/ha-year)[2/]

ETXC = expected taxes on modern cattle--Equation 6.40d (Ps/ha-year)

EVLDTX = expected taxes on modern grazing land--Equation 6.40c (Ps/ha-year)

ECADEM = expected depreciation on equipment and improvements--Equation 6.40c (Ps/ha-year).

[1/] For a detailed computation of this variable see subroutine DEMOG in the Appendix.

[2/] For a detailed computation of this variable see subroutine AGACC in the Appendix.

Total revenue and total cost of cash crops in the uplands are computed simply as:

$$TRCRU(t) = EPCRPU(t)*EYLDCU(t) \quad (5.35e)$$

$$TCCRUL(t) = TCCRUL(t-DT) + \frac{DT}{DEL22}*(TCCRU(t-DT) - TCCRUL(t-DT)) \quad (5.35f)$$

where:

TCCRU = total costs (unlagged) (Ps/ha-year)[1/]

EYLDCU = expected yield--Equation 6.1 (Tons/ha-year)

EPCRPU = expected producer price--Equation 7.5b (Ps/Ton)

DEL22 = lag parameter (years).

Promotion and Diffusion

In the process of estimating the profitability differentials of the various alternatives, farmers need certain information. The information required by farmers include future producer prices, expected yields, government or private subsidy and loan programs, and expected costs. In the model this is provided as part of the promotion effort and in the form of "information units." These information units not only include extension agents, the main instruments of disseminating information, but also any other means of mass communication (radio broadcasts, films, and newspapers).

[1/] For a detailed computation of this variable see subroutine AGACC in the Appendix.

While promotional information units (extension agent equivalents) are exogenously generated as a policy (Chapter 8), the model also computes (Equation 5.39) the demonstration effect of farmers learning from one another about alternative land uses.

Transition Responses

Changes in land use patterns reflect farmers' responses to the perceived profitabilities of the available grazing alternatives. The assumption is made that all farmers modernizing their systems of production, either because of promotion or diffusion, will receive the same type of public and private incentives. Therefore, the perception of the profitability of the new methods will be the same in both cases.

The profitability response function (Equation 5.36) determines how many hectares of land an information unit can transfer per year from traditional to modern management. This calculation depends on the profitability of the alternative and the behavioral characteristics of the farm decision makers (see Figure II.1).

$$PR1(t) = \max[E7*(1-EXP(-E8*(PDR(t)-E9))), 0] \qquad (5.36)$$

where:

PR1 = a variable which introduces the effects of the profitability criterion, PDR, upon the adoption rate (proportion)

E7 = maximum proportion attainable--a model parameter

E8 = the rate of promotion response with respect to profitability (dimensionless)

E9 = the promotion response threshold (dimensionless)

EXP = exponential function

max = takes the maximum of the term within the brackets

PDR = the relative profitability differential--Equation 5.30 (dimensionless).

As shown in Figure II.1, the parameter E7 determines the maximum value of the function. The threshold (E9) and response rate (E8) parameters reflect the farmers' attitudes and behavioral characteristics which affect the rate of their response to the relative profitabilities of their various alternatives. These two parameters represent a wide range of attitudes toward risk involved in the new methods, uncertainty related to social stability, government programs

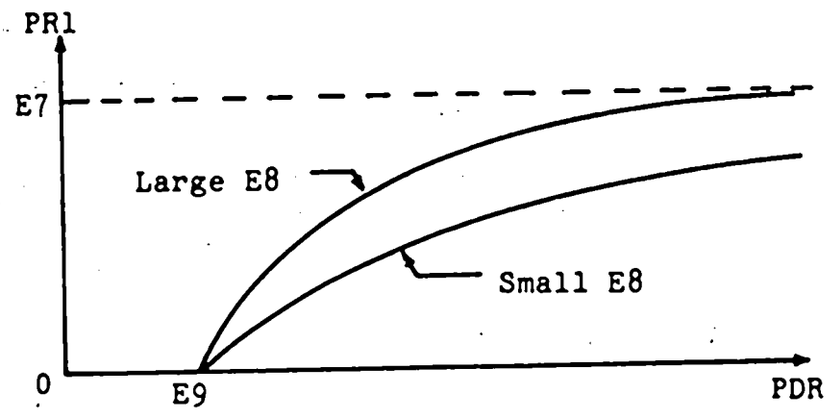


FIGURE II.1. The profitability response function.

and promises in general, and the land tenure system. It is clear that a wide range of adaptor behaviors can be simulated by appropriately assigning values to these three parameters. Since farmers will have different attitudes toward extension agents (or other promotional efforts) than they will toward one another, the values of the parameters may be different for promotion responses than for diffusion responses.

The profitability and behavioral criteria are instrumental in determining the rates at which farmers will respond in a diffusion process or to overt campaigns introducing modern methods. The rate at which land enters a modernization process as a result of overt promotion is given by Equation 5.37.

$$RLMPI(t) = E3(t)*PR1(t)*EXT1(t) \qquad (5.37)$$

where:

RLMPI = rate at which grazing land enters modernization due to promotion (has/year)

EXT1 = units of pre-campaign promotion--a policy variable

E3 = the maximum feasible adoption rate per unit of EXT1 (has/year per unit of EXT1)

PR1 = as defined in Equation 5.36.

As the program progresses, the promotion effort becomes more efficient and the adoption rate likely will be increased. This phenomenon is simulated by Equation 5.38. Here, E3 has its maximum value (E31-E32) at the beginning of a campaign (TCAM=0) and approaches its maximum value

(E31) when TCAM is large. Again, a wide range of real-world situations can be simulated by appropriately assigning values to the model parameters.

$$E3(t) = E31 - E32*EXP(-E33*TCAM(t)) \qquad (5.38)$$

where:

TCAM = the length of time the production campaign has been in operation (years)

E31, E32, E33 = model parameters.

The rate of adoption due to demonstration effects depends on the differential between modern and traditional productivities and on the behavioral characteristics of farmers. The diffusion rate (Equation 5.39) is also a function of the land which remains under traditional management (TTGL) and the land which has been modernized (TLMOD). If there is no land in either use, there is no demonstration effect and no diffusion, while the diffusion rate is greatest when there is as much land in the alternative use as in the present use. Thus, the rate at which diffusion takes place reflects the S-shaped curve of diffusion theory [1].

$$RLMDI(t) = \frac{PR1(t)*TTGL(t)*TLMOD(t)}{TGL0} \qquad (5.39)$$

where:

RLMDI = rate at which grazing land enters modernization due to diffusion (has/year)

TGL0 = total (flood free) grazing land at the beginning of the simulation (has)

The total land entering modernization, RLMI, due to the combined effect of promotion and diffusion is simply computed as:

RLMI(t) = RLMPI(t) + RLMDI(t) (5.40)

The transition rate (Equation 5.41) is constrained by available capital and lagged to account for delays in establishing a modern alternative. Since the Coast is a surplus area (see Chapter 5), requirements of capital for buying cattle are not considered in the aggregate for the region, though this is an important factor in analysing individual farms. Thus, the demand for capital for investment is restricted to farm improvements. The capital available (NCFR) includes capital generated endogenously as income (after allowing for consumption), transfers from the crops subsector, and potential credit. The model does not consider competition for capital between investments and consumption; it is assured that consumption is a first claimant to farm income and investment is treated as a residual. This oversimplification of the consumption/saving decisions is justified here because of the lack of information on the consumption and saving patterns of farmers in the region. In addition, a realistic simulation of the consumption/saving and asset balance decisions of farmers requires the establishment of a preference function in order to maximize both satisfaction as well as returns from different investments

under conditions of changing interest rates, risk, and uncertainty.

The availability of capital and credit will be discussed more fully in the discussion of the Accounting and Performance Criteria Component (Chapter 9). The requirements of credit for development (Equation 5.42a) are determined by subtracting from the total establishment costs the proportion of these costs met by the farmers' own resources. Establishment costs are reduced to an annual basis, so the credit required in the year the transition is made can be related to whatever credit funds are available that same year.

$$CRM(t) = \max\{\min[RLMI(t), [\min(ARM1(t), ARM2(t)) + ARM3(t)]], 0\} \quad (5.41)$$

where:

CRM = unlagged rate of modernization constrained by development credit and farmers' investment capital (has/year)

RLMI = unlagged and unconstrained rate at which grazing land enters modernization--Equation 5.40 (has/year)

ARM1 = allowable rate of modernization depending on availability of development credit--Equation 5.42a (has/year)

ARM2 = allowable rate of modernization depending on capability of farmer to meet his required share of the establishment costs--Equation 5.42b (has/year)

ARM3 = allowable rate of modernization depending on farmer's capability to meet total establishment costs without development credit--Equation 5.24c (has/year)

min[a,b] = a function equal to the minimum of terms within the brackets

max[a,b] = a function equal to the maximum of terms within the brackets.

The variables ARM1, ARM2, and ARM3 (Equations 5.42)[1/] that determine the constraints to the rate of modernization require further explanation. If credit for development is not available (ARM1 = 0; ARM3 > 0) the rate of modernization depends on the farmers' capability to meet the total establishment costs. If development credit is in ample supply but the investment capital of the participating farmers is not enough to meet their required share of the establishment costs (ARM1 > ARM2; ARM3 = 0), the rate of modernization depends on the farmers' available investment capital. If development credit is available and the investment capital of the participating farmers is more than enough to meet their share of the establishment costs (ARM1 < ARM2; ARM3 > 0), the model assumes that the remaining capital is reinvested in the farm and the rate of modernization is increased by an amount equal to the allowable rate without credit support (ARM3). This is to say that resources in modern cattle production are being used at a low opportunity cost.

$$ARM1 = \frac{CREDT(t)}{CRTREQ(t)} \qquad (5.42a)$$

$$ARM2 = \frac{NCFR(t-DT)*LT1}{TCEC(t)*RPTN} \qquad (5.42b)$$

[1/] Equations 5.42b and 5.42c have implicit in the denominator a one-year multiplicative factor that provides the desired units.

ARM3(t) =

$$\frac{(NCFR(t-DT)-\min(ARM1(t),\ ARM2(t))*RPTN*TCEC(t)/LT1)*LT1}{TCEC(t)} \qquad (5.42c)$$

where:

ARM1 = allowable rate of modernization depending on availability of credit (has/year)

ARM2 = allowable rate of modernization depending on capability of ranchers to meet their share of establishment costs (has/year)

ARM3 = allowable rate of modernization depending on ranchers capability to meet total establishment costs without development credit support (has/year)

CREDT = credit available for modernization--Equation 9.4 (Ps/year)

CRTREQ = per hectare credit requirement (Ps/ha)

LT1 = time over which development loans are paid--a policy variable (years)

RPTN = farmers' participation of total establishment costs--a policy variable ($0 \leq RPTN \leq 1$) --proportion

NCFR = net investment capital of farmers--Equation 9.13 (Ps/year)

TCEC = total cash establishment costs--Equation 6.37 (Ps/ha).

The modernization process is simulated as a series of exponential delays which allow for the possibility of "dropouts" and represents the phenomena of random modernization times for individual farms in the aggregate. Equations 5.43 describe this process.

$$R1(t) = R1(t-DT) + \frac{DT}{XDEL}*(CRM(t-DT) - R1(t-DT)) \qquad (5.43a)$$

$$XR1(t) = R1(t)*A5 \qquad (5.43b)$$

$$R2(t) = R2(t-DT) + \frac{DT}{XDEL}*(XR1(t-DT) - R2(t-DT)) \qquad (5.43c)$$

$$RLM(t) = RLM(t-DT) + \frac{DT}{XDEL}*(R2(t-DT) - RLM(t-DT)) \qquad (5.43d)$$

where:

CRM = as defined in Equation 5.41

RLM = average rate land leaves the modernization process and begins producing at modern levels (has/year)

XDEL = one-third of the average time required for modernization (years)

A5 = one minus the proportion of land that "drops out" due to shortage of technical assistance and credit--Equation 5.44.

R1, XR1, R2
= intermediate rates (has/year).

The "dropouts" response function (Equation 5.44) determines the proportion of land that remains, A5, after land "drops out" due to the shortage of extension workers and/or development credit.

$$A5(t) = \min(E12*\frac{EXTA(t)}{EXTR(t)}, 1)*(AUX7(t) + AUX9(t)*\min$$

$$(E13*\frac{ACRDT(t)}{DCRDT(t)}, 1)) \qquad (5.44)$$

where:

EXTR = extension workers (or the equivalent) required to sustain the modernization program --Equation 5.45 (man-years)

EXTA = extension workers available (man-years)

ACRDT = credit allocated for modernization--a policy variable (Ps/year)

DCRDT = total demand for development credit--Equation 9.3 (Ps/year)

AUX7 = actual proportion of total land being modernized with resources other than development credit

AUX9 = actual proportion of total land being modernized with development credit resources

E12, E13 = adjustable model parameters

min[a,b] = the minimum of a and b.

The calculation of A5 involves the combined effect of two functions which have the same response patterns. One depends on the ratio of available extension workers to the number of extension workers required to sustain the modernization programs; the other on the ratio of credit allocated for modernization to the total demand for development credit. As Figure II.2 shows, the parameter E12 (E13) which governs the shape of the response function determines the threshold at which dropouts from the modernization process start and the dependence of the dropout rate upon the ratios EXTA/EXTR and ACRDT/DCRDT.

The extension workers required (EXTR) are computed in Equation 5.45 as the number of man-years needed to provide technical assistance to the land in transition from traditional to modern management (TRSL).

EXTR(t) = C257*TRSL(t) (5.45)

where:

C257 = the extension workers to grazing land ratio--a model parameter (man-years/ha).

In order to compute inputs required for modernization it is important to know how much land is in the modernization process at any given time. The land in modernization is simply the sum of the time integrals of Equations 5.43. Equation 5.46 computes TRSL--the land in transition from traditional to modern practices due to overt promotion and diffusion.

$$TRSL(t+DT) = (XR1(t) + R2(t) + RLM(t))*XDEL \qquad (5.46)$$

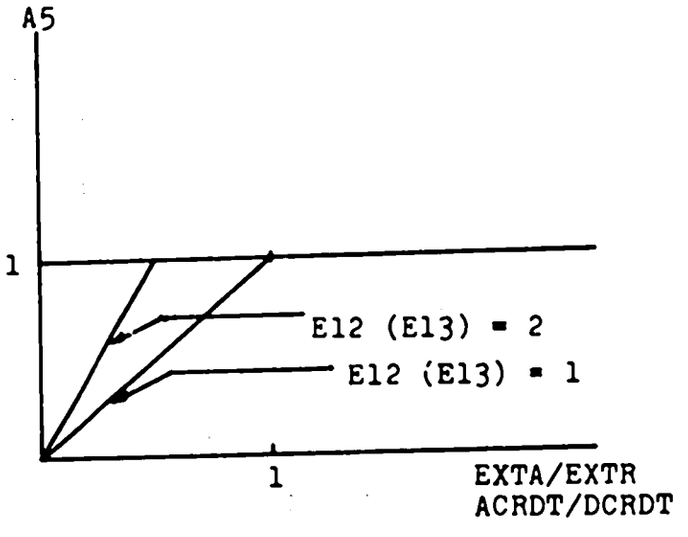


FIGURE II.2. The land "dropout" function.

A final economic decision to be made is whether some modern grazing land should be reverted to traditional practices if the profitability of modern methods drops significantly due to declining output prices, increasing input prices, etc. Figure II.3 shows how the model (Equation 5.47) handles this decision. It is clear that no reversion will occur unless the profitability cirteria relating modern returns to traditional returns (PDR) drop below some threshold value, in which case, the reversion to traditional practices will occur at an increasing rate, up to a maximum, as the profitability continues to fall. The adoption response function and the reversion response function, which are not symmetrical, attempt

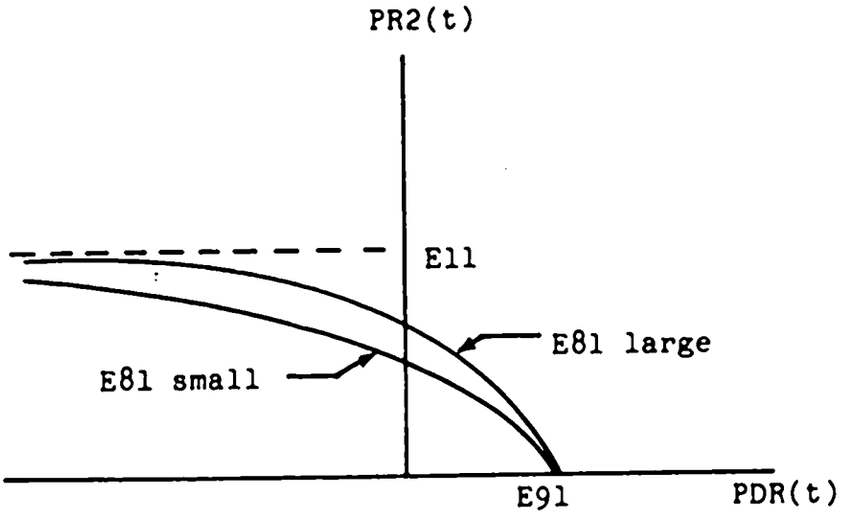


FIGURE II.3. The reversion response function.

to capture by proxy the farmers' investment and disinvestment decisions.

$$PR2(t) = \max(E11*(1-EXP(-E81*(E91-PDR(t)))), 0) \qquad (5.47)$$

where:

PR2 = proportion of total land in modern production which reverse to traditional practice

PDR = the profitability criteria of Equation 5.30

E11 = maximum proportion that will be reverted (proportion/year)

E81 = a parameter regulating the reversion rate (dimensionless)

E91 = reversion threshold (Ps/ha).

The rate by which modern land reverts to traditional uses is simply the product TLMOD(t)*PR2(t).

where:

TLMOD = the total land in modern production (has).

Given this reversion rate and the rates land is being modernized by production campaigns and diffusion, it is possible to compute the total modern land, TLMOD, assumed to produce at modern productivities. This is done in the model separately for agricultural region 2 (lowland) and for subregions 1 and 2 of agricultural region 3 (uplands). Equation 5.48 first allocates grazing land entering modernization among the three regions in the same proportion grazing land in each region is of total flood-free grazing land, then subtracts the modern land reverting to traditional practices, and finally allocates any change in total grazing land over time between traditional and modern practices.

$$TLMOD_i(t+DT) = \max\{\min[TLMOD_i(t) + DT*(RLM(t)*\frac{GLTOT_i(t)}{TGL(t)} - TLMOD_i(t)*PR2(t) + \frac{ENT*TLMOD_i(t)*RTGL_i(t)}{GLTOT_i(t)}, GLTOT_i(t)], 0\} \quad (5.48)$$

where:

RLM = as defined in Equation 5.43d

GLTOT = total grazing land in the given agricultural region (has)

RTGL = rate of change of total grazing land in the given agricultural region (has/year)[1/]

ENT = a model parameter (E6, E10, E14) that determines the percentage of land entering or leaving pasture production that enters or leaves modern production

TGL = total (flood-free) grazing land (has)

i = indexes the agricultural regions, i=1, ..., 3.

The inclusion in Equation 5.48 of the term involving RTGL requires further discussion. Since, over time, the land allocated by decision makers to cattle production will change, there is a question about how these changes should be allocated to traditional and modern production. The model formulation permits the user to make a number of assumptions about this through adjustment of the parameter ENT. For example if ENT = 0, the model allocates all increases and decreases in total land to traditional production. If ENT = 1, the model allocates changes in land area to traditional and modern

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[1/] For detailed computation of rate of change in lowlands, subregion 1 and subregion 2 (RTGLL, RTGLU1 and RTGLU2, respectively) see subroutine LANDAL in the Appendix.

production proportionately according to the percentage each is of total land. Further, if:

ENT = 1 when RTGL $\geq$ 0 and

ENT = 0 when RTGL < 0,

the model allocates net increases in total land proportionately to modern and traditional production and subtracts all decreases from traditional production, etc.

Total flood-free land in modern (TLMODR) and traditional (TTGL) production in the Costa is computed as:

$$TLMODR(t) = \sum_{i=1}^{3} TLMOD_i(t) \qquad (5.49)$$

$$TTGL(t) = TGL(t) - TLMOD(t) - TRSL(t) \qquad (5.50)$$

where:

TTGL = total flood-free grazing land in traditional production in the Costa (has).

Finally, Equation 5.51 computes flood-free and seasonally flooded grazing land in traditional production (TTGLR) in the Costa.

$$TTGLR(t) = TTGL(t) + TGLSF(t)*C9 \qquad (5.51)$$

where:

TGLSF = total pasture land in the seasonally flooded region--Equation 5.14 (has)

C9 = a model parameter adjusting seasonally flooded grasslands to permanent grazing land.

Cattle Transfers

As pasture land is modernized and forage production increased, cattle are moved to graze in these lands under improved husbandry practices. The rate that animals are added to the modern grazing lands is a function of the rate of increase of their nutrition levels and the relative difference between the achieved nutrition and the desired one. This is computed by Equation 5.52.

$$RAA(t) = \frac{RTDN(t) + C12*TOPOPM(t)*(TDNAM(t) - TDNREQ)}{TDNREQ} \quad (5.52)$$

where:

RAA = rate animals are added to the modern sector (animals/year)

RTDN = rate of increase of TDN in the modern sector (tons/year-year)[1/]

TDNAM = TDN per animal in the modern sector (tons/animal-year)[1/]

TDNREQ = desired TDN per animal in the modern sector (tons/animal-year)

TOPOPM = total animal population in the modern sector (animals)[1/]

C12 = a model parameter that determines the influence which the difference between the achieved nutrition level and the desired nutrition level in the modern sector has on the rate animals are added to the modern sector (proportion/year).

The rate at which males and females, summing to RAA, are added to the modern population is given by Equations 5.53. It is assumed that the sex ratio of transferring animals is

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[1/] For detailed computation of these variables see subroutine DEMOG in the Appendix.

the same as that of the traditional population (this could also be a policy variable). It is also assumed that only fertile females are transferred from the producing cohort.

$$RFGTT(t) = \frac{RAA(t)*PFGT(t)}{TOPOPT1(t)} \quad (5.53a)$$

$$RFPTT(t) = \frac{RAA(t)*FERT(t)}{TOPOPT1(t)} \quad (5.53b)$$

$$RMGTT(t) = \frac{RAA(t)*PMGT(t)}{TOPOPT1(t)} \quad (5.53c)$$

$$RMPTT(t) = \frac{RAA(t)*PMPT(t)}{TOPOPT1(t)} \quad (5.53d)$$

where:

RFGTT = rate growing females are transferred out of the traditional sector (animals/year)

RFPTT = rate producing females are transferred out of the traditional sector (animals/year)

RMGTT = rate growing males are transferred out of the traditional sector (animals/year)

RMPTT = rate producing males are transferred out of the traditional sector (animals/year)

FERT = total traditional fertile producing females --Equation 6.18 (animals)

TOPOPT1 = total cattle population in the traditional sector net of females unsuitable for reproduction--Equation 5.54 (animals).

The rates animals leave the modern sector are the negatives of RFGTT, RFPTT, RMGTT and RMPTT (negative departures are arrivals):

$$RFGTM(t) = -RFGTT(t) \quad (5.53e)$$

$$RFPTM(t) = -RFPTT(t) \quad (5.53f)$$

$$RMGTM(t) = -RMGTT(t) \quad (5.53g)$$

$$RMPTM(t) = -RMPTT(t) \qquad (5.53h)$$

The traditional cattle population base for these transfers (TOPOPT1), computed in Equation 5.54 below, excludes all females which are unfit for reproduction, i.e., old cows, infertile cows, and cows with severe cases of mastitis.

$$TOPOPT1(t) = TOPOPT(t) - OLDFT(t) - FINFT(t) - FMAST(t) \qquad (5.54)$$

where:

TOPOPT = total cattle population in the traditional sector (animals)

OLDFT = traditional population of old females--Equation 6.12 (animals)

FINFT = traditional producing females which are infertile--Equation 6.17a (animals)

FMAST = traditional producing females with mastitis --Equation 6.17b (animals).

The preceding equations define the most relevant variables and structural relationships of the land allocation and modernization component. The interested reader can find the complete list of equations performing the land allocation and modernization decisions described here in subroutines LANDAL, MODCRD and MODRAT of the computer program shown in the Appendix. The output of component LAMDAC is used as an input to the component AGPRAC described in the next chapter.

Table II.1 at the end of this chapter shows the values of a selected number of variables used in component LAMDAC.

TABLE II.1. Selected Coefficients and Initial Values in the Land Allocation and Modernization Decisions Component (LAMDAC).

Definition (Equation No.)		Value
DT (5.1a)	Determines the time increment of the model (years)	.25
AL2 (5.4)	Determines the rate of growth in food crops land (proportion/year)	.03
CFD1 (5.8)	Determines the allocation of food crop land to subregion 1 (proportion)	.5
CL1 (5.21)	Determines the speed of land adjustment in subregion 1 (proportion/year)	.03
CL2 (5.23a)	Determines the allocation of food crop land between cash crop and grasslands (proportion)	.5
C9 (5.29)	Determines permanent grazing land equivalent (proportion/year)	.55
C12 (5.52)	Determines the speed of animals transfer (proportion/year)	1
C249 (5.6)	Determines the allocation of food crop land to region 3 (proportion)	.8
C257 (5.45)	Determines extension workers requirements (man-years/ha)	.0005
E7 (5.36)	Determines maximum adoption rate (proportion)	1
E11 (5.47)	Determines maximum proportion of reversion to traditional practices (proportion/year)	.5
E12 (5.44)	Determines the extension "drop-outs" response threshold (dimensionless)	1.2
E13 (5.44)	Determines the credit "dropouts" response threshold (dimension-less)	1
E31 (5.38)	Determines maximum value of E3 when accumulated time is large (han/year per unit of extension)	4,000

TABLE II.1. (continued)

Definition (Equation No.)		Value
E32 (5.38)	Determines minimum value of E3 at time zero (has/year per unit of extension)	2,000
E33 (5.38)	Determines the rate at which E32 decreases over time (dimensionless)	.3
RLCRL (5.11)	Determines the rate of growth in cash crop land in region 2 (has/year)	4,500
RLDRN (5.3)	Determines the rate flooded land is drained (has/year)	13,500
RPTN (5.42b)	Determines farmers' participation of total establishment costs (proportion)	.2
EXTA (5.44)	Determines extension workers available (man-years)	250
TDNREQ (5.52)	Determines TDN desired for modern animals (tons/animal-year)	1.85
PRM (5.35a)	Determines the price of milk (Ps/liter)	1
XDEL (5.43a)	Determines one-third of the time to complete modernization (years)	1
TLAVL0 (5.1a)	Initial flood-free agricultural land potentially available in region 2 (thous. has)	533.3
TLAVL(0) (5.1a)	Initial flood-free agricultural land actually available in region 2 (thous. has)	431.0
TLAVU01 (5.1b)	Initial agricultural land potentially available in subregion 1 (thous. has)	2,169.06
TLAVU1(0) (5.1b)	Initial agricultural land actually available in subregion 1 (thous. has)	1,720.73
TLAVU02 (5.1c)	Initial agricultural land potentially available in subregion 2 (thous. has)	1,676.0

TABLE II.1. (continued)

Definition (Equation No.)		Value
TLAVU2(0) (5.1c)	Initial agricultural land actually available in subregion 2 (thous. has)	1,293.02
TGLSF0 (5.1d)	Initial potential grazing land in region 1 (thous. has)	3,137.95
TLDRNL0 (5.2)	Initial land capable of drainage (thous. has)	3,137.95
TLFCU1(0) (5.20)	Initial land in food crops in subregion 1 (has)	40,915

Source: [13, 15, 36, 37, 38, 42, 53, 58, 59] and initial guesstimates and model tuning.

CHAPTER 6

AGRICULTURAL PRODUCTION--CROPS/CATTLE (AGPRAC)

Component AGPRAC generates the production of crops, pastures and cattle, and determines the yields of farm crops and the sales of cattle.

Crop Yields

Crop yields are a composite of the major crops grown in the Costa and are assumed to remain constant throughout the simulation. Increases in crop yields over time are allowed in the model as part of the modernization policies that will be discussed in Chapters 8 and 12.

Cash crop yields are computed for each agricultural region according to the crop mix assumed in Chapter 5. Further, it is assumed that yields in the more fertile lowlands (YLDCL) are 10 percent higher than in the uplands (YLDCU). With these assumptions and using the average yields derived from the Caja Agraria crop reports [7], it is possible to compute the average yield of individual commodities for each agricultural region. Then, using the same crops allocating weights of component LAMDAC, it is possible to compute a composite yield for each agricultural region. Table II.2 shows the computed average yield of each commodity, and Table III.3 on page 232 shows the composite yields used in

computing crop production and income below (Equation 6.20a). The computation of food crop yields (YLDFC) is simply a composite of the average yields of plantain and cassava as reported by the Caja Agraria for the period 1965-1969 [7].[1/]

The five-year average yield of cash crops in the uplands used in the land allocation decisions of component LAMDAC is computed as:

$$EYLDCU(t) = EYLDCU(t-DT) + \frac{DT}{DEL8}*(YLDCU(t-DT) - EYLDCU(t-DT)) \quad (6.1)$$

where:

EYLDCU = exponential average of cash crop yields in the uplands, used in Equation 5.35e in LAMDAC (tons/ha-year)

YLDCU = average yield of cash crops grown in the uplands (tons/ha-year)

DEL8 = average lag (years).

The increase in crop yields as a result of crop modernization efforts is computed in Equations 6.2. Here, it is assumed that crops reach their maximum target yield gradually, over a period of several years (DEL9 and DEL10). This length of time can be interpreted as being responsive to the crop modernization campaigns and could be a policy

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[1/] Average regional yields (tons/ha-year) of each commodity are: sesame--.66; cotton--1.4; corn--1.11; sorghum --1.8; rice--1.9; plantain--8.38; and cassava--8.28.

TABLE II.2. Average Annual Yield and Initial Costs by Farming Sectors.

Crop	Yield (Tons/ha-yr)		Cost* (Ps/ha-yr)	
	Uplands	Lowlands	Uplands	Lowlands
Sesame	.63	.693	400	408
Cotton	1.34	1.47	1,639	1,672
Corn	1.08	1.19	313	319
Sorghum	1.73	1.9	564	575
Rice	--	1.9	--	1,270
Plantain	8.38		600	
Cassava	8.28		787	

*Costs are reported for 1970 and adjusted to 1960 prices.

Source: [7, 57, 69]

variable. Target or desired yields have been derived from targets set by the Ministry of Agriculture for Colombian major crops [58][1/] and then weighted by the crop allocating weights of component LAMDAC to obtain a composite average for each agricultural region.

$$YLDCU(t+DT) = YLDCU(t) + \frac{DT}{DEL9}*(DYLDCU - YLDCU(t)) \qquad (6.2a)$$

$$YLDCL(t+DT) = YLDCL(t) + \frac{DT}{DEL9}*(DYLDCL - YLDCL(t)) \qquad (6.2b)$$

$$YLDFC(t+DT) = YLDFC(t) + \frac{DT}{DEL10}*(DYLDFC - YLDFC(t)) \qquad (6.2c)$$

where:

YLDCU = the projected yield of cash crops in the uplands (tons/ha-year)

YLDCL = the projected yield of cash crops in the lowlands (tons/ha-year)

YLDFC = the projected yield of food crops (tons/ha-year)

DYLDCU = the target yield of cash crops in the uplands (tons/ha-year)

DYLDCL = the target yield of cash crops in the lowlands (tons/ha-year)

DYLDFC = the target yield of food crops (tons/ha-year)

DEL9, DEL10
= average lag (years).

Pasture Production

Before generating the production of cattle, component AGPRAC determines the output of fodder as total digestible

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[1/] Target yields (tons/ha-year) for the major crops grown in the Costa are: sesame--.75; cotton--1.8; corn--1.6; sorghum--3.8; rice--4.1; plantain--10; cassava--10.

nutrients (TDN) from traditional and modern grasslands. First, the component computes (Equations 6.3) the regional average TDN yields of artificial and native grasses under both traditional and modern practices. Production of artificial and native grasses is estimated as an average of dry and rainy season yields based on the permanent carrying capacity of these pastures. Traditional artificial pastures in the uplands under continuous grazing and without fertilizer, yield 5.5 tons of dry forage per hectare annually or approximately 3.48 tons of TDN (1 kilogram of dry forage produces .633 kilograms of TDN [33].) This is enough feed to support 1.9 head of cattle throughout a year on the basis of an average nutritional requirement of 1.82 tons TDN/head-year. Further, it is assumed that artificial grasses in the more productive lowlands (mostly para grass) yield about 10 percent higher than upland pastures (mostly guinea and puntero grasses). It is also assumed that native grasses yield two-thirds less than artificial grasses [61, 66]. Improved pastures are estimated to have a carrying capacity 40 percent higher than pastures under traditional management. The average yields used in these computations are shown in Table III.3 on page 232.

$$CGO(t) = \frac{(CGOU*(TTGLU1(t) + TTGLU2(t)) + CGOL*TTGLL(t))}{TTGL(t)} \qquad (6.3a)$$

$$CGO1(t) = \frac{(CGOU1*(TTGLU1(t) + TTGLU2(t)) + CGOL1*TTGLL(t))}{TTGL(t)} \qquad (6.3b)$$

$$CG1(t) = \frac{(CGU1*(TLMOD2(t) + TLMOD3(t)) + CGL1*TLMOD1(t))}{TLMOD(t)} \quad (6.3c)$$

$$CG2(t) = \frac{(CGU2*(TLMOD2(t) + TLMOD3(t)) + CGL2*TLMOD1(t))}{TLMOD(t)} \quad (6.3d)$$

where:

CGO = average TDN yield from traditional artificial grasses in the Costa (tons/ha-year)

CGO1 = average TDN yield from traditional native grasses in the Costa (tons/ha-year)

CG1 = average TDN yield from improved artificial grasses in the Costa (tons/ha-year)

CG2 = average TDN yield from improved native grasses in the Costa (tons/ha-year)

CGOU = average TDN yield from traditional artificial grasses in the uplands (tons/ha-year)

CGOU1 = average TDN yield from traditional native grasses in the uplands (tons/ha-year)

CGU1 = average TDN yield from improved artificial grasses in the uplands (tons/ha-year)

CGU2 = average TDN yield from improved native grasses in the upland (tons/ha-year)

CGOL = average TDN yield from traditional artificial grasses in the lowlands (tons/ha-year)

CGOL1 = average TDN yield from traditional native grasses in the lowlands (tons/ha-year)

CGL1 = average TDN yield from improved artificial grasses in the lowlands (tons/ha-year)

CGL2 = average TDN yield from improved native grasses in the low lands (tons/ha-year)

TTGLL, TTGLU1, TTGLU2
= total land in traditional grazing in region 2, subregion 1 and subregion 2, respectively (has)

TTGL = total Costa flood-free land in traditional pasture production--Equation 5.50 (has)

TLMOD1, TLMOD2, TLMOD3
= total land in modern grazing in region 2, subregion 1 and subregion 2, respectively--Equation 5.48 (has).

Total digestible nutrients available to the traditional sector come from pasture in the flood-free and in the seasonally flooded lands. Crop residues, particularly of cotton, are added to the nutrient supply. Since there are indications of overgrazing in the region, the deteriorating effect of this practice is introduced into the model by Equations 6.4.

$$GRT(t) = \frac{TTGLR(t)}{TOPOPT(t)} \qquad (6.4a)$$

where:

GRT = grazing rate in the traditional sector (has/animal)

TTGLR = total traditional grazing land in the Costa--Equation 5.51 (has)

TOPOPT = total traditional cattle population (animals)[1/]

$$RCON(t+DT) = \max(RCON(t) + DT*C5*(GRT(t) - GRE), .1) \qquad (6.4b)$$

where:

RCON = range condition (a dimensionless number)

GRE = equilibrium grazing rate (which results in constant range condition) (has/animal)

C5 = a parameter that determines the extent of influence of grazing rate upon range condition

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[1/] For a detailed computation of this variable see subroutine DEMOG in the Appendix.

max(a,b) = the maximum of a and b.

Range condition is prevented from diminishing below an unrealistic limit by establishing a lower bound for RCON.

The above equations stipulate that range condition increases or decreases over time if GRT is respectively greater or less than GRE. Given range condition, it is now possible to compute the total TDN available from the flood-free traditional grazing land.

$$TDNTG(t) = RCON(t)*(CGO(t)*CPLPT*TTGL(t) + CGO1(t) *(1 - CPLPT)*TTGL(t)) \quad (6.5)$$

where:

TDNTG = total traditional TDN from flood-free grasslands (tons/year)

CPLPT = proportion of artificial grasses in traditional grazing land

CGO = as defined in Equation 6.3a

CGO1 = as defined in Equation 6.3b

TTGL = as defined in Equation 6.3a.

Total TDN available from crop residues and seasonally flooded lands is computed as:

$$TDNRE(t) = C7*C220*(TLCRU(t) + TLCRL(t)) \quad (6.6)$$

$$TDNSF(t) = TGLSF(t)*C9*C10 \quad (6.7)$$

where:

TDNRE = TDN available to traditional animals from crop residues (tons/year)

TLCRU = land in cash crops in the uplands--Equation 5.24 (has)

TLCRL = land is cash crops in flood-free lowland--Equation 5.11 (has)

TDNSF = TDN available to traditional animals from seasonally flooded land (tons/year)

TGLSF = total pasture land from seasonally flooded areas--Equation 5.14 (has)

C7 = TDN yield of crop residues (tons/ha-year)

C220 = a model parameter determining the proportion of cash crops producing residues used to feed traditional animals

C9 = proportion of time that flooded land is available for grazing

C10 = TDN yield of grasses from seasonally flooded lands (tons/ha-year).

Finally, the total TDN available annually to the traditional sector, TDNT, is simply computed as:

$$TDNT(t) = TDNTG(t) + TDNRE(t) + TDNSF(t) \qquad (6.8)$$

Total TDN available to the modern sector depends on the alternative adopted. Land in transition from traditional to modern practices (TRSL) is considered part of the modern sector, but as producing forage at a rate intermediate between traditional and improved pastures. Briefly, alternatives 1 and 3 consider the improvement of both native and artificial grasses, as well as the production of forage crops in the latter to supplement nutrition during the dry season. Alternatives 2 and 4 consider the improvement of artificial pastures and the substitution of improved artificial grasses for traditional native grasses. In addition, alternative 4 includes the production of forage crops to supplement nutrition from grasses. The component computes the average yield

from improved and transition grasses as well as the average yield from forage crops in the form of silage. Given the average yields and the land in pasture and forages, it is possible to compute the total TDN available to the modern sector from each alternative. Forages are planted to the extent needed to make up for the deficit in nutrition as shown by the difference between the TDN obtained from grasses and a target level of TDN (TDND in Equation 6.9f). Although TDND could be a policy parameter, the model assumes this target is set at the nutrition level required to support four head per hectare, the current average carrying capacity in the Costa during the rainy season. Equation 6.9g, which computes area in forages, implies that land is taken out of modern production and transition in the same proportion. Mathematically, these computations are carried out in Equation 6.9.

$$CGA(t) = CG1(t)*CPLPT + CG2(t)*(1 - CPLPT) \qquad (6.9a)$$

$$CTR(t) = CG3*CPLPT + CG4*(1 - CPLPT) \qquad (6.9b)$$

$$TDNF = \frac{C253*C254*TDNSG}{C250} \qquad (6.9c)$$

Further, CGA(t) = CG1, and

CTR(t) = CG3 for alternatives 2 and 4.

where:

CGA = TDN yield from improved grasses (tons/ha-year)

CTR = TDN yield from grasses in transition (tons/ha-vear)

CG3 = TDN yield from transition artificial grasses (see Table III.3) (tons/ha-year)

CG4 = TDN yield from transition native grasses (see Table III.3) (tons/ha-year)

TDNF = TDN yield from forages (tons/ha-year)

TDNSG = TDN yield from silage (tons/ton of silage)

C250 = a model parameter to account for weight losses when green forage is converted into silage

C253 = yield of green forage (tons/ha-cutting)

C254 = the number of times forages are harvested during the growing season (cuttings/year).

In computing Equation 6.9c it has been assumed that forages are grown without irrigation and the growing season is thus restricted to the rainy period.

$$TMPL_i(t) = TLMOD_i(t) + TRSL_i(t) - TLF_i(t) \qquad (6.9h)$$

where:

TMPL = total land in pasture (has)

i = indexes the alternatives--i=3,4.

Finally, TDN available to the modern sector from alternatives 3 and 4 is computed as:

$$TDNM_i(t) = TDNF*TLF_i(t) + TDNG_i(t)*TMPL_i(t),\ i=3,4 \qquad (6.9i)$$

where:

TDNM = TDN output from modern land (tons/year).

Cattle Production

Demography

Cattle inventories and output are modeled dynamically as populations distributed over time and stage of production. The demographic model of the cattle population is divided into three age cohorts for females and two age cohorts for males (Figure II.4). The respective cohort lengths reflect the three production stages the model identifies: a growing stage, a producing stage, and a stage in which animals without reproductive capabilities remain. The aging of animals through the first two cohorts is modeled by distributed lags.[1/] When females finally enter the old age cohort, their aging rate is no longer modeled, and cows remain there affected by deaths and sales through herd management policies. Based on the census data available [15] the model assumes that all animals two years old and less are included in the growing cohort; the producing cohort includes those animals over two years.

The preceding production process is simulated by four calls to DELAY subroutine [52, 54], one for each sex cohort. Since the structure of the subroutine is alike for each cohort and differences in output arise only from differences in inputs, only the production of growing females

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[1/] The distributed lag model used here has been adapted following Abkin [1, Chapter 3].

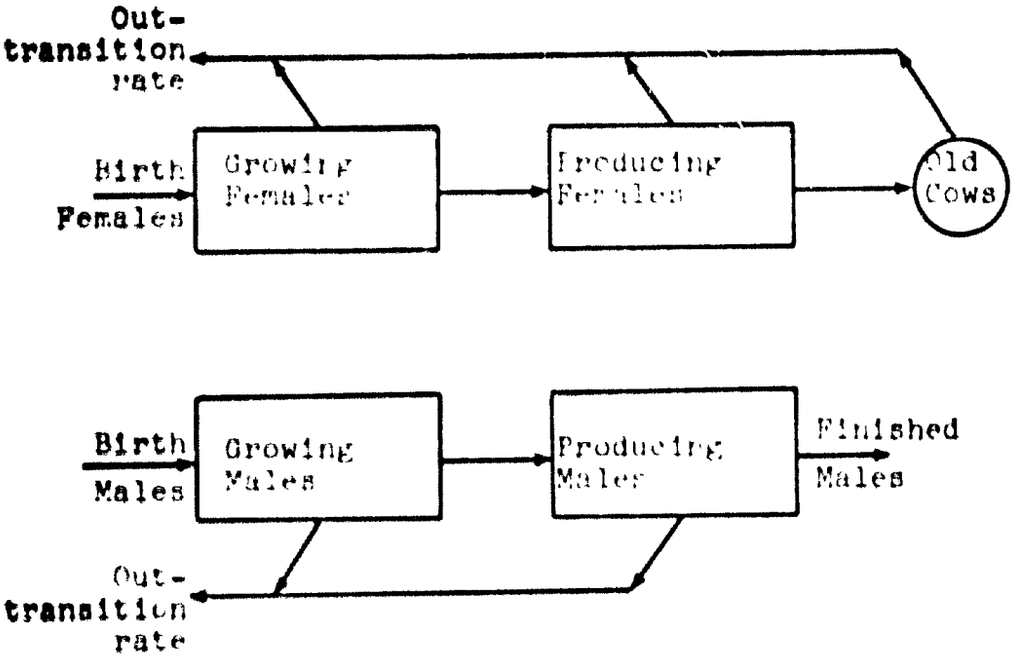

FIGURE II.4. Cattle production cohorts.

will be discussed in detail here. The growing males cohort uses the male birth rate as an input, and the producing cohorts use as an input the output of the growing cohorts. Equations 6.10 define traditional or modern populations depending upon whether DLLDT is supplied with traditional or modern data.

```
CALL DELDT(BF(t-DT), RFOU1(t), RINTF1(t), DOROF, IDTF1,
     DT, KOROF)                                          (6.10a)
```

where:

BF = rate females enter the first cohort, i.e., the female birth rate--Equation 6.19b (animals/year)

RFOU1 = rate growing females leave cohort 1 and enter the producing stage (animals/year).

DGROF = average length of time females remain in Cohort 1 (years)

KGROF = a parameter that determines the probability distribution for the length of time individual females remain in Cohort 1

RINTF1, IDTF1
= other variables associated with the use of the DELDT subroutine

DT = time increment of the model (years).

The purpose of this call to subroutine DELDT is to compute RFOU1(t), the rate females leave Cohort 1. This rate minus any losses (due to deaths, sales and transfers) becomes the input to Cohort 2, the producing stage, RFOUP1(t):

$$RFOUP1(t) = RFOU1(t) - RFOU1(t)*(DRL1(t) + PSFG(t) + PPFGT(t))*DT \quad (6.10b)$$

where:

DRL1 = death rate of the growing population--Equation 6.16 (proportion/year)

PSFG = proportion of growing females sold (proportion/year)[1/]

PPFGT = proportion of growing females transferred out of a given sector (modern or traditional) (proportion/year)[1/]

The output of the male producing cohort, RMOU2, is the number of finished males available annually for immediate consumption, and the output of the female producing cohort, RFOU2, is the rate at which females leave the producing stage

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[1/] For detailed computation of these variables see subroutine DEMOG in the Appendix.

as a result of old age. Given the basic model of the cattle demographic process, it is possible to compute the population in each cohort, total population and other variables of importance in the model.

The number of animals in the female and male cohorts are computed as time integrals of population flow rates. As stated earlier, old females are not transferred but stored for sales decisions based on herd management policies. Since the structural equations are alike for Cohorts 1 and 2, the computation of the number of growing females will be shown in Equation 6.11 below. Yet it must be remembered that each equation uses the variables relevant to each cohort, and that the producing cohorts use as an input the output of the growing cohorts. Equation 6.12 computes the population of old females. Total cattle populations in the traditional and modern sectors and in the region are computed simply by adding the populations from each cohort.

$$PFG(t+DT) = PFG(t) + DT*(BF(t) - DRL1(t)*PFG(t) - SLSFG(t) - RFGT(t) - RFOUP1(t)) \quad (6.11)$$

where:

PFG = population of growing females (animals)

SLSFG = sales of growing females--Equations 6.22 (animals/year)

RFGT = rate growing females are transferred--Equations 5.53 (animals/year)

RFOUP1 = rate females leave the growing stage and enter the producing stage--Equation 6.10b (animals/year).

$$OLDF(t+DT) = OLDF(t) + DT*(RFOUP2(t) - SOLDF(t) - DRL2(t)*OLDF(t)) \quad (6.12)$$

where:

OLDF = population of old females (females which have concluded the reproductive life) (animals)

SOLDF = sales of old females--Equation 6.22e (animals/year)

RFOUP2 = rate females leave the producing stage and enter old age--Equation 6.10b where transfers = 0 (animals/year)

DRL2 = death rate of the producing population--Equation 6.16 (proportion/year).

Once cattle demography has been simulated, the model computes the variables affecting the transition rates of this population. Live birth rates and death rates are computed as a function of the level of nutrition (TDNA). Death rates are computed separately for the growing and producing populations as shown in Equations 6.13. The table look-up functions [52, 54] used in these equations compute traditional or modern birth and death rates depending upon whether the VAL arrays are supplied with traditional or modern data. Figures II.5 graphically depict these functions.

$$BR(t) = TABLIE(VALB, SMALLB, DIFFB, KB, TDNA) \quad (6.13a)$$

$$DRG(t) = TABLIE(VALDG, SMALLDG, DIFFDG, KDG, TDNA) \quad (6.13b)$$

$$DRP(t) = TABLIE(VALDP, SMALLDP, DIFFDP, KDP, TDNA) \quad (6.13c)$$

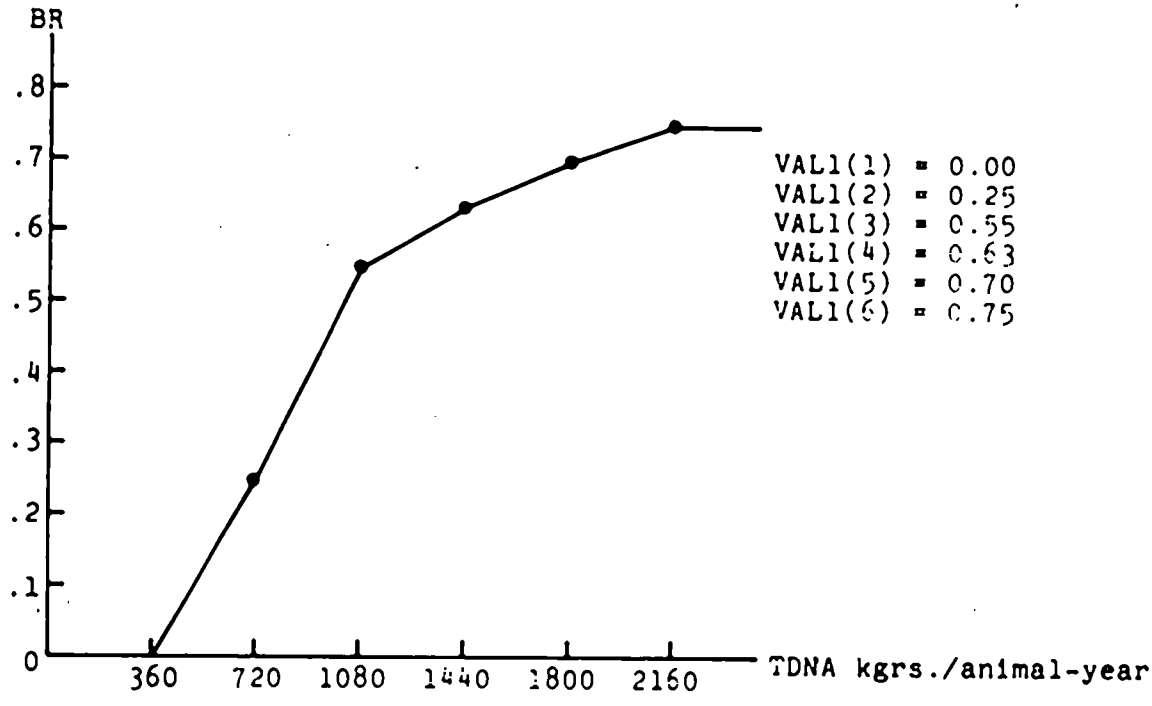

FIGURE II.5.a. Traditional birth rate versus total digestible nutrients.

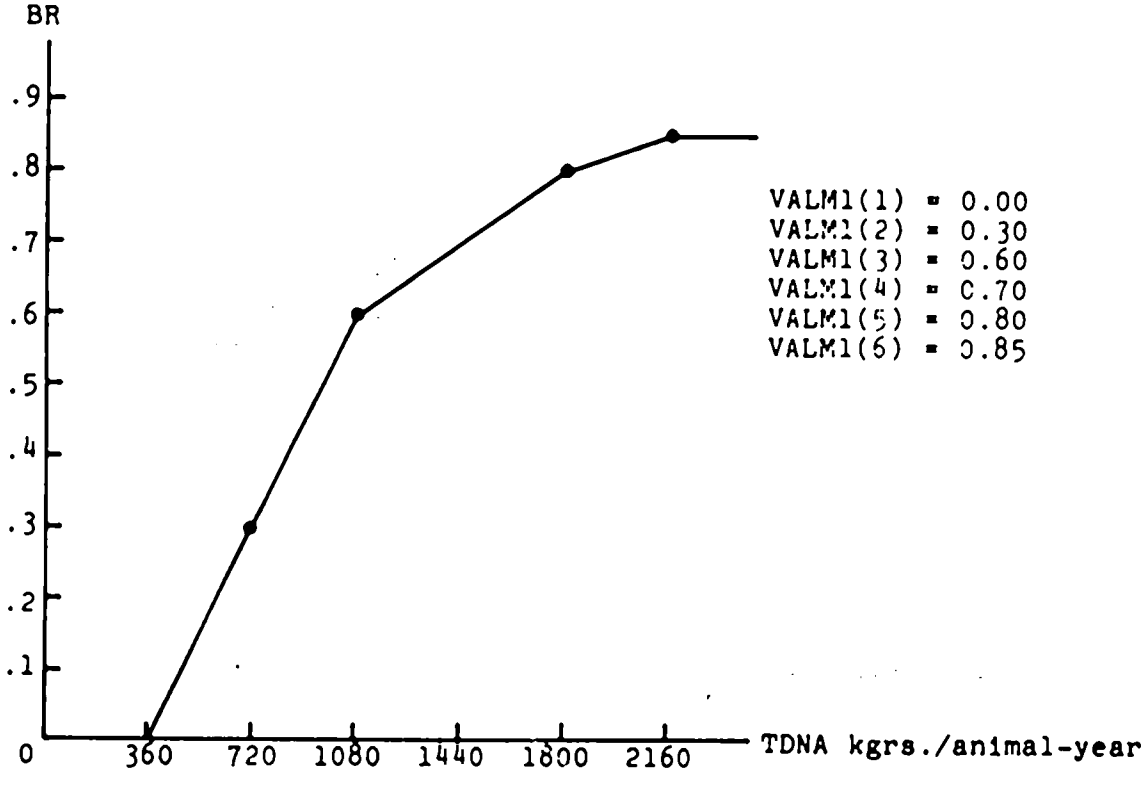

FIGURE II.5.b. Modern birth rate versus total digestible nutrients.

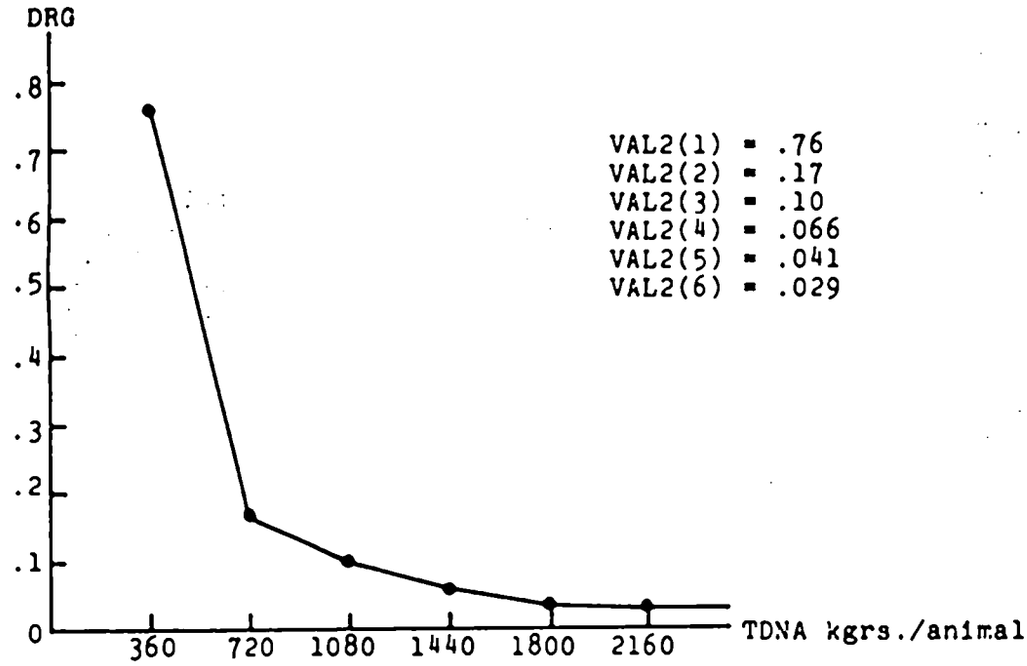

FIGURE II.5.c. Traditional death rate of growing cohort versus total digestible nutrients.

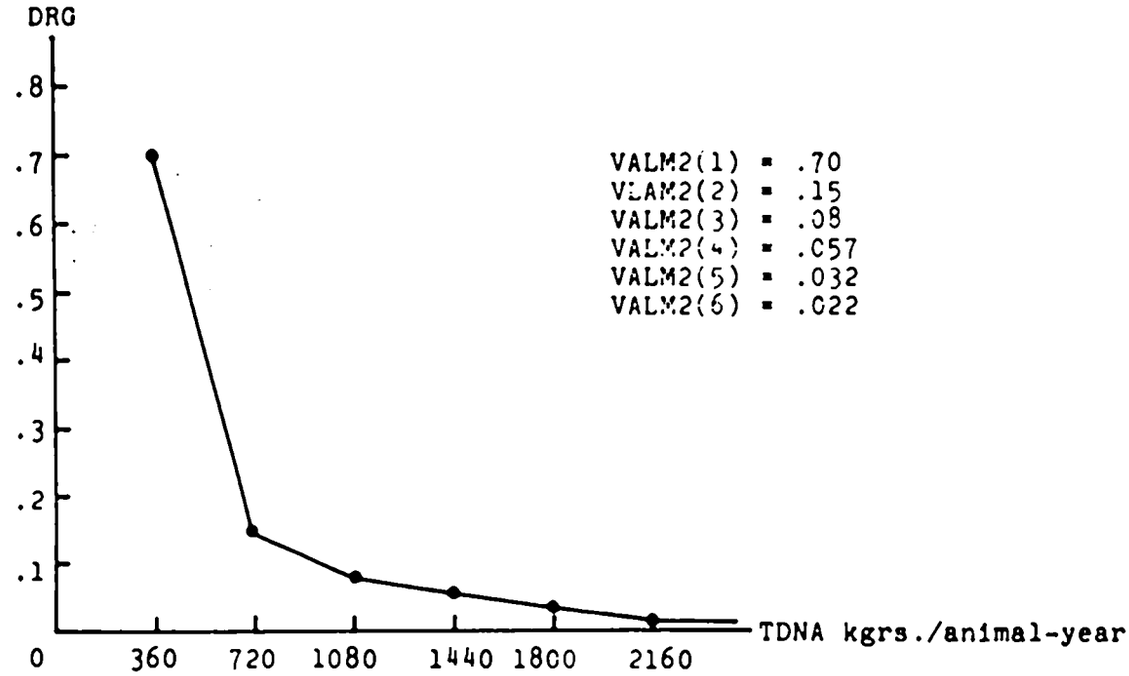

FIGURE II.5.d. Modern death rate of growing cohort versus total digestible nutrients.

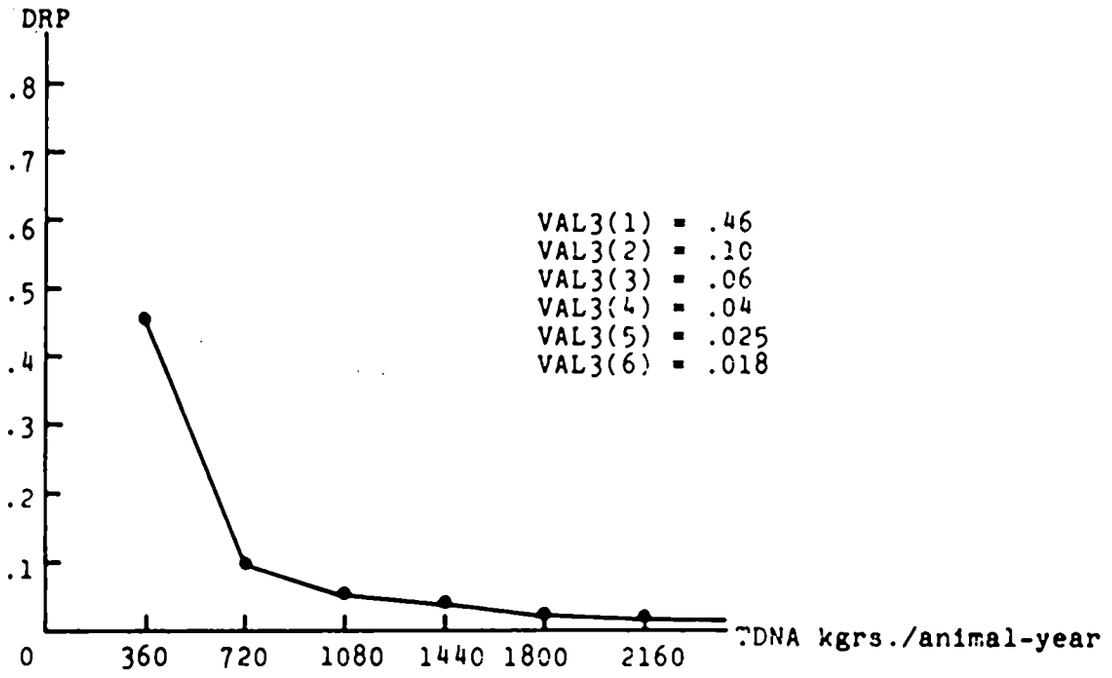

FIGURE II.5.e. Traditional death rate of producing cohort versus total digestible nutrients.

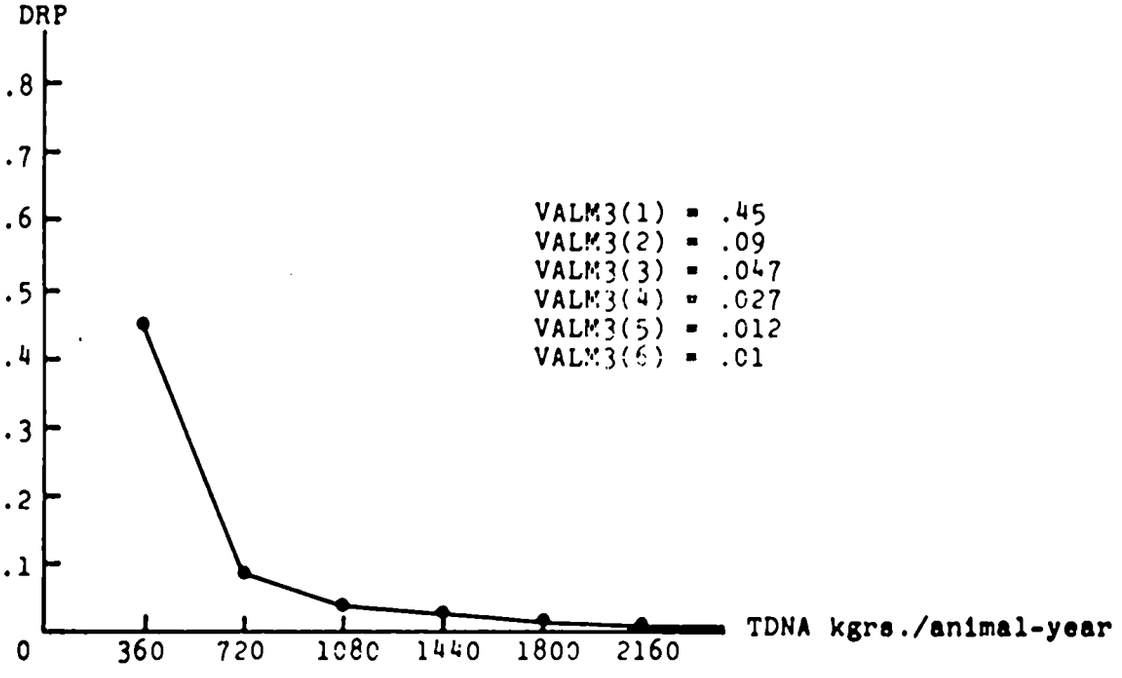

FIGURE II.5.f. Modern death rate of producing cohort versus total digestible nutrients.

where:

BR = live birth rate--proportion of producing females calving per year. In the model is also taken as a pregnancy rate

DRG = death rate--proportion of growing population dying per year

DRP = death rate--proportion of producing population dying per year

TABLIE = a simulation subprogram which approximates arbitrary functional relationships by straight line segments

VAL = an array of numbers which defines the dependent argument of the function

SMALL = smallest value of TDNA in the data which defines the function

DIFF = the fixed differences between values of TDNA

K = the number of line segments used to approximate the birth or death rate functions

TDNA = total digestible nutrients (tons/animal-year) --the independent argument of the function.[1/]

In reality, births and deaths do not change instantaneously with changes in nutritional levels and/or population sizes, but rather lag behind changes in these variables. The variables BR, DRG and DRP must therefore be operated on to introduce these lag effects. Equation 6.14 shows this computation for birth rates:

$$BR2(t) = BR2(t-DT) + \frac{DT}{DEL1}*(BR(t-DT) - BR2(t-DT)) \qquad (6.14)$$

[1/]For a detailed computation of this variable see subroutine DEMOG in the Appendix.

where:

BR2 = actual live birth rate (proportion/year)

DEL1 = lag parameter (years).

The actual death rate of the growing population, DR1, and the actual death rate of the producing population, DR2, are computed using similar equations to the one above.

Nutrition and management are not the only factors affecting birth and death rates. Diseases have a major role in determining the value of these variables, and we are particularly concerned here with brucellosis and foot-and-mouth disease (FMD) which are epidemic in the region. The effect of brucellosis on birth rates is introduced into the model by the variable CBANG which depends on the proportion of cows treated. This is shown in Equation 6.15 where the variable BR2 is taken as a pregnancy rate.

$$BRL2(t) = BR2(t)*(1 - CBANG(t)) \qquad (6.15)$$

where:

BRL2 = the effective live birth rate (proportion/year)

CBANG = proportion of pregnant cows aborting due to brucellosis, where $0 \leq CBANG \leq .04$.[1/]

The effect of FMD on death rates is introduced into the model by the variable DRA which depends on the proportion of animals treated annually. This effect is shown in Equation 6.16 for the growing cohort.

[1/] For a detailed computation of this variable see subroutine DEMOG in the Appendix.

$$DRL1(t) = DR1(t)*DRA(t) \qquad (6.16)$$

where:

DRL1 = the effective death rate of growing animals (proportion/year)

DR1 = the actual death rate of growing animals--Equation 6.14 (proportion/year)

DRA = proportional increase in death rates due to FMD, where $1 \leq DRA \leq 1.33$.

Before computing total births it is necessary to determine the number of cows capable of calving found in the population of producing females. This is done in the model with Equations 6.17 by computing the number of infertile cows and those affected by severe cases of mastitis, caused by FMD, that have to be discarded from the breeding herd. Equations 6.17 are the time integrals of female population flow rates where affected animals come out from each of the transition rates in the same proportion. Equation 6.17a incorporates both the effects of malnutrition and infectious abortion on fertility (see Chapter 2). The effect of malnutrition is introduced by the variable PIFNU which depends on the level of nutrition available and a rate of response to changes in nutrition. The function has an upper bound that is reached when nutrition is below a predetermined level; the lower bound indicates that a minimum of infertility is always present (due to heredity and/or other causes) despite high levels of nutrition [24]. The effect of brucellosis is introduced by the variable, CB(t) = BR2(t)*CBANG(t), which determines the proportion of cows aborting (see Equation

6.15); it is also assumed that 10 percent of the cows aborting become infertile [31].

$$PINF(t+DT) = PFINF(t)*[PFP(t) - DT*(DFP(t) + RFOU2(t) + SLMAS(t))] - SLINF(t)*DT + DT*(CB(t)*0.10 + PIFNU(t))*[(PFP(t) - DT*(DFP(t) + RFOU2(t) + SLMAS(t))*(1 - PFINF(t))) + DT*(RFOU1(t) - RFPT(t) - SLFER(t))] \quad (6.17a)$$

where:

PINF = producing females which are infertile (animals)

PFINF = proportion of producing females which are infertile

PFP = population of producing females--Equation 6.11 (animals)

DFP = actual deaths of producing females--Equation 6.20b (animals/year)

RFOU2 = actual rate at which producing females leave the producing stage--Equations 6.10 (animals/year)

SLMAS = sales of producing females with mastitis due to FMD--Equations 6.22 (animals/year)

SLINF = sales of infertile females--Equation 6.22 (animals/year)

CB = producing females aborting per year (proportion/year)

PIFNU = producing females becoming infertile due to malnutrition where $.01 \leq PIFNU \leq .05$ (proportion/year)

RFOU1 = actual rate at which females leave the growing stage--Equations 6.10 (animals/year)

RFPT = rate producing females are transferred out of a sector--Equations 5.53 (animals/year)

SLFER = sales of fertile producing females--Equations 6.22 (animals/year).

Equation 6.17b below assumes that 18 percent of the cows without treatment against FMD get the disease; further, it is assumed that 5 percent of the cows getting FMD are affected by severe mastitis [31]. This equation also implies, as a simplification, that treatment against FMD is applied to animals in each cohort in the same proportion.

$$FMAS(t+DT) = PFMAS(t)*[PFP(t) - DT*(DFP(t) + RFOU2(t) + SLINF(t))] - SLMAS(t)*DT + (1 - PATAF(t))*DT*0.18*0.05*[(PFP(t) - DT*(DFP(t) + RFOU2(t) + SLINF(t)*(1 - PFMAS(t))) + DT*(RFOU1(t) - RFPT(t) - SLFER(t))] \quad (6.17b)$$

where:

FMAS = producing females with mastitis due to FMD (animals)

PFMAS = proportion of producing females with mastitis

PATAF = animals treated against FMD--Equation 6.28c (proportion/year).

Finally, the number of fertile cows is simply computed as:

$$FER(t) = PFP(t) - FMAS(t) - FINF(t) \quad (6.18)$$

Given the population of fertile females and the effective birth rate, it is possible to compute total births. It is assumed in the model that births are evenly distributed between males and females.

$$BA(t) = BRL2(t)*FER(t) \quad (6.19a)$$

$$BF(t) = 0.5*BA(t) \quad (6.19b)$$

$$BM(t) = BA(t) - BF(t) \quad (6.19c)$$

where:

BA = total animal births (animals/year)

BF = total female births (animals/year)

BM = total male births (animals/year)

BRL2 = as defined in Equation 6.15.

Animal deaths are computed for growing and producing animals and for each sex category. Equations 6.20 show this computation for females only.

$$DFG(t) = PFG(t)*DRL1(t) \quad (6.20a)$$

$$DFP(t) = PFP(t)*DRL2(t) \quad (6.20b)$$

where:

DFG = actual deaths of growing females (animals/year)

DFP = actual deaths of producing females (animals/year)

PFG = population of growing females--Equation 6.11 (animals)

PFP = population of producing females--Equation 6.11 (animals)

DRL1, DRL2 = as defined in Equation 6.16.

Milk and Animals Output

Next, the model computes the output from cattle in the form of milk and total sales, and the marketing equations

used in the generation of prices. The quantity of milk produced depends on the number of fertile cows, cows getting foot-and-mouth disease (FMD) and the level of nutrition. It is assumed that cows affected by FMD produce 15 percent less milk than healthy cows [31].

```
QM(t) = [FER(t)*(PATAF(t) + (1 - PATAF(t))*0.82 + (1 -
        PATAF(t))*0.18*0.85)]*PFLAC(t)*C202*YMA*TABEXE
        (VAL6, .31, .31, 4, TDNA)                        (6.21a)
```

where:

QM = quantity of milk produced (liters/year)

PFLAC = proportion of females lactating

YMA = average milk output per cow (liters/cow-year)

C202 = a model parameter determining the number of lactating cows which are milked (proportion)

TABEXE(VAL6, ..., TDNA)
= a subprogram which introduces a milk production factor determined by the level of nutrition--TDNA.

The expected production of milk used in Equation 5.35a of component LAMDAC is computed as:

```
EQMT(t) = FERT(t)*PFLACT(t)*CT202*YMAT                   (6.21b)
```

where:

EQMT = the expected milk production in the traditional sector (liters/year).

Cattle sales are computed for each cohort and are part of the herd management policies introduced into the

model. Although the sales policies have been designed with enough flexibility to permit simulation of farmers' behavior the current formulation allows little supply response. Cash flow imbalances that might induce sales are not considered as a factor influencing sale decisions, and the model assumes that these decisions depend on prices and the level of nutrition. Price changes may have a short-term response effect but, in the long run, sales seem to be dominated by nutritional considerations. As a general sales policy the model assumes the following priorities (for other than finished males): (1) old cows; (2) cows with reproductive problems; (3) growing males; (4) growing females; (5) fertile cows; and (6) producing males.

According to the preceding assumptions, sales are used to control the cattle population to maintain a prescribed level of nutrition, and animals exceeding carrying capacity are marketed following the order discussed earlier. If pastures are being undergrazed, the decision mechanism operates to reduce sales and increase the retention of animals until the appropriate grazing rate is achieved. This nutrition effect is introduced in the sales equations by the variable PAN. This variable is recalculated each time a sale is performed.

The sales equations describe a family of supply curves which first are completely inelastic, then are positively sloped, and finally become completely inelastic (Figure II.6). The inelastic portions of the curve place an upper bound to sales preventing the herd from being liquidated, and a lower

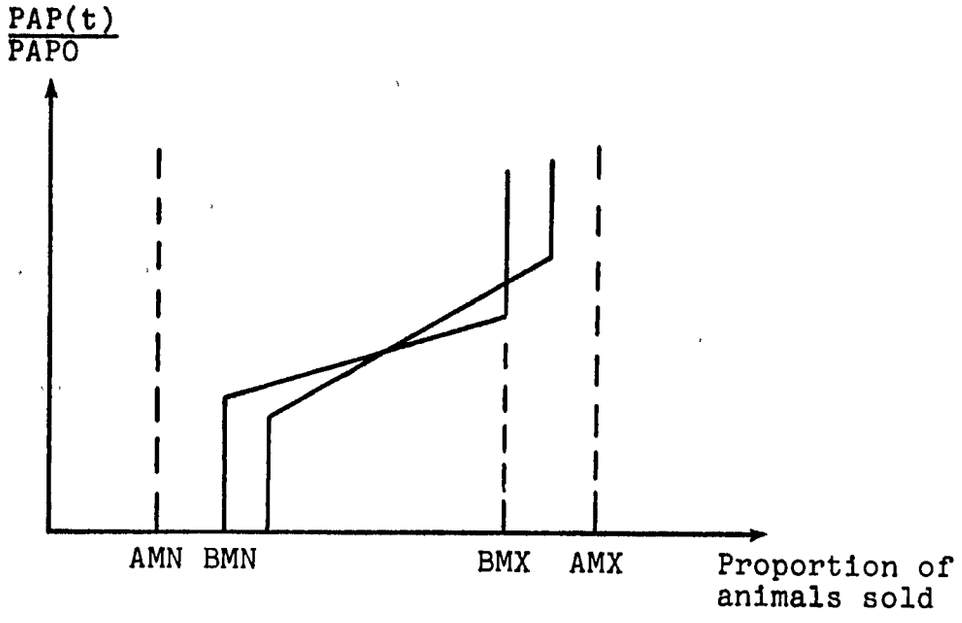

FIGURE II.6. The cattle sales function.

bound indicating that a minimum of animals are marketed from the herd despite low price incentives and/or excess carrying capacity. These bounds are set by the model parameters BMN, BMX, AMX and AMN which permit simulating farmers' behavior and herd management policies (see Table II.3). Since there are similar relationships between management of the traditional and modern herds and for each of the six sale groups, the sale of old cows will be shown in detail here. Response to price is given by the relationship $\left(\frac{PAP}{PAPO}\right)^{ELAS}$ in Equation 6.22c, and nutrition relationships are given by $\frac{PAN}{COHS}$ in Equation 6.22d.[1/]

[1/] COHS is used here as a general form to indicate the number of animals in a given sales group.

TABLE II.3. Maximum and Minimum Proportions of Cattle Sales.

Sales Group and Parameter[1/]		Management Practice	
		Traditional	Modern
Old Cows:			
	AMX1	0.75	1.00
	AMN1	0.50	0.90
	BMX1	0.75	1.00
	BMN1	0.50	0.90
Intertile cows:			
	AMX2	0.25	1.00
	AMN2	0.15	0.80
	BMX2	0.18	0.95
	BMN2	0.15	0.80
Cows with mastitis:			
	AMX3	1.00	1.00
	AMN3	0.70	0.80
	BMX3	1.00	1.00
	BMN3	0.70	0.80
Growing males:			
	AMX4	0.23	0.30
	AMN4	0.11	0.11
	BMX4	0.14	0.20
	BMN4	0.11	0.11
Growing females:			
	AMX5	0.21	0.25
	AMN5	0.13	0.13
	BMX5	0.17	0.19
	BMN5	0.13	0.13
Fertile cows:			
	AMX6	0.06	0.06
	AMN6	0.02	0.02
	BMX6	0.05	0.05
	BMN6	0.02	0.02
Producing males:			
	AMX7	0.20	0.20
	AMN7	0.10	0.10
	BMX7	0.15	0.15
	BMN7	0.10	0.10

[1/] AMX_i, BMX_i and AMN_i, BMN_i are model parameters determining upper and lower bounds to cattle sales (Equations 6.22c and 6.22d)--proportion/year.

Source: Guesstimates and model tuning.

$$TOPEQ(t) = TDN(t)*NREQ \tag{6.22a}$$

$$PAN(t) = TOPOP(t) - TOPEQ(t) \tag{6.22b}$$

where:

TOPEQ = total animal population in equilibrium with nutrient availability (animals)

TDN = total digestible nutrients (tons/year)

NREQ = the reciprocal of the TDN required per animal (animal-year/tons TDN)

PAN = defines the difference between the current animal population TOPOP and the equilibrium population TOPEQ (animals).

$$PRES1(t) = \min\{BMX1, \max[BMN1, PRSI1*\left(\frac{PAP(t)}{PAPO}\right)^{ELAS1}]\} \tag{6.22c}$$

$$PSFO(t) = \min\{AMX1, \max[AMN1, PRES1(t) + C206*\frac{PAN(t)}{OLDF(t)}]\} \tag{6.22d}$$

$$SOLDF(t) = OLDF(t)*PSFO(t) \tag{6.22e}$$

$$PAN(t) = PAN(t) - SOLDF(t) \tag{6.22f}$$

Market Model

Component AGPRAC computes the demand and supply of beef which are part of the simple market model used in determining the price of cattle. First, the model determines the number of animals marketed for consumption and/or export from the Costa herd (Equation 6.24). Although some of these animals are finished in other regions, it has been assumed they are slaughtered and enter the retail market as they leave the Costa farms. Nevertheless, this simplifying

assumption does not greatly alter the total supply of beef as computed in the model.

$$SUPCTA(t) = SLSCCT(t) + SLSMLT(t) + SOLDFT(t) + C212*(SLSCCM(t) + SLSMLM(t) + SOLDFM(t) + C213*(TDTHST(t) + TDTHSM(t)) + C214*(SLFERT(t) + C212*SLFERM(t)) + C215*(SLSFGT(t) + C212*SLSFGM(t)) + C216*(SLSMGT(t) + C212*SLSMGM(t)) \quad (6.24)$$

where:

SUPCTA = supply from the Costa herd (animals/year)

SLSCCT, SLSCCM = sale of cows with reproductive problems traditional and modern, respectively (animals/year)

SLSMLT, SLSMLM = sale of mature males traditional and modern, respectively (animals/year)

SOLDFT, SOLDFM = sale of old cows traditional and modern, respectively (animals/year)

TDTHST, TDTHSM = total animal deaths traditional and modern, respectively (animals/year)

SLFERT, SLFERM = sale of fertile cows traditional and modern, respectively (animals/year)

SLSFGT, SLSFGM = sale of growing females traditional and modern, respectively (animals/year)

SLSMGT, SLSMGM = sale of growing males traditional and modern, respectively (animals/year)

C212 = a parameter accounting for heavier animals from the modern sector (dimensionless)

C213, ..., C216 = parameters determining the proportion of sales which is consumed (proportion).

Non-Costa cattle population, TOPOPK, and supply are exogenously determined in Equations 6.25. Cattle population is assumed to grow in a non-cyclical, exponential fashion and its rate of growth could take different values in order to test the effect of government policies on the development of the non-Costa cattle economy. Beef supply is computed as the off-take for exports and slaughter from this population, where the extraction ratio reflects the oscillations of the long-term cycle (see Chapter 3). This cycling effect is approximated in Equation 6.25b by a TABLIE function which completes a cycle every seven years with the extraction ratio reaching a simulated peak at .17 and a bottom at .118.

$$TOPOPK(t+DT) = TOPOPKO*EXP(C217*t) \qquad (6.25a)$$

$$SUPB(t) = SUPCTA(t) + TOPOPK(t)*TABLIE(VAL9, 0, 1, 7, AMOD(t,7)) \qquad (6.25b)$$

where:

TOPOPK = total non-Costa cattle population (animals)

TOPOKO = non-Costa cattle population at the beginning of simulation (animals)

EXP = the exponential function

C217 = rate of growth of non-Costa cattle population (proportion/year)

SUPB = total Colombian supply of beef (animals/year)

TABLIE(VAL9, ..., AMOD)
= a subprogram which introduces a cycling factor on extraction ratios determined by the length of the long-term cycle--seven years

t = simulated time in the model (years).

Domestic demand for beef is computed in Equation 6.26a and its growth is due to population, income and price effects.

$$DEM(t+DT) = DEM(t) + DT*(DEM(t)*RDEM(t)) \quad (6.26a)$$

$$RDEM(t) = ELASI*C237 + ELASP*C238 - ELASD* \frac{PA(t) - PA(t-DT)}{PA(t-DT)*DT} \quad (6.26b)$$

where:

DEM = domestic demand for beef (animals/year)

RDEM = the rate of growth of demand (proportion/year)

PA = market price of finished males--Equation 7.2 (Ps/animal)

ELASI = income elasticity of demand for beef

ELASP = population elasticity of demand for beef

ELASD = price elasticity of demand for beef

C237 = rate of increase in income (proportion/year)

C238 = rate of increase in population (proportion/year).

Total demand for Colombian beef, TDEM, is simply computed as the sum of domestic demand, official exports,

EXPL, and illegal exports, UNEXPL. Due to the lack of statistics on illegal exports, these are handled as a constant throughout the simulation. Yet it would be realistic to treat UNEXPL as a variable since it can be expected this border trade will be responsive to market conditions in Colombia as well as in the neighboring countries (mainly Venezuela and Ecuador). Official or registered exports are computed from recorded statistics between 1964 and 1971, and from projected targets from 1972 forward (see Table I.1, p. 19 for figures and sources).

$$TDEM(t) = DEM(t) + EXPL(t) + UNEXPL \qquad (6.26c)$$

Disease Control

Since foot-and-mouth disease and brucellosis seriously impair cattle production, and the Colombian government is committed to their control and eradication (see Chapter 2), it is relevant to the model to include some equations to test the effect of control measures. Component AGPRAC includes a simple exogenous model which permits evaluation of disease control policies. Here it is assumed that all the effort is directed toward the traditional sector and that all animals in the modern sector are treated according to recommended practices. Further, it is assumed that before the campaign starts, animals are treated at a constant proportion, but afterwards (i.e., after 1971) this proportion gradually increases until it reaches the value one. At this point the model indicates that all the cattle population is being

treated. This effect is introduced in the model by the exponential function involving the variable TCAD(TCAD = t -TDO) where TDO is the year at which the disease control program starts. The treatment against brucellosis is shown in Equations 6.27 below. This treatment is applied only once when heifers are three to six months old, but for simplicity the model assumes that heifers are treated at birth.

$$ATABTT(t) = BFT(t)*\max[1 - C198*EXP(-C199*TACAD), C242] \quad (6.27a)$$

where:

ATABTT = heifers treated against brucellosis in the traditional sector (animals/year)

BFT = total traditional female births--Equation 6.19b (animals/year)

C242 = proportion of heifers treated without the campaign

C198 = proportion of heifers left untreated (C198 = 1 - C242)

C199 = model parameter regulating the shape of the exponential curve.

The movement of the treated heifers is tracked through the growing stage until they reach the producing stage, and this allows the model to compute the proportion of cows treated, PCTAB, which is needed in determining the variable CBANG used in Equation 6.15. The equations computing PCTAB have the same structure for both the traditional and modern sectors, with the exception that the latter keeps track of the treated females transferred from the traditional sector. Equations 6.27b through 6.27d show this computation for the traditional sector.

$$PGFTB(t) =$$

$$\frac{ATABTT(t)*DT + PGFTBT(t-DT)*(PFGT(t) - BFT(t-DT)*DT)}{PFGT(t)} \quad (6.27b)$$

$$CTABT(t) = RFOUT1(t-DT)*PGFTBT(t-DT)*DT + PCTABT(t-DT)*$$

$$(PFPT(t) - RFOUT1(t-DT)*DT) \quad (6.27c)$$

$$PCTABT(t) = \frac{CTABT(t)}{PFPT(t)} \quad (6.27d)$$

where:

PGFTBT = proportion of growing females treated against brucellosis in the traditional sector

PFGT = population of growing females in the traditional sector--Equation 6.11 (animals)

CTABT = cows treated against brucellosis in the traditional sector (animals)

RFOUT1 = rate females leave the growing stage--Equation 6.10b (animals/year)

PCTABT = proportion of cows treated against brucellosis in the traditional sector.

Although the campaign against FMD and brucellosis is being carried out simultaneously, the data available [31] do not allow a breakdown of expenditures between the two programs. This problem was simplified in the model assuming that treatment against FMD was the only one depending on government expenditures. But since farmers have been and continue to treat a part of the herd on their own, the model computes both animals treated privately and by campaign personnel. Equation 6.28b implies that eventually all animals could be treated by the campaign, in which case farmers who have been

treating their herds privately will be charged for the service. The current program involves charging services to medium- and large-size farmers, and providing subsidized services to small farmers [31].

Since treatment against FMD is applied two or three times every year to all animals, the computation of the proportion of animals treated, PATAFT, used in determining the variable DRA in Equation 6.16 is more straightforward than the preceding for brucellosis.

$$ATAFT(t) = \min\left[\frac{EXPAFT(t)}{COSTFT}, TOPOPT(t)\right] \qquad (6.28a)$$

where:

ATAFT = government treated animals against FMD in the traditional sector (animals)

EXPAFT = government expenditures against FMD--a policy variable (Ps/year)

COSTFT = government cost of treatment against FMD (Ps/animal-year)

TOPOPT = total traditional cattle population in the Costa (animals).

$$ATAFPT(t) = (TOPOPT(t) - ATAFT(t))*\max[1 - C200*EXP(-C201*TACAD), C244)] \qquad (6.28b)$$

$$PATAFT(t) = \frac{ATAFTT(t)}{TOPOPT(t)} \qquad (6.28c)$$

where:

ATAFPT = privately treated animals against FMD in the traditional sector (animals)

ATAFTT = total privately and government treated animals against FMD in the traditional sector (animals)

PATAFT = proportion of animals treated against FMD in the traditional sector

C244 = proportion of animals treated privately without the campaign

C200 = proportion of animals left untreated (C200 = 1 - C244)

C201 = model parameter regulating the shape of the exponential curve.

Equation 6.28b above also implies a promotion and/or diffusion effect among farmers due to the campaign. As time of campaign passes, the proportion of animals treated privately increases approaching one.

Agricultural Accounting

Finally, component AGPRAC performs the macroeconomic accounting for the agricultural production. This section also simulates farmers' varying expectations about the accounting variables during the planning horizon. These expectations are introduced in component LAMDAC for the computation of discounted profitabilities. First, revenues and costs of crops production are generated. Costs are a composite of the major crops grown in each of the agricultural regions and are computed using the same crop allocating weights of component LAMDAC. It is also assumed that costs increase over time at the inflation rate for farm inputs. Table II.2 on page 128, shows the computed average cost of each commodity, where costs in the lowlands are slightly higher to account for increased harvesting costs because of higher yields. Equations 6.29 show these computations for cash crops in the uplands.

ARCRU(t) = TLCRU(t)*YLDCU(t)*PCROPU(t) (6.29a)

where:

ARCRU = accounting revenue from cash crops in the uplands (Ps/year)

TLCRU = total land in cash crops in the uplands--Equation 5.24 (hectares)

YLDCU = the projected yield of cash crops in the uplands--Equation 6.2a (tons/ha-year)

PCROPU = the projected producer price of cash crops from the uplands--Equation 7.4a (Ps/ton).

ACCRU(t) = TLCRU(t)*CSTHCU(t-DT)*(1 + DT*RCST) (6.29b)

where:

ACCRU = accounting cost of cash crops in the uplands (Ps/year)

CSTHCU = the average cost of cash crops in the uplands (Ps/ha-year)

RCST = the rate of increase in farm costs (proportion/year).

Next, the model generates costs and revenues from cattle. Operating costs have been computed separately for the pasture lands and for the herd. The operating cost of land in the traditional and in the modern sectors are computed by Equations 6.30 below. Equation 6.30a is flexible to account for the seasonally flooded lands in TTGLR where it is likely that expenditures on range management are kept to a minimum.

OPCLNT(t) = TTGLR(t)*CLNDT(t)*C267 (6.30a)

where:

OPCLNT = total operating costs of traditional grasslands (Ps/year)

TTGLR = total traditional grazing land in the Costa --Equation 5.51 (hectares)

CLNDT = average operating cost of traditional grasslands (Ps/ha-year)

C267 = a model parameter controlling total land where costs are incurred (proportion).

Equation 6.30b has been designed with enough flexibility to be used in any alternative. If the model is supplied with data for alternatives 1 and 2, this equation reduces to TLMOD(t)*CLNDM(t). Maintenance costs in lands in transition (TRSL) are included in establishment costs.

$$OPCLNM(t) = TLMOD(t)*CLNDM(t)*(1 - CPLF(t)) + TLF(t-DT)*$$
$$CSRFGH(t) + TLF(t)*CSHARV(t)*C253*C254 \quad (6.30b)$$

where:

OPCLNM = operating cost of modern grasslands (Ps/year)

TLMOD = total land in modern grazing--Equation 5.49 (hectares)

CLNDM = the average operating cost of modern grasslands (Ps/ha-year)

CPLF = proportion of modern land in forage crops--Equation 6.9f

TLF = total land in forage crops--Equation 6.9g (hectares)

CSRFGH = cost of replanting and growing forages (Ps/ha-year)

CSHARV = cost of harvesting and storing forage (Ps/ton)

C253 = a parameter determining the yield of forages per cutting (ts/ha-cutting)

C254 = a parameter determining the number of cuttings per year.

Operating costs per animal include labor, drugs, supplemental feed if any, and other miscellaneous costs. The computation of total animal costs for the traditional and modern sector use the same structure shown in Equation 6.31 for the traditional herd.

$$OPCLAT(t) = TOPOPT(t)*CSTANT(t) \quad (6.31)$$

where:

OPCLAT = operating costs of traditional cattle (Ps/year)

TOPOPT = total cattle population in the traditional sector (animals)

CSTANT = average operating cost of traditional animals (Ps/animal-year).

Another component of operating costs is depreciation of grazing land capital and equipment, as well as taxes on land. Because of lack of data on initial capital stock, the model simplifies the computation of replacement investments in cattle production by a lump annual sum per unit of land in production. Total value of depreciation is determined exogenously in Equation 6.32 for the traditional and modern sectors. The value of EQLM varies with the alternative chosen[1/] and the corresponding value (EQLT) for the traditional sector is adjusted by a model parameter to account for the flooded grasslands (see discussion for Equation 6.30a

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[1/] EQLM = 110; 120; 150; 170 Ps/ha-year for alternatives 1, 2, 3 and 4, respectively.

above). The value of the property tax is based on the assessed capitalized value of land (see Chapter 2) and is computed in Equation 6.33 for the traditional sector.

CAPDEM(t) = TLMOD(t)*EQLM (6.32)

where:

CAPDEM = modern sector replacement investment in grasslands and equipment (Ps/year)

EQLM = capital costs for modern cattle production (Ps/ha-year)

TLMOD = as defined in Equation 6.30b (hectares).

VLDTXT(t) = VLANDT(t-DT)*TAXLND*C248 (6.33)

where:

VLDTXT = value of taxes on land in traditional cattle production (Ps/year)

VLANDT = capitalized asset value of land in traditional cattle production--Equation 9.15 (Pesos)

TAXLND = the land tax rate (proportion/year)

C248 = a model parameter adjusting the capitalized value of land to the cadastral (assessed) value (proportion).

Finally, the special taxes on cattle discussed in Chapter 2 are computed in Equations 6.34. The general inventory tax (TAXC3) based on the net investment on cattle has been the most difficult to estimate because of the complexity involved in the accounting of assets and liabilities of farmers. This problem was circumvented in the model by assuming a constant tax rate per animal estimated from

Ministry of Agriculture sources.[1] The assessed liveweight tax rate (PKGR) used in computing the selective inventory tax (TAXC1) was recorded from values set by the government between 1967 and 1970[2] and then extrapolated by means of a TABEXE function [52]. These computations for the traditional sector are shown below:

$$TAXCT1(t) = (PMGT(t)*C222 + PMPT(t))*C223*PKGR \quad (6.34a)$$

where:

TAXCT1 = the traditional cattle selective inventory tax (Ps/year)

PMGT, PMPT = traditional growing and producing male population, respectively--Equation 6.11 (animals)

PKGR = the assessed liveweight tax rate (Ps/kilogram-year)

C222 = a model parameter determining the proportion of growing males over one year of age (proportion)

C223 = the animal-liveweight conversion factor (kilograms/animal).

$$TAXCT2(t) = FEMSCT(t)*C277*SFTAX + SLSMLT(t)*C278*SMTAX \quad (6.34b)$$

where:

TAXCT2 = the traditional cattle export and consumption tax (Ps/year)

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[1] Ministerio de Agricultura, "Estudio Sobre la Renta Presuntiva." Bogota, 1971, pp. 1-111. (Mimeographed.)

[2] The Ministry of Agriculture sets the liveweight price at the end of each fiscal year. The values used in the model were obtained by personal information.

FEMSCT = total traditional females sold for consumption (animals/year)

SLSMLT = total traditional adult males sold for consumption (animals/year)

SFTAX = the female consumption tax rate (Ps/animal)

SMTAX = the male consumption tax rate (Ps/animal)

C277 = a model parameter determining the proportion of females sold for immediate consumption (proportion)

C278 = a model parameter determining the proportion of males sold for immediate consumption (proportion).

Equation 6.34b above needs a further discussion. First, it implies that the tax on animals sold for export is paid by the producer. The coefficients C277 and C278 introduce flexibility into the model to determine those animals which are sold to be finished in other regions and whose tax is not paid by the Costa producers. The variable FEMSCT includes cows with reproductive problems, old cows, fertile cows and heifers; and SLSMLT includes finished steers and males sold out of the producing cohort.

$$TAXCT3(t) = TOPOPT(t)*C279 \qquad (6.34c)$$

where:

TAXCT3 = the traditional general inventory tax (Ps/year)

TOPOPT = total traditional cattle population (animals)

C279 = the estimated general inventory tax rate (Ps/animal-year).

After computing operating costs, the model generates the cost of establishing any modern alternative at market

factor prices, and then determines the actual cash outlays made by farmers. Equation 6.35 is a composite of costs of improving native and artificial pastures, planting artificial pastures and forages, and building storage for forages. It is clear that not all these costs apply to every alternative; a subprogram in the model assigns the relevant costs to each alternative, and in addition, computes costs per unit of land weighted by the proportion of land in artificial pastures and forages.

$$TEC(t) = CSIMNP(t) + CSIMAP(t) + CSPLAP(t) + CSPLFG(t) + CSTGH(t) \quad (6.35)$$

where:

TEC = total establishment costs at market prices (Ps/ha)

CSIMNP = average cost of improving native pastures (Ps/ha)[1/]

CSIMAP = average cost of improving artificial pastures (Ps/ha)[1/]

CSPLAP = average cost of substituting artificial for native pastures (Ps/ha)[1/]

CSPLFG = average cost of establishing forage crops (Ps/ha)[1/]

CSTGH = average cost of building forage storage (Ps/ha)[1/]

[1/] For a detailed computation of these variables see subroutine MODCRD in the Appendix.

Equation 6.35 above is the general approach of accounting for establishment expenditures at their opportunity cost. Yet some of the inputs required can be supplied on the farm at no extra cash expense, decreasing the need for the use of credit and/or savings. Examples of these inputs are family labor, materials for fencing and building, existing tools and equipment, etc. The function ALPH1 computed in Equation 6.36 is an attempt to simulate the response of farmers' behavior to changing profitabilities. This behavior includes changing attitudes toward work and leisure, a more efficient use of the inputs at hand (including management), and incentive to utilize more fully the farm natural resources. As shown in Figure II.7 ALPH1 depends on a profitability threshold (C235) below which there is no incentive for farmers to use their resources intensively. As profitability increases, farmers exploit their resources more fully until they reach a limit (C234) where it is assumed that the ability to use on-farm resources has been exhausted. A parameter (C236) determines how rapidly the attitudes change with changes in the profitability criterion. It is clear that a wide range of farmers' behavior can be simulated by appropriately assigning values to these three parameters.

$$ALPH1(t) = C234 + \min[1 - C234, (1 - C234)*EXP(-C236*(PDR(t-DT) - C235))] \quad (6.36)$$

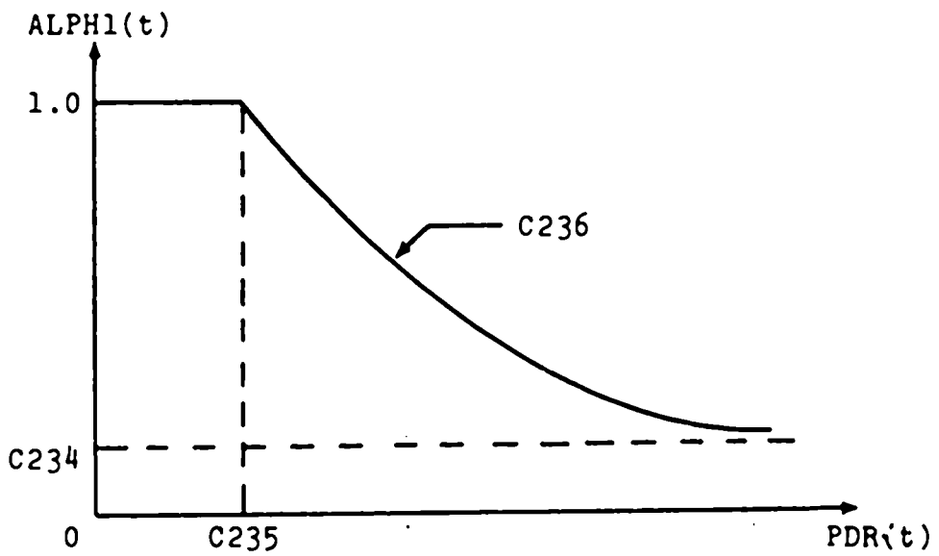

FIGURE II.7. The on-farm resource use response function.

where:

ALPH1 = a variable which introduces the effect of the profitability criterion PDR upon total outlays for establishing an alternative (proportion)

PDR = the relative profitability differential of Equation 5.30 (dimensionless)

C234 = a model parameter determining the minimum proportion of establishment costs met with outside resources (proportion)

C235 = the on-farm resources intensity of use response threshold (dimensionless)

C236 = the rate of on-farm resource use response with respect to profitability (dimensionless)

min[a,b] = the minimum value between a and b

EXP = the exponential function.

Finally, the total cash requirements for establishing an alternative, TCEC, are simply computed as:

$$TCEC(t) = TEC(t)*ALPH1(t) \qquad (6.37)$$

Given the components that enter in the formation of cattle production costs, it is possible to generate the accounting costs, ACLA. Equation 6.38 makes this computation for the modern sector. Accounting costs in the traditional sector are computed using only the first five terms of Equation 6.38 below.

$$ACLAM(t) = OPCLAM(t) + OPCLNM(t) + CAPDEM(t) + VLDTXM(t) + TAXCM(t) + ALINT(t) + ALREP(t) + (TCEC(t) - ALPH1(t)*CSTGH(t))*\frac{TRSL(t)}{3*XDEL} + RPCAPT(t) \qquad (6.38)$$

where:

ACLAM = total accounting costs of modern sector (Ps/year)

OPCLAM = operating costs of modern cattle--Equation 6.31 (Ps/year)

OPCLNM = as defined in Equation 6.30b (Ps/year)

CAPDEM = as defined in Equation 6.32 (Ps/year)

VLDTXM = value of taxes on land in modern cattle production--Equation 6.33 (Ps/year)

TAXCM = total special taxes on modern cattle ($TAXCM(t) = \sum_{i=1}^{3} TAXCM_i(t)$)--Equations 6.34 (Ps/year)

ALINT = interest payments on development credit--Equation 9.8b (Ps/year)

ALREP = repayment of development credits--Equation 9.5 (Ps/year)

CSTGH = cost of building forage storage (Ps/ha)

TCEC = total cash establishment costs--Equation 6.37 (Ps/ha)

ALPH1 = as defined in Equation 6.36 (proportion)

TRSL = total land in transition from traditional to modern practices--Equation 5.46 (hectares)

3*XDEL = time required to complete a land improvement program--Equations 5.43 (years)

RPCAPT = the rate farmers' cost is increased by execution of additional storage capacity (Ps/year).

Accounting revenues from cattle are computed from sales of milk and animals and increased by any direct subsidy paid to farmers. In the modern sector, revenues are also increased by the payment of development loans, but due to the difficulty in allocating commercial loans between the two sectors, these are computed in a more aggregated accounting in Chapter 9. Since the market model only generates the price of finished males, the pricing of other animals sold is computed as a proportion of the price of finished males. This computation is done with a set of coefficients estimated from time series recorded by the Central Bank and published by Garcia Samper [23]. Equations 6.39 show the computation of revenues from the modern sector.

$$SLSPM(t) = (SLSCCM(t) + SOLDFM(t))*C224 + SLSMPM(t)*C225 + SLSMFM(t) + SLFERM(t)*C226 + SLSFGM(t)*C227 + SLSMGM(t)*C228 \quad (6.39a)$$

$$YAM(t) = PAP(t)*SLSPM(t) \qquad (6.39b)$$

where:

SLSPM = sales from the modern sector weighted by price relationships (i.e., finished males equivalents) (animals/year)

SLSCCM, SOLDFM, SLFERM
= as defined in Equation 6.24 (animals/year)

SLSMPM, SLSMFM
= as defined in Equation 6.24 (animals/year)

SLSFGM, SLSMGM
= as defined in Equation 6.24 (animals/year)

YAM = income from sales of modern animals (Ps/year)

PAP = producer price of finished males--Equation 7.3 (Ps/animal)

C224, ..., C228
= model parameters determining price relationships between finished males and other sale groups (proportion)

$$ARLAM(t) = YAM(t) + YMM(t) + ALOAN(t) + AGSUM(t) \qquad (6.39c)$$

where:

ARLAM = accounting revenues from modern cattle (Ps/year)

YMM = income from milk in the modern sector (Ps/year)

ALOAN = credits paid for farm development--Equation 9.4a (Ps/year)

AGSUM = subsidies paid to the modern sector (Ps/year).

Accounting costs and revenues provide estimates at a given point in time. Yet when farmers are considering the adoption of a new method they require an estimate of the future stream of revenues and costs throughout a relevant

planning horizon. These projections into the future and within a planning horizon are simulated in the model by assigning a weight to each year and for each accounting variable involved based on farmers' past experience and on their judgment about changes brought about by the new methods. As can be expected, each alternative produces a set of different expectations and therefore the above-mentioned weights vary accordingly (see Table II.4). Expected revenues and costs are computed in Equations 6.40 below:

$$EOPCLM(t) = \frac{CSTANTL(t)*CAINCR_i}{GRE} \qquad (6.40a)$$

$$EOCLNM_i(t) = CLNDTL(t)*CLINCR_i \qquad (6.40b)$$

$$EVLDTX_i(t) = VLTXTL(t)*VLTXTP_i \qquad (6.40c)$$

$$ETXC_i(t) = TAXCTL(t)*TXCP_i \qquad (6.40d)$$

$$ECADEM_i(t) = EQLT*C268*CAPDTP_i \qquad (6.40e)$$

where:

EOPCLM = expected operating costs of modern cattle (Ps/ha-year)

EOCLNM = expected operating costs of modern grasslands (Ps/ha-year)

EVLDTX = expected taxes on land in modern cattle production (Ps/ha-year)

ETXC = expected special taxes on modern cattle (Ps/ha-year)

ECADEM = expected capital depreciation in the modern sector (Ps/ha-year)

CSTANTL = the exponential average of traditional animals cost (Ps/animal-year)

TABLE II.4. Perceived Changes in Cattle Output and Costs During the Planning Horizon.

Parameter Definition (Eqn. No.)	Planning Horizon (years)											
	1	2	3	4	5	6	7	8	9	10	11	12
SINCR(5.35c) determines change in sales												
Alternative: 1	1	1	1.15	1.45	1.65	1.9	1.9	2	2	2	2	2
2	1	1	1.15	1.7	2	2.25	2.45	2.6	2.6	2.6	2.6	2.6
3	1	1	1.5	2.7	3.2	3.9	4	4	4	4	4	4
4	1	1	1.5	2.7	3.2	3.9	4	4	4	4	4	4
TMINCR(5.35c) determines change in milk output												
Alternative: 1	1.1	1.2	1.25	1.25	1.35	1.35	1.35	1.4	1.4	1.4	1.4	1.4
2	1.2	1.22	1.29	1.36	1.43	1.46	1.53	1.57	1.57	1.57	1.57	1.57
3	1.3	1.37	1.57	1.8	2	2.2	2.22	2.22	2.22	2.22	2.22	2.22
4	1.32	1.39	1.6	1.82	2.2	2.4	2.4	2.4	2.4	2.4	2.4	2.4
BINCR(5.35c) determines change in inventory												
Alternative: 1	0	0.05	0.15	0	0.15	0	0	0.1	0	0	0	0
2	0	0.08	0.22	0.15	0.15	0.1	0.05	0.05	0	0	0	0
3	0	0.35	0.45	0.5	0.4	0.2	0.2	0	0	0	0	0
4	0	0.35	0.45	0.5	0.4	0.2	0.2	0	0	0	0	0
CAINCR(6.40a) determines change in animal costs												
Alternative: 1	1.17	1.27	1.42	1.42	1.57	1.57	1.57	1.67	1.67	1.67	1.67	1.67
2	1.17	1.32	1.47	1.47	1.62	1.62	1.62	1.77	1.77	1.77	1.77	1.77
3	1.2	1.67	1.97	2.47	2.87	3.07	3.27	3.27	3.27	3.27	3.27	3.27
4	1.2	1.67	1.97	2.47	2.87	3.07	3.27	3.27	3.27	3.27	3.27	3.27

TABLE II.4. (continued)

Parameter Definition (Eqn. No.)	Planning Horizon (years)											
	1	2	3	4	5	6	7	8	9	10	11	12
CLINCR(6.40b) determines change in land costs												
Alternative: 1	1	1	1.25	1.25	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5
2	1	1	1.25	1.25	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5
3	1	1.3	1.6	1.8	2	2.5	2.5	2.5	2.5	2.5	2.5	2.5
4	1	1.2	1.4	1.6	1.8	2.2	2.2	2.2	2.2	2.2	2.2	2.2
VLTXTP(6.40c) determines change in value of land tax												
Alternative: 1	1	1	1	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3
2	1	1	1	1.25	1.25	1.25	1.35	1.35	1.35	1.35	1.35	1.35
3	1	1	1	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.4
4	1	1	1	1.32	1.32	1.32	1.42	1.42	1.42	1.42	1.42	1.42
TXCP(6.40d) determines change in value of cattle taxes												
Alternative: 1	1.1	1.16	1.19	1.21	1.26	1.27	1.28	1.3	1.3	1.3	1.3	1.3
2	1.1	1.25	1.3	1.33	1.35	1.36	1.37	1.4	1.4	1.4	1.4	1.4
3	1.1	1.35	1.6	2	2.4	2.55	2.6	2.6	2.6	2.6	2.6	2.6
4	1.1	1.35	1.6	2	2.4	2.55	2.6	2.6	2.6	2.6	2.6	2.6
CAPDTP(6.40e) determines change in capital depreciation												
Alternative: 1	1	1.5	2	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
2	1	1.6	2.5	2.8	3	3	3	3	3	3	3	3
3	1.1	2	2.8	3	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
4	1.1	1.9	2.7	2.9	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3

Source: [42] and initial guesstimates and model tuning.

GRE = equilibrium grazing rate (has/animal)

CLNDTL = the exponential average of traditional grasslands cost (Ps/ha-year)

VLTXTL = the exponential average of traditional land tax (Ps/ha-year)

TAXCTL = the exponential average of special taxes on traditional cattle (Ps/ha-year)

EQLT*C268 = capital costs for traditional cattle production--Equation 6.32 (Ps/ha-year)

CAINCR = the expected increase in animal costs (dimensionless)

CLINCR = the expected increase in range management costs (dimensionless)

VLTXTP = the expected increase in land tax (dimensionless)

CAPDTP = the expected increase in capital costs (dimensionless)

i = indexes the planning horizon--i=1, ..., n.

Expected establishment costs are computed as equal allotments during the years required to complete a modern alternative. A model subprogram allocates these values among the relevant years in the planning horizon.

$$ETCEC(t) = \frac{TCEC(t)}{3*XDEL} \qquad (6.40f)$$

where:

ETCEC = expected cash establishment costs of a modern alternative (Ps/ha-year)

TCEC = as defined in Equation 6.37 (Ps/ha)

3*XDEL = time required to complete a modern alternative--Equations 5.43 (years).

The expected debt service, EDBSER, is generated by a model subprogram that first computes interests paid on the

entire credit received for development during the period of establishment and the grace period. Next the subprogram computes repayments in equal allotments during the repayment period, and charges interest on the unpaid balances. Finally, the expected credits paid are computed in a way similar to ETCEC above. The time during which credits are paid (LT1) may not necessarily be equal to the time required to establish the alternative (3*XDEL). A model subprogram allocates these values among the relevant years in the planning horizon.

$$ELOAN(t) = \frac{TCEC(t)*(1 - RPTN)}{LT1} \qquad (6.40g)$$

where:

ELOAN = expected credits paid for farm development (Ps/ha-year)

RPTN = farmers' participation of total establishment costs--a policy variable ($0 \leq RPTN \leq 1$) (proportion)

LT1 = time development loans are paid--a policy variable (years).

Table II.5 at the end of this chapter shows the values of a selected number of variables used in component AGPRAC.

TABLE II.5. Selected Coefficients and Initial Values in the Agricultural Production Component (AGPRAC).

Definition (Equation No.)		Value
DYLDCU (6.2a)	Determines target yield of cash crops in the uplands (tons/ha-year)	1.65
DYLDCL (6.2b)	Determines target yield of cash crops in the lowlands (tons/ha-year)	2.9
DYLDFC (6.2c)	Determines target yield of food crops (tons/ha-year)	10
GRE (6.4b)	Determines the equilibrium grazing rate (has/animal)	.74
CPLPT (6.5)	Determines proportion of artificial grasses	.45
TDNSG (6.9c)	Determines the average TDN from sorghum silage (tons TDN/ton silage)	.2343
TDND (6.9f)	Determines target yield of TDN of grazing lands (tons/ha-year)	7.4
NREQT (6.22a)	Determines appropriate traditional animal nutritional requirements (animal-year/ton TDN)	.55
ELASI (6.26b)	Determines income elasticity of demand for beef	.6
UNEXPL (6.26c)	Determines illegal cattle exports (animals/year)	300,000
COSTFT (6.28a)	Determines cost of treatment against foot-and-mouth disease (Ps/animal-year)	4.5
TAXLAND (6.33)	Determines the land tax rate (proportion/year)	.0042
SFTAX (6.34b)	Determines the female consumption tax rate (Ps/animal)	100
SMTAX (6.34b)	Determines the male consumption tax rate (Ps/animal)	50
CT202 (6.21b)	Determines number of traditional lactating cows milked (proportion)	.4

TABLE II.5. (continued)

Definition (Equation No.)		Value
C217 (6.25a)	Determines rate of growth of non-Costa cattle population (proportion/year)	.0285
C223 (6.34a)	Determines the liveweight tax rate (kilograms/animal-year)	4.0
C224 (6.39a)	Determines price relationship between finished males and cull cows (proportion)	.68
C225 (6.39a)	Determines price relationship between finished and producing males (proportion)	.92
C226 (6.39a)	Determines price relationship between finished males and breeding cows (proportion)	.88
C227 (6.39a)	Determines price relationship between finished males and growing females (proportion)	.42
C228 (6.39a)	Determines price relationship between finished and growing males (proportion)	.535
C237 (6.26b)	Determines the rate of increase in income (proportion/year)	.1
C238 (6.26b)	Determines the rate of increase in population (proportion/year)	.032
C242 (6.27a)	Determines proportion of heifers treated against brucellosis without campaign (proportion)	.05
C244 (6.28b)	Determines proportion of animals treated against foot-and-mouth without campaign (proportion)	.3
C248 (6.33)	Determines the assessed value of land (proportion)	.5
C250 (6.9c)	Determines the relationship between green forage and silage (tons forage/ton silage)	1.2
C253 (6.9c)	Determines yield of green forages (tons/ha-cutting)	40

TABLE II.5. (continued)

Definition (Equation No.)		Value
C254 (6.9c)	Determines the number of forage cuttings (cuttings/year)	3
C279 (6.34c)	Determines the cattle general inventory tax rate (Ps/animal-year)	3.1
CSTHCU(0) (6.29b)	Initial cost of cash crops in the uplands (Ps/ha-year)	560
CSTHCL(0) (6.29b)	Initial cost of cash crops in the lowlands (Ps/ha-year)	1,097
CSTHFC(0) (6.29b)	Initial cost of food crops (Ps/ha-year)	723
CLNDT(0) (6.30a)	Initial operating cost of traditional grazing lands (Ps/ha-year)	35.8
CLNDM(0) (6.30a)	Initial operating cost of modern grazing lands (Ps/ha-year)	100
CSRFGH(0) (6.30b)	Initial cost of replanting and growing forages (Ps/ha-year)	570
CSHARV(0) (6.30b)	Initial cost of harvesting and storing forages (Ps/ton)	6.25
CSTANT(0) (6.31)	Initial operating cost of traditional animals (Ps/animal-year)	24.14
CSTANM(0) (6.31)	Initial operating cost of modern animals (Ps/animal-year)	56
CSINPH(0) (6.35)	Initial cost of improving native grasses (Ps/ha)	576
CSIAPH(0) (6.35)	Initial cost of improving artificial grasses (Ps/ha)	576
CSPAPH(0) (6.35)	Initial cost of planting artificial grasses (Ps/ha)	660
CSPFGH(0) (6.35)	Initial cost of establishing forage crops (Ps/ha)	590
CBSTG(0) (6.35)	Initial cost of building forage storage (Ps/m^3)	8.5

Source: [19, 20, 23, 31, 32, 33, 42, 57, 58, 61, 66, 69, 71] and initial guesstimates and model tuning.

CHAPTER 7

PRICE GENERATION (PG)

Component PG generates world prices for beef and market and producer prices of cattle, cash crops and food crops. In addition, five-year exponential averages of the producer prices are computed for use by component LAMDAC in the profitability calculations for the land allocation decisions.

Export and Market Price of Cattle

Colombian beef exports have been mainly live cattle, but the government has announced plans to export only dressed animals after 1974. The model assumes this change in export policy will be effectively implemented, and that the relevant world price is for frozen carcass beef. For the period 1964 to 1974, prices are for a composite of live animals and frozen carcass beef. Although it has been assumed that exports will continue in the form of frozen carcass beef, it is clear that the export price will be modified if chilled, refrigerated or processed beef is exported. All export prices are given as live animal prices; carcass beef is converted to live animals by use of the factor 4.3 which is the number of animals to produce a metric ton of carcass. World prices for cattle (U. S. $/animal) are exogenously generated

by Equation 7.1 below. Since cattle exports were negligible until 1964, no world prices are generated for the years prior to 1964. For the period 1964 to 1970, prices are a composite of live animals and carcass beef as reported by Sarmiento [63]. From 1971 to 1974 these composite prices are projections based on Instituto de Comercio Exterior (INCOMEX) estimates [35]. Finally, after 1974 world prices are projected assuming various trends that will be discussed in Chapter 12.

$$WPB(t) = \begin{cases} 0 & 0 < t < 4 \\ 117,\ 115.5,\ 127,\ 147,\ 164,\ 163.5,\ 174 & 4 \leq t \leq 10 \\ WPB1970*(1+WPBR*(t-10) & 10 < t \leq 14 \\ \frac{WPBC(t)}{4.3} & t > 14 \end{cases} \quad (7.1a)$$

$$WPBC(t) = WPBC1970*(1+WPBCR*(t-10)) \quad (7.1b)$$

where:

WPB = world (FOB) price of beef (US$/animal)

WPBC = world (FOB) price of frozen carcass beef (US$/metric ton)

WPB1970, WPBC1970 = recorded world price in 1970

WPBR = rate of change of world price after 1970 as a proportion of 1970 price. This is a composite of live animals and frozen carcass beef (proportion/year)

WPBCR = rate of change of world price of frozen carcass beef after 1970 as a proportion of 1970 price (proportion/year)

t = simulated time (t=0 is 1960)--years.

The market price of cattle is computed in Equation 7.2. This equation, which generates the market price of finished males as a function of excess demand, is derived directly from the definition of demand price elasticity ε:

$$\varepsilon = \frac{\Delta q/q}{\Delta p/p}$$

where $\Delta q = q_t - q_{t-DT}$ and $\Delta p = p_t - p_{t-DT}$ and the ratios are taken relative to the initial price and quantity demanded, p_{t-DT} and q_{t-DT}.[1/]

$$PA(t) = PA(t-DT) + DT*C219*PA(t-DT)*$$

$$\frac{(TDEM(t-DT) - SUPB(t-DT))}{ELASD*TDEM(t-DT)} \qquad (7.2)$$

where:

PA = market price of finished males (Ps/animal)

SUPB = total Colombian supply of beef--Equation 6.25b (animals/year)

TDEM = total demand for Colombian beef--Equation 6.26c (animals/year)

ELASD = price elasticity of demand for beef

C219 = a model parameter regulating the beef price response to excess demand (proportion/year).

Equation 7.2 assumes that the target change in quantity, Δq, will be the excess demand in the previous period and that the equilibrium price will not necessarily be reached in one period, i.e., if DT*C219 < 1. The

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[1/] For a detailed derivation see Abkin [1, Chapter 5].

domestic price of other types of cattle are computed as a constant proportion of the price of finished males. This computation will be more fully discussed in Chapter 9.

Producer Prices and Price Averages

Next, producer prices are computed for cattle and crops. Producer prices of crops are exogenously determined and are a composite of the major crops grown in each of the agricultural regions. The model assumes a constant profit margin in the production of crops and projects increases in their prices over time at the same rate that costs of production are increased. Producer prices in the base year (1960) are as reported by the World Bank report on Colombia [41] and weighted by total yields in each agricultural region. Weights are derived from hectares in production reported by DANE [15] and average yields reported by the Instituto de Mercadeo Agropecuario (IDEMA)[1/] as shown in Table II.6. Further, it is assumed that 50 percent of the harvested yield of sesame and sorghum, 35 percent of that of cotton, and 70 percent of that of corn come from the uplands.[2/]

[1/] IDEMA. Informe Sobre la Superficie Sembrada, Produccion Total y Rendimientos de los Productos Basicos. Bogota. Mayo 1971. Unpublished Report.

[2/] Weights used for 1960 are, for cash crops in the lowlands: sesame--.012; cotton--.13; corn--.24; sorghum--.015; and rice--.6. For cash crops in the uplands: sesame--.018; cotton--.11; corn--.85; and sorghum--.023. For food crop: plantain--.48; and cassava--.52.

TABLE II.6. Land in Crops, Average Yields and Producer Prices in the Costa, 1960.

Crop	Area Planted (has)	Average Yield (tons/ha-yr)	Price (Ps/ton)
Sesame	9,787	.59	1,519
Cotton	38,815	1.34	1,726
Corn	162,806	1.19	474
Sorghum	2,952	2.46	369
Rice	74,588	1.98	883
Plantain	48,578	8.38	224
Cassava	53,243	8,28	303

Source: As indicated above. Price of sorghum was obtained by personal information.

The producer price of cattle is computed in Equation 7.3 below:

$$PAP(t) = PA(t)*(1-MKM) \qquad (7.3)$$

where:

PAP = producer price of finished males (Ps/animal)

MKM = the marketing margin for cattle--proportion ($0 \leq MKM \leq 1$) (see Table III.2).

Because of a lack of information on producer price changes, crop prices are increased over time at the same rate of increase in farm costs (RCST). The assumption of maintaining a constant profit margin throughout the

simulation is an accounting simplification that finds justification in the secondary concern of the model on the crop subsector. Equations 7.4 compute these prices as:

$$PCROPU(t+DT) = PCROPU(t)*(1+DT*RCST) \quad (7.4a)$$

$$PCROPL(t+DT) = PCROPL(t)*(1+DT*RCST) \quad (7.4b)$$

$$PFCROP(t+DT) = PFCROP(t)*(1+DT*RCST) \quad (7.4c)$$

where:

PCROPU = the projected producer price of cash crops from uplands (Ps/ton)

PCROPL = the projected producer price of cash crops from lowlands (Ps/ton)

PFCROP = the projected producer price of food crops (Ps/ton)

RCST = the rate of increase in farm costs (proportion/year).

Exponential price averages are computed in Equations 7.5 for use in determining land allocation decisions (Equations 5.35a and 5.35e).

$$EPAP(t) = EPAP(t-DT) + \frac{DT}{DEL5}*(PAP(t-DT) - EPAP(t-DT)) \quad (7.5a)$$

$$EPCRPU(t) = EPCRPU(t-DT) + \frac{DT}{DEL7}*(PCROPU(t-DT) - EPCRPU(t-DT)) \quad (7.5b)$$

where:

EPAP = exponential average of finished males producer price (Ps/animal)

EPCRPU = exponential average of upland cash crops producer price (Ps/ton)

DEL5, DEL7
= averaging lags (years).

The values of a selected number of variables used in generating prices are shown in Table II.7.

TABLE II.7. Selected Coeffic.nts and Initial Values in the Price Generation Component (PG).

Definition (Equation No.)		Value
WPBR (7.1a)	Determines change in live-carcass world price of beef (proportion of 1970 price/year)	.11[a/]
WPBCR (7.1b)	Determines change in frozen carcass world price of beef (proportion of 1970 price/year)	.384[b/]
ELASD (7.2)	Price elasticity of demand for beef (dimensionless)	.7
RCST (7.4)	Determines change in cost of farm inputs (proportion/year)	.12
SUPB(0) (7.2)	Initial total Colombian beef supply (animals/year)	1,889,100
TDEM(0) (7.2)	Initial total demand for Colombian beef (animals/year)	1,889,100
PCROPU(0) (7.4a)	Initial composite price of cash crops in uplands (Ps/m.ton)	630
PCROPL(0) (7.4b)	Initial composite price of cash crops in lowlands (Ps/m.ton)	892
PFCROP(0) (7.4c)	Initial composite price of food crops (Ps/m.ton)	265
PA(0) (7.2)	Initial price of finished males (Ps/animal)	1,067
WPBC1970 (7.1b)	World price for Colombian carcass beef in 1970 (dollars/ m.ton)	588

a/ Based on price increase between 1964 and 1968 and assuming a gradual increasing weight of carcass beef on exports from 1970 to 1974.

b/ Based on 1970 price reported by Sarmiento [63], and on 1972 price (US$1040/m.ton) reported by El Espectador, Bogota, April 8, 1973.

Sources: [15, 16, 23, 41, 63, 67]

CHAPTER 8

POLICIES FOR THE CATTLE INDUSTRY

In a policy-oriented model, there are a number of places in which the policy maker can interact with researchers to perform experiments in a simulated system. These experiments may involve changing system parameters and technological coefficients to see the effect on the model's performance or direct policy experimentation. In the latter course, policies and programs are specified explicitly and the consequences are simulated as a result of the system structure of the model. When experimenting with different values of system parameters and/or technological coefficients, the policy maker acquires a better judgment about those parameters to which the model is insensitive and about those which significantly affect the system performance and therefore would play a role in future policy and planning decisions. In addition, technological research may be suggested by policy runs speculating on the likely consequences of the introduction of an innovation which may not actually be developed at the moment.

Simulation runs testing parameter sensitivity and conducting direct policy experiments are discussed in Chapters 11 and 12.

Policies

Three basic policy strategy alternatives are structured in the simulation model. Others could be added, but the three included seemed to be quite relevant for Colombian policy makers at the time the model was defined. Policies may be set and experimented with in any one or a combination of the following: production campaigns, tax policies and export policies.

Production Campaigns

Production campaigns make up the first class of policies which may be investigated. Promotion efforts aimed at modernizing cattle production can generate substantial returns to both the public and private sectors. Such modernization may entail the introduction of better animal husbandry and/or the encouragement of improved pasture management practices and increased fodder production. The increase in output can then result in higher incomes for the farmers, increased availability of basic food for the mass of the population, and increased tax revenues and foreign exchange earnings for the public sector. The nonagricultural sector, though not modeled, could be expected to grow also as a result of increased demands from the agricultural sector.

Associated with this modernization effort is a policy of providing credit for farm improvements at special lending terms. These terms include the interest rate, the grace period, the repayment schedule, the farmers' participation

on the total cost of the project and the technical assistance. Both the promotional information units discussed in component LAMDAC, Equation 5.37, and the funds for development credit discussed in component CRTACC, Equation 9.4, are generated exogenously using a promotion and credit allocation routine. The maximum yearly size (VMAX) and time spans (T0, T1, T2, TF) of these services may be specified by the experimenter, and the model generates the time profile shown in Figure II.8.[1/]

Other policies related to production campaigns are the control of foot-and-mouth disease and brucellosis, and the improvement of crop production. Currently, the model takes the disease control campaign as aimed toward the traditional sector since it is assumed that animals in the modern sector are appropriately treated as part of the improved husbandry adopted. As indicated in Chapter 6 (Equations 6.27 and 6.28), animals are treated regardless of their profitability. All that is required is an exogenous rate of vaccination (C199 and C200) which can be set as a policy. Government expenditures in the Costa on control of foot-and-mouth disease, EXPAFT in Equation 6.28a, are generated using a TABLIE function which steps up these expenditures from the years preceding the campaign until they reach a maximum, and

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[1/]This routine has been adapted from the modernization budget executive routine used in the simulation of the Nigerian Agricultural Economy [53].

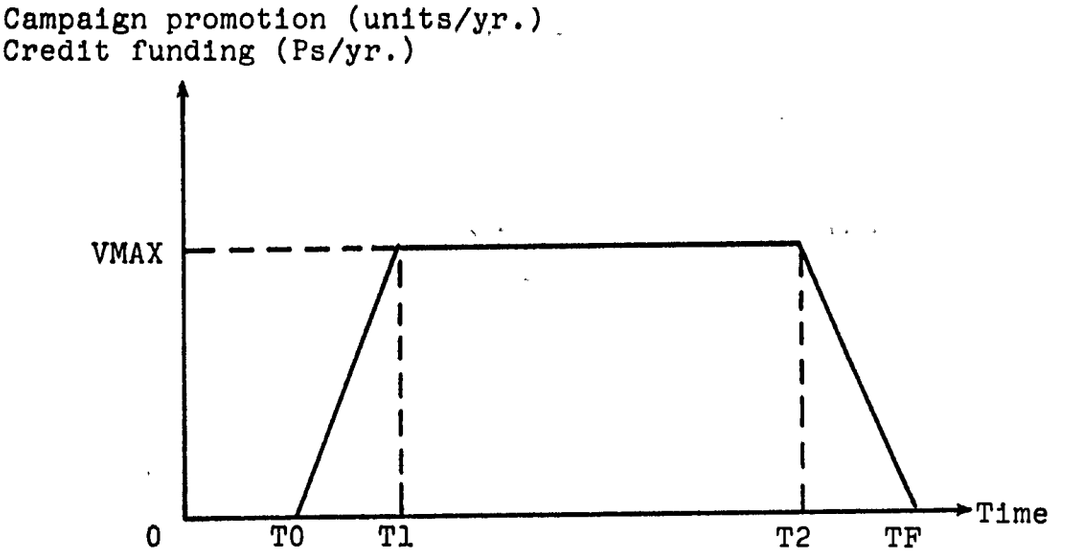

FIGURE II.8. Promotion and development credit profile.

then the function projects them at a constant annual rate. The values used in this function have been approximated from estimates supplied by ICA [31] and show the more limited efforts that have been achieved in this program prior to 1971. The profile generated by the table function could be changed to one similar to Figure II.8 as part of the policy experiments. Finally, the improvement of crops is determined exogenously using the simple model described by Equations 6.2, and its effect is measured in the land allocation decisions and in farm income.

Taxes

The second major policy which can be investigated with the model is the area of taxing policies. Taxes are

levied on net income, net worth, cattle, and land, but we are concerned here only with the last two categories. Taxes on cattle as described in Chapter 2 affect the cost of production and therefore cause adjustments in the use of factors of production that affect farm income and output. Taxes on land are amortized to its value and therefore decrease the asset position of farmers. Yet both cattle and land taxes are a main source of government revenue. With simulation runs incorporating different levels of tax rates for both cattle and land, questions can be answered regarding the likely consequences these policies will have on production levels, agricultural income, and other relevant economic performance criteria.

Export Policies

Finally, the model allows experimentation with several kinds of export policies aimed at generating foreign earnings and regulating domestic supply. Specifically, targets can be set on cattle exports, exchange rates can be varied and subsidies can be paid to exporters. In addition to these, the effects of different levels of exports on domestic consumption and price can be investigated and their consequences projected. Further, the value of transfers from public revenues to the private sector in the form of an export subsidy can also be examined.

CHAPTER 9

ACCOUNTING AND PERFORMANCE CRITERIA (CRTACC)

Component CRTACC completes the farm accounting and computes the performance indices used to evaluate the outcome of the cattle and crops policy experiments.

Budget Accounting

Given incomes, costs of crops and cattle and the rate of land improvment, it is possible to determine credit requirements, debt service, investment constraints and farm income on a regional basis. The farm development budget is modeled dynamically as cash flows distributed over time. The development budget model is divided into three stages of varying lengths. The respective stage lengths reflect the three investment periods which the model identifies: a period of expenditures on farm improvements and credit payments, a grace period, and a period of credit repayments. These lengths (LT) are policy variables which allow testing the effect of different credit schemes.

The preceding budget flow is simulated dynamically by three calls to BOXC, a "boxcar train" subroutine, one for each stage. This subroutine is used to delay a flow for a considerable period of time, with no outflow until the delay time is over [21, 52]. The credit-investments period

uses as an input the outlays required for farm improvement, net of farmers participation and use of private funds. These requirements are determined by the rate at which land enters modernization (Equation 5.41) and the establishment costs (Equation 6.37). The remaining stages use the output of the preceding stage as an input. Equations 9.1 describe this process.

CALL BOXC(AUX5(t-DT), BOUT1(t), TRAIN1, NCOUN1, NOCY1,

LT1, SUMIN) (9.1a)

CALL BOXC(BOUT1(t-DT), BOUT2(t), TRAIN2, NCOUN2, NOCY2,

LT2, SUMIN) (9.1b)

CALL BOXC(BOUT2(t-DT), BOUT3(t), TRAIN3, NCOUN3, NOCY3,

LT3, SUMIN) (9.1c)

where:

AUX5 = credit needs for land entering modernization (Ps/year)[1/]

BOUT1 = rate credit investments leave the first stage (this is the output variable of the first call to BOXC) (Ps/year)

BOUT2 = rate credit investments leave the second stage (this is the output variable of the second call to BOXC) (Ps/year)

BOUT3 = rate credit investments leave the third stage (Ps/year)

LT1 = time development loans are paid (years)

[1/] For detailed computation of this variable see subroutine MODCRD in the Appendix.

LT2 = time after completing farm development adding up to the grace period (LT1 + LT2) (years)

LT3 = time development loans are repaid (years)

TRAIN, NCOUN, NOCY, SUMIN
= other variables associated with the use of the BOXC subroutine.

The purpose of these calls to subroutines BOXC is to compute TRNSL(t), the sum of credit invested in each stage. These levels are computed in Equations 9.2 as time integrals of credit flow rates.

$$TRNSL1(t+DT) = TRNSL1(t) + DT*(AUX5(t) - BOUT1(t) - TRAIN1(3)*(1 - A5(t))) \quad (9.2a)$$

$$TRNSL2(t+DT) = TRNSL2(t) + DT*(BOUT1(t) - BOUT2(t)) \quad (9.2b)$$

$$TRNSL3(t+DT) = TRNSL3(t) + DT*(BOUT2(t) - BOUT3(t)) \quad (9.2c)$$

where:

TRNSL1 = total credits paid during the first stage--the period when improvements are implemented (Ps)

TRNSL2 = total credits completing the grace period (Ps)

TRNSL3 = total credits that have to be repaid (Ps)

A5 = the proportion of land remaining in the program after dropouts--Equation 5.44.

The term involving TRAIN1(3) in Equation 9.2a needs further explanation. The credit rates that flow through the first

BOXC delay are adjusted to allow for the possibility of "dropouts" from the program. This dropout effect is introduced by the variable A5 discussed in Chapter 5. Equation 9.2a also implies that dropouts, if any, occur during the first year after entering the modernization program.

Development Credit

Once the total outlays of investment credit are generated, it is easy to determine the credit constraints to development and the debt service. First the model computes demand for credit, DCRDT, and availability of credit, CREDT, which are used to determine the credit-based rate of modernization in component LAMDAC (ARM1 in Equation 5.41).

$$DCRDT(t) = \frac{TRNSL1(t)}{LT1} \qquad (9.3)$$

$$CREDT(t) = \max(ACRDT(t) - DCRDT(t), 0) \qquad (9.4)$$

where:

DCRDT = demand for development credit from ranchers already in the program (Ps/year)

CREDT = credit available for additional modernization (Ps/year)

ACRDT = total credit allocated for modernization--a policy variable (Ps/year).

Next, the model computes the debt service on development loans. As a simplification, the model assumes that all farmers entering a modernization program receive credit if it is available. This is to say that:

$$ALOAN(t) = \min(CREDT(t), DCRDT(t)) \qquad (9.4a)$$

$$ALREP(t) = \frac{TRNSL3(t)}{LT3} \quad (9.5)$$

$$ALOANA(t+DT) = ALOANA(t) + DT*ALOAN(t) \quad (9.6)$$

$$ALREPA(t+DT) = ALREPA(t) + DT*ALREP(t) \quad (9.7)$$

where:

ALREP = development loans repaid (Ps/year)

ALOAN = development loans paid (Ps/year)

ALREPA = accumulated development loans repaid (Ps)

ALOANA = accumulated development credits paid (Ps).

Interests on development loans are charged on the outstanding debt balance. These are computed in Equations 9.8 below:

$$DBTOUS(t) = ALOANA(t) - ALREPA(t) \quad (9.8a)$$

$$ALINT(t) = DBTOUS(t)*RINTL \quad (9.8b)$$

where:

DBTOUS = the outstanding development debt (Ps)

ALINT = interest payments on development loans (Ps/year)

RINTL = interest rate on development loans--a policy variable (proportion of debt/year).

Commercial Credit

Commercial credit as used in the model is short-term credit, usually for one year provided through the development and private banks under a variety of government-regulated schemes (see Chapter 1). Since interest charges

on these loans vary widely, the model uses an estimated average rate (RINTC) when computing the short-term debt service. As a general policy, short-term credit is supplied to cover operating costs and buying feeder cattle, although the latter use has been ruled out in the model (see Chapter 5, p. 109). Regional allocation of commercial credit by the banking system determines its availability to farmers and this could be an important constraint in the model. Yet lack of information on this matter led us to the simplifying assumption that the only constraint to the use of commercial credit was the farmers' capacity to provide an acceptable security. It is clear that with more information the allocation of commercial credit by the banking system, ACRDTC, could be a policy variable. Equations 9.9 below compute the availability of commercial credit and its debt service.

$$CRDAV(t) = \min(PEQCR*EQPOS(t), ACRDTC(t)) \quad (9.9a)$$

$$EQPOS(t) = VLAND(t) + VACAPL(t) - CDEB(t) - DBTOUS(t) \quad (9.9b)$$

where:

CRDAV = commercial credit available to the cattle sector (Ps/year)

EQPOS = equity position of cattle producers (Ps)

ACRDTC = commercial credit allocated (Ps/year)

PEQCR = proportion of equity which can be used as a credit base (proportion/year)

VLAND = capitalized asset value of land in cattle production--Equation 9.15c (Ps)

VACAPL = value of cattle inventories--Equation 9.14 (Ps)

CDEB = commercial debt of cattle sector--Equation 9.9f (Ps)

DBTOUS = as defined in Equation 9.8a (Ps).

Total demand for commercial credit, TDCRDC, is determined by the difference between net income from cattle, increased by internal transfers of capital from the crops sector, and the expenditures for consumption.

$$TDCRDC(t) = \max(-FARIL(t) - C239*FARMIC(t) + EXPLIV(t), 0) \quad (9.9c)$$

where:

TDCRDC = total demand for commercial credit by the cattle sector (Ps/year)

FARIL = aggregated net farm income from cattle--Equation 9.10c (Ps/year)

FARMIC = aggregated net farm income from crops--Equation 9.11 (Ps/year)

EXPLIV = aggregated consumption expenditures of cattle producers--Equation 9.12a (Ps/year)

C239 = a model parameter determining the proportion of income from crops internally transferred to cattle production.

Commercial loans paid to cattle producers, CLOAN, are computed as:

$$CLOAN(t) = \min(CRDAV(t), TDCRDC(t)) \quad (9.9d)$$

The repayment of the commercial debt is computed as:

$$CREP(t) = \max(CREPR*CDEB(t-DT), 0) \quad (9.9e)$$

where:

CREP = commercial loans repaid (Ps/year)

CREPR = repayment rate (proportion of debt/year).

Given credit payments and repayments, it is possible to compute the outstanding commercial debt and interest payments by the cattle sector.

$$CDEB(t+DT) = CDEB(t) + DT*(CLOAN(t) - CREP(t)) \quad (9.9f)$$

$$CINT(t) = RINTC*CDEB(t) \quad (9.9g)$$

where:

CDEB = commercial debt of cattle sector (Ps)

CINT = interest payments on commercial debt (Ps/year)

RINTC = interest rate on commercial loans (proportion of debt/year)

Aggregated Income and Consumption

Component AGPRAC generates revenues and costs of traditional and modern cattle (Equations 6.38 and 6.39) disregarding the accounting effect of commercial credit. Now it is possible to incorporate this effect into the general accounting and determine farm income on a regional basis. First, Equations 9.10 compute aggregated income from cattle.

$$ARLSK(t) = ARLAT(t) + ARLAM(t) + CLOAN(t) \quad (9.10a)$$

where:

ARLSK = aggregated revenues from cattle (Ps/year)

ARLAT = accounting revenues from traditional cattle--Equation 6.39c (Ps/year)

ARLAM = accounting revenues from modern cattle--Equation 6.39c (Ps/year)

CLOAN = as defined in Equation 9.9d (Ps/year).

$$ACLSK(t) = ACLAT(t) + ACLAM(t) + CREP(t) + CINT(t) \quad (9.10b)$$

where:

ACLSK = aggregated costs of producing cattle (Ps/year)

ACLAT = accounting costs of traditional cattle--Equation 6.38 (Ps/year)

ACLAM = accounting costs of modern cattle--Equation 6.38 (Ps/year)

CREP = as defined in Equation 9.9e (Ps/year)

CINT = as defined in Equation 9.9g (Ps/year).

Finally, aggregated net farm income from cattle, FARIL, is simply computed as:

$$FARIL(t) = ARLSK(t) - ACLSK(t) \quad (9.10c)$$

Next, aggregated farm income from crops is computed from net income of cash and food crops (as discussed in Chapter 6). The value of property tax used in this computation is based on the assessed capitalized value of all land in crops as will be discussed later in this section.

$$FARMIC(t) = FARICC(t) + FARIFC(t) - VLDTXC(t) \quad (9.11)$$

where:

FARMIC = aggregated net farm income from crops (Ps/year)[1/]

FARICC = net farm income from cash crops (Ps/year)[1/]

FARIFC = net farm income from food crops (Ps/year)[1/]

VLDTXC = value of taxes on land in crop production (Ps/year)[1/]

Due to a lack of data on family expenditure patterns and statistics on the number of family heads operating cattle farms, the computation of living expenditures posed a difficult problem. This was circumvented in the model by developing a simply income-consumption submodel which uses estimates based on experienced judgments. The number of cattle farm operators was roughly estimated from the number of farms supplied by DANE [14] and an annual minimum consumption expenditure was set for the region based on reasonable living requirements per family.[2/] The income-consumption equations attempt to incorporate into the model consumers' behavior related to income elasticity of demand, wealth effects and Engel's law. Savings in the cattle economy are implied when the combined income from cattle and crops exceed consumption expenditures. Equations 9.12 determine the income-consumption relationships discussed above.

[1/] For detailed computation of these variables, see subroutine AGACC in the Appendix.

[2/] The assumed number of farm families is 40,000 and the minimum expenditures for consumption Ps 5,000/family-year.

$$EXPLIV(t) = \max(ALPH2(t)*GINC(t), EXLMIN) \qquad (9.12a)$$

where:

EXPLIV = living or consumption expenditures of cattle farmers (Ps/year)

GINC = aggregated gross income from sales of animals and milk (Ps/year)[1/]

ALPH2 = as defined in Equation 9.12b (proportion)

max(a,b) = the minimum value between a and b.

$$ALPH2(t) = C261 + (C262 - C261)*EXP(-C263*C264*\max(GINC(t) - EXLMIN, 0)) \qquad (9.12b)$$

where:

ALPH2 = a variable which introduces the effect of income upon consumers' behavior (proportion)

C261 = a model parameter determining the minimum proportion of income which is consumed

C262 = a model parameter determining the maximum proportion of income which is consumed

C263 = the rate of consumption expenditures response with respect to changes in income (dimensionless)

C264 = a scale factor

max(a,b) = the maximum value between a and b

EXP = the exponential function.

Equations 9.12 imply that a minimum level of consumption always takes place despite low incomes. Further, when income is low a higher proportion of it is consumed,

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[1/] For detailed computation see subroutine AGACC in the Appendix.

but as this increases the proportion consumed decreases until it is stabilized when high levels are attained. This expenditure pattern reflects consumers' behavior with respect to changes in income. It is clear that by assigning different values to the model parameters in the function ALPH2, a wide range of consumers' behavior can be simulated. The preceding computation can be improved and probably reformulated as more information on this subject is available.

Once aggregated income and consumption are determined, the model generates the farmers' investment capital that is used in component LAMDAC as a constraint to the rate of land modernization (Equations 5.41 and 5.42c). This is computed in Equation 9.13 below, which assumes an internal transfer of capital from the crops sector to the cattle sector.

$$NCFR(t) = \max(FARIL(t) + C239*FARMIC(t) - EXPLIV(t), 0) \quad (9.13)$$

where:

NCFR = net investment capital of farmers (Ps/year)

FARIL = as defined in Equation 9.10c (Ps/year)

FARMIC = as defined in Equation 9.11 (Ps/year)

EXPLIV = as defined in Equation 9.12a (Ps/year)

C239 = a model parameter determining the proportion of income from crops internally transferred to cattle production.

Capital Formation and Export Incentives

Two measurements of internally generated capital by the cattle subsector are considered in the model: the value

of cattle inventories and the value of land. Changes in asset value of cattle over time reflect changes in both prices and cattle population. The asset value of land considered here is based on its capability to generate an income stream independent of location, population pressure and other external factors. Any increase in the asset value of cattle and land not only increases the "wealth level" of farmers but also the collateral value of their assets, enabling them to borrow more capital for further agricultural expansion.

The value of cattle in the model is related to the price of finished males since this is the only price generated by the market model (see Chapter 6, Equation 6.39a for a detailed discussion). It is clear that an expanded market model pricing of each animal category will provide a better estimate of the value of cattle inventories. The model accounts for a likely higher value of animals in the modern sector, and assumes that finished males are not kept in the herd but are marketed as soon as they complete the fattening period.

```
VACAPL(t) = PAP(t)*[C227*(PFGT(t) + C212*PFGM(t)) + C226*
            (PFPT(t) + C212*PFPM(t)) + C224*(OLDFT(t) +
            C212*OLDFM(t)) + C228*(PMGT(t) + C212*PMGM(t))
            + C225*(PMPT(t) + C212*PMPM(t))]                (9.14)
```

where:

VACAPL = value of cattle inventories (Ps)

PAP = producer price of finished males--Equation 7.3 (Ps/animal)

PFGT, PFGM = population of growing females, traditional and modern, respectively--Equation 6.11 (animals)

PFPT, PFPM = population of producing females, traditional and modern, respectively --Equation 6.11 (animals)

PMGT, PMGM = population of growing males, traditional and modern, respectively--Equation 6.11 (animals)

PMPT, PMPM = population of producing males, traditional and modern, respectively--Equation 6.11 (animals)

OLDFT, OLDFM = population of old females, traditional and modern, respectively--Equation 6.12 (animals)

C212 = a parameter accounting for heavier animals from the modern sector

C224, ..., C228 = model parameters determining price relationships between finished males and other sex and age groups (proportion).

The asset value of pasture land used in the model is its capitalized value which is obtained by dividing the annual average returns in a hectare of land by the prevailing interest rate. The total capitalized value in the Costa is the sum of the values of the total land in the traditional and modern sectors. It should be mentioned that the capitalized value of a hectare of agricultural land can be increased by the increase in output, output price and decrease in the cost of production. Furthermore, the change in the interest rate in the economy

affects the capitalized land value. In the model, when the average returns from traditional cattle become negative, the land is valued at a salvage price assumed to be one peso per hectare. But when average returns from modern cattle or crops are negative, the assumed salvage value of land is that of land in traditional cattle production. The capitalized value of land in cattle production is computed in Equations 9.15 below, where RINT attempts to represent the opportunity cost of capital rather than the interest rate of bank loans.

$$VLANDT(t) = \max(SVALT*TTGLR(t), \frac{FARILT(t)}{RINT}) \qquad (9.15a)$$

where:

VLANDT = capitalized asset value of land in traditional cattle (Ps)

TTGLR = total Costa land in traditional cattle--Equation 5.51 (hectares)

FARILT = net farm income from traditional cattle (Ps/year)

RINT = the current rate of interest (proportion/year)

SVALT = the salvage value of traditional land (Ps/ha.).

The computation of FARILT does not account for income and/or liabilities arising from credit. This accounting procedure implies that borrowing does not affect land values and the procedure is also applied in the modern sector. The capitalized value of crop land, VLANDC, is computed in a fashion similar to traditional pasture and is not shown here. Yet there are two exceptions: the salvage value of land discussed earlier, and the farm income that is an aggregate of all cash and food crops. Capitalized values per unit of

land are simply computed dividing total value of land by total land in each use.

$$VLANDM(t) = \max\left(VLNDHT(t)*(TRSL(t) + TLMOD(t)),\ \frac{FARILM1(t)}{RINT}\right) \quad (9.15b)$$

$$VLAND(t) = VLANDT(t) + VLANDM(t) \quad (9.15c)$$

where:

VLANDM = capitalized asset value of land in modern cattle (Ps)

VLAND = capitalized asset value of land in cattle in the Costa (Ps)

VLNDHT = the per hectare capitalized value of the traditional land (Ps/ha.)

FARILM1 = farm income from modern cattle net of credit accounts (Ps/year)

TLMOD = total grazing land in modern production--Equation 5.48 (hectares)

TRSL = land in transition from traditional to modern practices--Equation 5.46 (hectares).

Finally, the model generates the variables associated with the export sector which are needed to evaluate policy alternatives toward cattle exports in Chapter 12. Since the instruments of export promotion have been mainly the payment of subsidies and adjustments in the exchange rate, we will be concerned with these two policy elements here. Export subsidies are paid as a proportion of the peso value of exports and are computed as follows:

$$SUBSE(t) = FOREX(t)*EXCHR(t)*EXSUB \quad (9.16)$$

where:

SUBSE = export subsidies paid to cattle sector (Ps/year)

FOREX = foreign exchange earnings from cattle exports--Equation 9.17 (US $/year)

EXCHR = the official exchange rate--a policy variable--Equation 9.18a (Ps/dollar)

EXSUB = the export subsidy--a policy variable (proportion of value of exports).

Foreign exchange earnings are simply computed as:

$$FOREX(t) = WPB(t)*EXPL(t) \qquad (9.17)$$

where:

WPB = world (FOB) price of beef--Equation 7.1a (US $/animal)

EXPL = official cattle exports--Equation 6.26c (animals/year).

Exchange rates are computed for the relevant period of cattle exports starting in 1964. Between 1964 and 1966, exchange rate values are those recorded by the International Monetary Fund [44], and average values for 1967 and at the beginning of 1968 are those recorded by the Central Bank [3]. From 1968 forward the exchange rate is projected at the rate of increase observed during the period 1967 to 1972 [45]. These computations performed in Equations 9.18 below incorporate into the model the effect of a fluctuating exchange rate introduced by the Colombian government in March 1967.

$$EXCHR(t) = \begin{cases} 0 \text{ (i.e., undefined)} & 0 < t < 4 \\ 12.77,\ 13.5,\ 13.5,\ 14.5,\ 15.76 & 4 \leq t \leq 8 \\ EXCHR(t-DT) + DT*RCHEX(t-DT) & t > 8 \end{cases} \qquad (9.18a)$$

where:

EXCHR = as defined in Equation 9.16 (Ps/dollar)

RCHEX = the rate of change in the official exchange rate--Equation 9.18b (Ps/year).

$$RCHEX(t) = AL1*EXCHR1968*EXP(AL1*(t-8)) \qquad (9.18b)$$

where:

AL1 = the annual exchange rate growth rate (proportion/year)

EXCHR1968 = the official exchange rate at the beginning of 1968 (Ps/dollar)

EXP = the exponential function

t = time (years).

Given exchange rates, export subsidies, and domestic and world price of beef from component PG, the model computes the export margin, EXMAR, as a proxy for the competitive position of Colombian beef in international markets. Another way of looking at EXMAR is as the profit for beef exporters. When exports are made in the form of carcass beef it is assumed that revenues from viscera, hides and other by-products cover slaughtering and handling costs. In Equation 9.19 below, the export subsidy, EXSUB, is reduced by a factor of .8 to account for the discounted price at which the tax certificates used to pay the subsidy are sold in the market. A negative export margin indicates that Colombian beef is priced out of international markets at the going effective rate of exchange.

$$EXMAR(t) = WPB(t)*EXCHR(t)*(1 + 0.8*EXSUB) - PA(t) \qquad (9.19)$$

where:

EXMAR = the profit margin of beef exports (Ps/animal)

EXCHR = as defined in Equation 9.16 (Ps/dollar)

WPB = world price of beef--Equation 7.1a (US $/animal)

EXSUB = the export subsidy--a policy variable (proportion of value of exports)

PA = market price of finished males--Equation 7.2 (Ps/animal).

Performance Criteria

Equations 9.20 through 9.23 compute a number of performance variables of the Costa model. These include: (1) farm assets and income; (2) foreign exchange and government revenues; (3) government expenditures on modernization campaigns; and (4) beef consumption. Other performance measures which may be useful in evaluating alternative modernization policies include output variables from other components. Examples of these are total cattle population, extraction ratios, and animals treated against contagious diseases.

Equations 9.20 compute value of capital in cattle production and farm income.

VALCAP(t) = VACAPL(t) + VLAND(t) (9.20a)

FARMI(t) = FARIL(t) + FARMIC(t) (9.20b)

FARMIA(t+DT) = FARMIA(t) + DT*FARMI(t) (9.20c)

FARILA(t+DT) = FARILA(t) + DT*FARIL(t) (9.20d)

$$DSREVL(t+DT) = DSREVL(t) + DT*FARIL(t)*EXP(-DIR*t) \quad (9.20e)$$

where:

VALCAP = total value of animal population and grazing land (Ps)

FARMI = total agricultural income (Ps/year)

FARMIA = accumulated agricultural income (Ps)

FARILA = accumulated farm income from cattle (Ps)

DSREVL = discounted future returns from cattle (Ps)

DIR = the discount rate (proportion per year).

Foreign exchange earnings and government revenues are computed by Equations 9.21.

$$FOREXA(t+DT) = FOREXA(t) + DT*FOREX(t) \quad (9.21a)$$

$$GOVREV(t) = TAXCT(t) + TAXCM(t) + VLDTAX(t) \quad (9.21b)$$

$$GOVREVA(t+DT) = GOVREVA(t) + DT*GOVREV(t) \quad (9.21c)$$

where:

FOREXA = accumulated foreign exchange earnings from cattle (Ps)

GOVREV = government revenues from the cattle sector (Ps/year)

TAXCT, TAXCM = value of taxes on traditional and modern cattle, respectively--Equations 6.34 (Ps/year)

VLDTAX = value of taxes on land based on the aggregated capitalized land value--Equations 6.33 and 9.15c (Ps/year)

GOVREVA = accumulated government revenues from the cattle sector (Ps).

Government expenditures on modernization campaigns, Equation 9.22, include allocation of funds for development credit and control of foot-and-mouth disease (FMD).

$$ACRDTA(t+DT) = ACRDTA(t) + DT*ACRDT(t) \quad (9.22a)$$

$$EXPDS(t+DT) = EXPDS(t) + DT*EXPAFT(t) \quad (9.22b)$$

where:

ACRDTA = accumulated funds allocated for development credit (Ps)

EXPDS = accumulated public expenditures on control of FMD (Ps).

Finally, beef consumption is computed in Equations 9.23 for the total Colombian population.

$$POP(t) = POPO*EXP(C282*t) \quad (9.23a)$$

$$PERCAP(t) = \frac{C281*(SUPB(t) - EXPL(t) - UNEXPL)}{POP(t)} \quad (9.23b)$$

where:

POP = total Colombian population (habitants)

POPO = total Colombian population at the beginning of simulation (habitants)

C282 = the rate of growth in population (porportion habitants/year)

PERCAP = the Colombian per capita beef consumption (kgs/habitant-year)

SUPB = total Colombian beef supply--Equation 6.25b (animals/year)

EXPL = registered beef exports--Equation 6.26c (animals/year)

UNEXPL = non-registered beef exports--Equation 6.26c (animals/year)

C281 = the average dressed carcass weight (kgs/animal).

Table II.8 shows the values of a selected number of variables used in component CRTACC.

TABLE II.8. Selected Coefficients and Initial Values in the Accounting and Performance Criteria Component (CRTACC).

Definition (Equation No.)		Value
LT1 (9.1a)	Determines the time development loans are paid (years)	3
LT2 (9.1b)	Completes the grace period (years)	1
LT3 (9.1c)	Determines the time development loans are repaid (years)	8
RINTL (9.8b)	Determines the interest rate on development loans (proportion of debt/year)	.14
PEQCR (9.9a)	Determines the proportion of equity which can be used as a credit base (proportion/year)	.5
CREPR (9.9e)	Determines the repayment rate on short term loans (proportion of debt/year)	1
RINTC (9.9g)	Determines the interest rate on short term loans (proportion of debt/year)	.1
EXLMIN (9.12a)	Determines the farmers aggregated minimum living expenditures (thous. Ps/year)	200,000
SVALT (9.15a)	Determines the salvage value of traditional grasslands (Ps/ha)	1
RINT (9.15a)	Determines the opportunity cost of capital (porportion/year)	.18
EXSUB (9.16)	Determines the export subsidy (proportion of value of exports)	.15
AL1 (9.18b)	Determines the rate of growth in the exchange rate (proportion/year)	.0728
C212 (9.14)	Determines increased weight of "modern" animals (dimensionless)	1.4
C239 (9.9c)	Determines internal transfer of capital from crops to cattle production (proportion)	.1

TABLE II.8. (continued)

Definition (Equation No.)		Value
C261 (9.12b)	Determines the minimum consumption from gross income (proportion)	.25
C262 (9.12b)	Determines the maximum consumption from gross income (proportion)	.75
C263 (9.12b)	Governs response rate of consumption to changes in income (dimensionless)	.3
C264 (9.12b)	A scale factor (dimensionless)	10^{-8}
C281 (9.23a)	Determines the average dressed carcass weight (kgs/animal)	200
C282 (9.23a)	Determines the rate of growth in population (proportion habitants/year)	.032
EXCHR1968	Official exchange rate at the beginning of 1968 (Ps/dollar)	15
POPO (9.23a)	Initial Colombian population (thous. habitants)	15,415.7

Sources: [3, 5, 17, 41, 42, 45] and initial guesstimates and model tuning.

P A R T I I I

VALIDATION AND TESTING

Introduction

Model testing is an ongoing process which should continue even after a model is implemented and in routine use. Testing, refining and validating a model are closely connected processes. A simulation model is tested both to check its internal consistency and to assure that it is an adequate representation of the complex processes of the real world. The validity of a model has to be established with some degree of confidence before a decision maker can base policy decisions on the experimental results of that model.

There are primarily three ways in which a model may be validated. The first method compares the structure of the model and its simulated output, using alternative assumptions about its behavior established by experts and from other published sources. This test uses the intuitive knowledge and expertise of people who have experience in Colombia and other developing countries.

The second approach attempts to compare the behavior predicted by the model under various conditions with what actually occurs as real time passes under the same conditions. Or alternatively, the model can be used to reproduce

historical data from the real world which are not used in the construction of the model. Once the model has been implemented, it is tuned and updated as an ongoing process with such comparisons.

Finally, sensitivity tests, which identify which of the model's parameters outcomes are most sensitive to their value changes, can also be conducted to validate the logic and internal consistency of the model.

Chapters 10 and 11 briefly discuss the model's data requirements and problems and examine two of the approaches commonly used to deal with these problems. These are tuning the model to track recorded time series and analyzing the model's sensitivity to variations in parameter value.

CHAPTER 10

DATA USAGE AND MODEL TUNING

Data requirements for the model are extensive. Data were obtained from a diversity of sources[1/] that included Ministry of Agriculture reports, FAO reports, World Bank reports, FEDEGAN reports, INCORA reports, Caja Agraria reports and statistics, DANE and Central Bank statistics, other published reports and informal guesstimates. Other data used were "synthesized" or "simulated" from various combinations of data. Often costs were one point estimates obtained from published sources that were later converted to base year values by means of indexes reflecting the rate of inflation in prices of farm inputs. Aside from the secondary sources, some informal primary information was obtained from a two-week survey of the Costa made in the summer of 1971. Yet, the data problems encountered were many and ranged from nonexistent information to unreliable and contradictory estimates. In Colombia, as in other developing countries, existing statistics on agricultural production are so deficient and deserve so low a degree of confidence that they create a problem in planning for

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[1/] Detailed references are found in Chapters 1 through 3.

agricultural development. A few exceptions include estimates on area harvested and of the production of cotton, coffee, tobacco, bananas for export and sugarcane for sugar production. In the case of other crops and cattle the estimates are no more than conjectures [40].

However, researchers, planners and policy makers cannot wait for accurate and reliable data to recommend, plan, and make decisions on policies and programs for development. Models have to be designed on the basis of the best information that is readily available, and techniques may be used not only to improve the quality of data but also to make best use of the data available at the time.

The system simulation approach offers three ways of coping with the information problem. Sensitivity tests (discussed in the next two chapters) can reveal the implications of parameter variability both for the validity of the model and for policy formulation. These tests can also provide guidance for determining priorities for data gathering activities. Secondly, given coarse probability distributions for a set of key parameters, running the model in a Monte Carlo mode can generate directly output statistics reflecting data uncertainties [1, Chapter 4]. Finally, the model may be tuned to track a number of recorded reliable time series by adjusting uncertain parameter values. This procedure will be discussed later in this chapter.

The entire data input to run the model can be found in various chapters where this information is relevant and

and in the Appendix. Tables present the numerical values of the parameters and coefficients used to run the model in its deterministic mode, since time constraints precluded use of a stochastic determination of their values.

Model Data Requirements

Data for the Costa cattle/crops model fall into four general categories: system parameters, technological coefficients, initial conditions, and historical time series. The data requirements of the first three categories are extensive and obtained from a diversity of sources including descriptive information and guesstimates from knowledgeable persons. In this section, we will briefly discuss the first three categories of data and their sources. Historical time series, used in tuning the model, will be discussed in the next section.

System Parameters

Fundamentally, system parameters reflect the behavioral characteristics of the system being modeled. These parameters and the interconnected basic equations, in fact, define the system. A few examples of the many system parameters of the Costa model are:

1. the land modernization and disinvestment profitability response parameters (E9, E8 in Equation 5.36 and E91, E81 in Equation 5.47);
2. the land use response rate parameter (CL1 in Equation 5.21);
3. the profitability discount rate (DIR in Equation 5.31);

4. the many delays and averaging and smoothing lags of the model (e.g., XDEL in Equations 5.43, DEL15, 16 and 17 in Equations 5.1);

5. the sales restriction parameters (BMN, BMX, AMX and AMN in Equations 6.22);

6. the farmers' resource use profitability response parameters (C235, C236 in Equation 6.36);

7. the income elasticity of expenditure parameters (C261, C263 in Equation 9.12b).

There is little or no information on most of the behavioral system parameters and acquisition of this type of data would entail survey research that has never been conducted. The values used in the early stages of building and testing the model were educated and intuitive guesstimates acquired from various secondary sources [e.g., 29, 42, 53], from experiences in other developing countries (mainly experience acquired by the Michigan State University simulation team for Nigeria) and from such primary sources as interviews with Colombian officials and farmers in the Costa. Although values of selected system parameters are shown in Tables III.1 and III.2, we will take a close look here at the pasture land modernization and reversion transition response thresholds as an example (E9 and E91 in Table III.1). The value of E9 shown (.5) means that the alternative to traditional grazing must be at least 50 percent more profitable before farmers will transfer the land to modern management. And the value of E91 (.3) means that the profitability of the modern operation must be at most 30 percent higher than that of the traditional one before farmers will reverse the modernization process. The relative

TABLE III.1. Profitability Response Parameters for Traditional and Modern Grazing (Dimensionless).

Variables (Eqn. No.) (definition)	Present Uses	Alternative Uses	
		Modern Grazing	Traditional Grazing
E9 (5.36) (response threshold)	Traditional Grazing	.5	--
E91 (5.47) (response threshold)	Modern Grazing	--	.3
E8 (5.36) (governs response rate)	Traditional Grazing	1.0	--
E81 (5.47) (governs response rate)	Modern Grazing	--	2.0
DIR (5.31) (discount rate)		.15	.15

Source: Initial guesstimates and model tuning.

TABLE III.2. Cattle Production Parameters.

Definition (Equation No.)		Value
MKM (7.3)	Marketing margin	.15
C213 (6.24)	Proportion of dead animals consumed	0
C214 (6.24)	Proportion of fertile cows sold for slaughter	.6
C215 (6.24)	Proportion of growing females sold for slaughter	.2
C216 (6.24)	Proportion of growing males sold for slaughter	0
C242 (6.27a)	Proportion of heifers treated against brucellosis	.05
C244 (6.28b)	Annual proportion of animals privately treated against foot-and-mouth disease	.3

Source: [29, 31, 63, 64] and initial guesstimates and model tuning.

values hypothesize different farmer attitudes (e.g., risk aversion and uncertainty as discussed in Chapter 5) toward cattle modernization.

Despite the lack of accuracy in parameters such as those highlighted above, they play an important role in the validation of the model. Some of them provide a range of values which may be tested in tuning the model to track historical time series and to improve the model's behavior in comparison to "reality." Some others, as shown by sensitivity tests, are not crucial to the model's performance and therefore the results are more sensitive to other elements in the system.

Technological Coefficients

Technological coefficients are probably the easiest to obtain and handle in the model. The various sources of data include Ministry of Agriculture reports, FAO reports, World Bank reports, INCORA reports, FEDEGAN reports and many other published reports [e.g., 5, 9, 20, 29, 31, 32, 33, 42, 43, 57, 58, 60, 61, 66]. The existence of data for these parameters does not mean they are completely reliable. Instead, more research and field work will be necessary to increase their level of confidence.

Some examples of technological coefficients used in the model are:

1. crop yields (YLDCL, YLDCU and YLDFC in Equations 6.2);
2. pasture yields (e.g., CGOU, CGOU1, CGOL and CGOL1 in Equations 6.3);

3. costs of production (e.g., CSTHCU, CSTHCL and CSTHFC in Equation 6.29b);

4. average carcass weight per slaughtered animal (C281 in Equation 9.23b);

5. mean times spent in the cattle production stages (DGROF, DGROM, DPRODF and DPRODM in Equation 6.10a).

Almost all the technological coefficients remain constant throughout a simulation run. Some exceptions are costs of production and price of crops that change with domestic inflation, and crop yields. Learning curves for yields are discussed in detail above in component AGPRAC, Equation 6.1. Values of selected technolgoical coefficients are presented in Tables III.3 and III.4.

Initial Conditions

Initial conditions (1960) define initial values of all levels (and some rates) that must be given before the first cycle of model computations can begin. Since their values change during the course of a run they must be reset at the start of each run. Some of these include:

1. land usage (e.g., TLFCO, TLCRL and TLCRU in Equations 5.4, 5.11 and 5.24);

2. cattle population in each cohort (PMG, PMP, PFG, PFP and OLDF in Equations 6.11 and 6.12);

3. crop prices and price averages (component Price Generation, Chapter 7)

4. total demand for beef (TDEM in Equation 6.26c).

Some of these variables present no data problems. For instance, assuming all cattle population at time zero (1960) is traditional, we determine that modern population in each cohort is zero. But the model is quite sensitive

to the initial cattle inventories, as we shall discuss later (Chapter 11), so more complete and accurate cattle population estimates would increase this model's accuracy. Values of selected initial conditions are shown in Table III.5.

It must be stressed that the model can be useful for planning economic development, in spite of imprecise parameter estimates, for it is not necessarily the aim of a development model to forecast in absolute terms the values that will be attained by certain variables at a specified time. The aim is to design a strategy of development by experimenting with the model under various assumptions and then by comparing alternatives.

Tuning

The major components of the Costa model were programmed, simulated and tested individually as part of the overall model-building process. During this process, conceptual and programming errors were detected and corrected, and then the components were integrated into the Costa model. Extensive model tests were performed on the larger model to eliminate programming errors and inconsistencies between related model components, and to examine its correspondence with the real system. Checking the model against time series of past behavior and adjusting the values of certain system parameters, adding new mechanisms, or modifying structural relationships is what is known as "tuning" the model. These checks are made before the model is implemented and they suggest which

TABLE III.3. Pasture and Crop Yields (tons/ha-year).

Pastures (Average TDN Yields)* (Variable) (Eqn. No.)	
Uplands	
Traditional artificial (CGOU) (6.3a)	3.48
Traditional native (CGOU1) (6.3b)	1.16
Modern artificial (CGU1) (6.3c)	5.0
Modern native (CGU2) (6.3d)	1.7
Lowlands	
Traditional artificial (CGOL) (6.3a)	3.8
Traditional native (CGOL1) (6.3b)	1.26
Modern artificial (CGL1) (6.3c)	5.1
Modern native (CGL2) (6.3d)	1.7
Land in Transition	
Transition artificial (CG3) (6.9b)	3.3
Transition native (CG4) (6.9b)	1.16
Crops	
Cash crops in lowland (YLDCL) (6.29a)	1.56
Cash crops in upland (YLDCU) (6.29a)	1.11
Food crops (YLDFC) (6.29a)	8.3

*TDN = Total digestible nutrients

Sources: [7, 33, 61, 66] and

Instituto Colombiano Agropecuario (ICA), Dia de Campo-Pastos y Forrajes--Ganado de Carne. (Monteria, September 12, 1970), 28-58.

_____. "Algunos Aspectos de la Fertilizacion de Pastos." Pastos y Ganados para la Costa Atlantica. Boletin Tecnico No. 15 (Bogota, 1967), 33-42.

_____. El Pasto Puntero. Hoja Divulgativa No. 029. (Bogota, April, 1970), 1-4.

_____. El Pasto Guinea. Hoja Divulgativa No. 029. (Bogota, March, 1971), 1-4.

TABLE III.4. Mean Length of Cattle Production Stages (years).

Production Cohorts* (Variable) (Eqns. No.)	
Growing females (DGROF) (6.10a)	2.5
Growing males (DGROM) (6.10a)	2.5
Producing females (DPRODF) (6.10a)	10.0
Producing males (DPRODM) (6.10a)	3.0

*Traditional and modern

Sources: [5, 29, 61, 66]

TABLE III.5. Selected Initial Conditions (1960).

Cattle Population (thousand head) (Variable) (Eqn. No.)	
Growing males (PMGT) (6.11)	1,174
Growing females (PFGT) (6.11)	1,183
Producing males (PMPT) (6.11)	943
Producing females (PFPT) (6.11)	2,424
Old cows (OLDFT) (6.12)	427
Land Use (thousand hectares) (Variable) (Eqn. No.)	
Cash crops in lowlands (TLCRL) (5.11)	140.5
Cash crops in uplands (TLCRU) (5.24)	281.0
Food crops (TLFCO) (5.4)	101.73
Export banana (TLBAN) (5.13)	20.0
Grazing land in region 1 (TGLSF1) (5.1d)	2,510.36
Grazing land in region 2 (TGLL) (5.16)	319.8
Grazing land in subregion 1 (TGLU1) (5.26)	1,471.7
Grazing land in subregion 2 (TGLU2) (5.18)	1,252.3

Sources: [Table I.2, 8, 15, 16, 29] and initial guesstimates and model tuning.

parameters need adjustment, or where a structural relation must be added to the model to improve its behavior in comparison to "reality."

Despite the deficiency of Colombian statistics on agricultural production, four time series (1961-1970) were used initially in tuning the Costa model: Colombian supply of beef, market price of finished males, land in crops, and cattle population in the Costa. Since the modernization campaign promotion started in 1965, the tuning process included many of the parameters and structural relationships used in the modernization decisions, and the simulated series reflect the effects of the first five years of campaign implementation. The combination of traditional management before 1966 and modern management with improvement of artificial grasses and substitution of artificial for native grasses (alternative 2) from that year on was used as a standard run for tuning the model. Alternative 2 was selected because it patterns more closely the modernization program currently carried out in the Costa. Plots of the above simulated series along with the actual ones are depicted in Figures III.1 and III.2. Table III.6 displays the four time series resulting after the initial coarse tuning. Data values generating this fit were used in the policy runs discussed in Chapter IV.

Although mathematical measures of the goodness-of-fit could have been used as a criterion to measure past behavior characteristics [1, 21, 53], at this stage in the

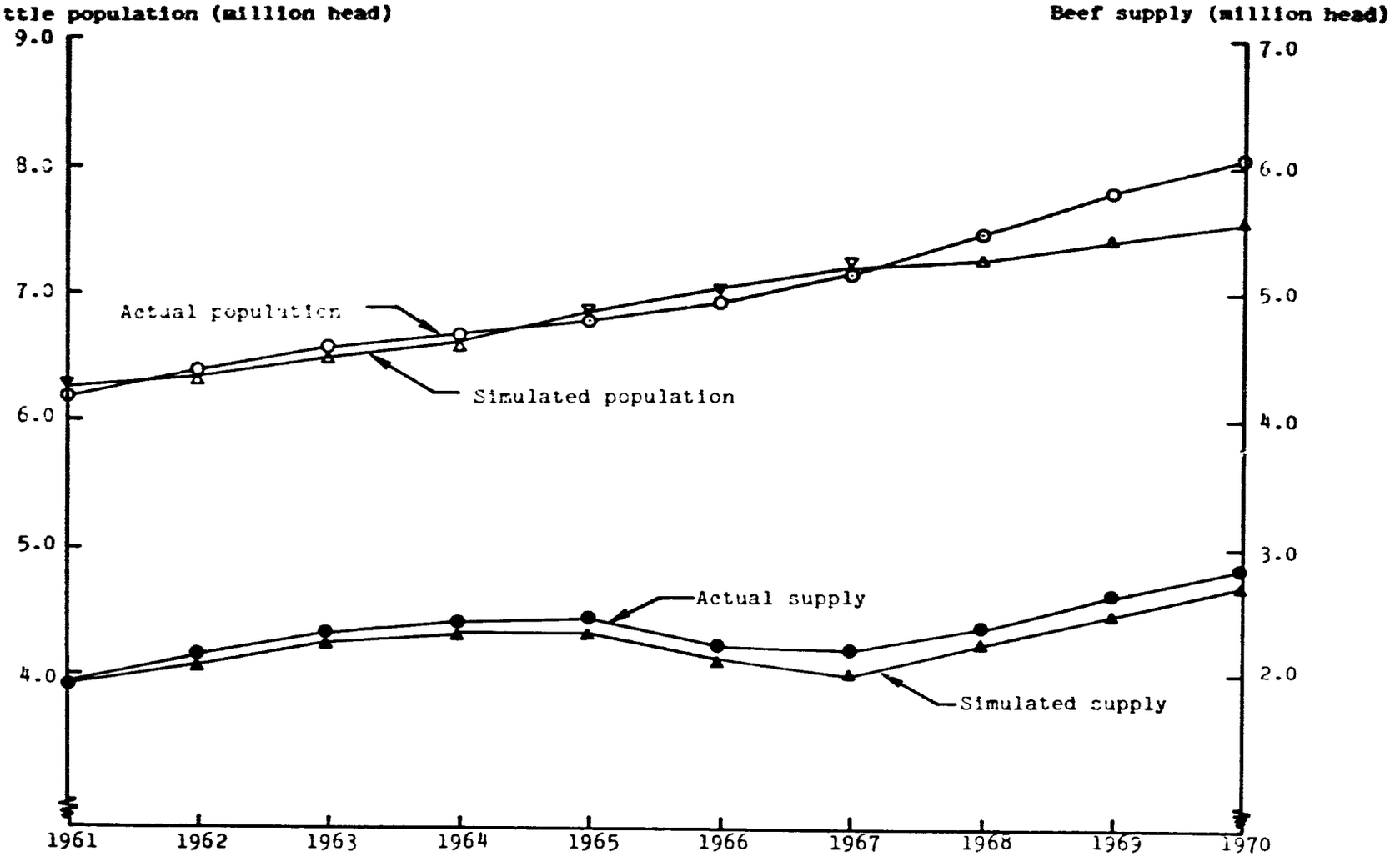

Figure III.1. Results of "coarse" model tuning--cattle population in the Costa and Colombian beef supply time series against simulated series. Cattle inventories are taken at the end of the year.

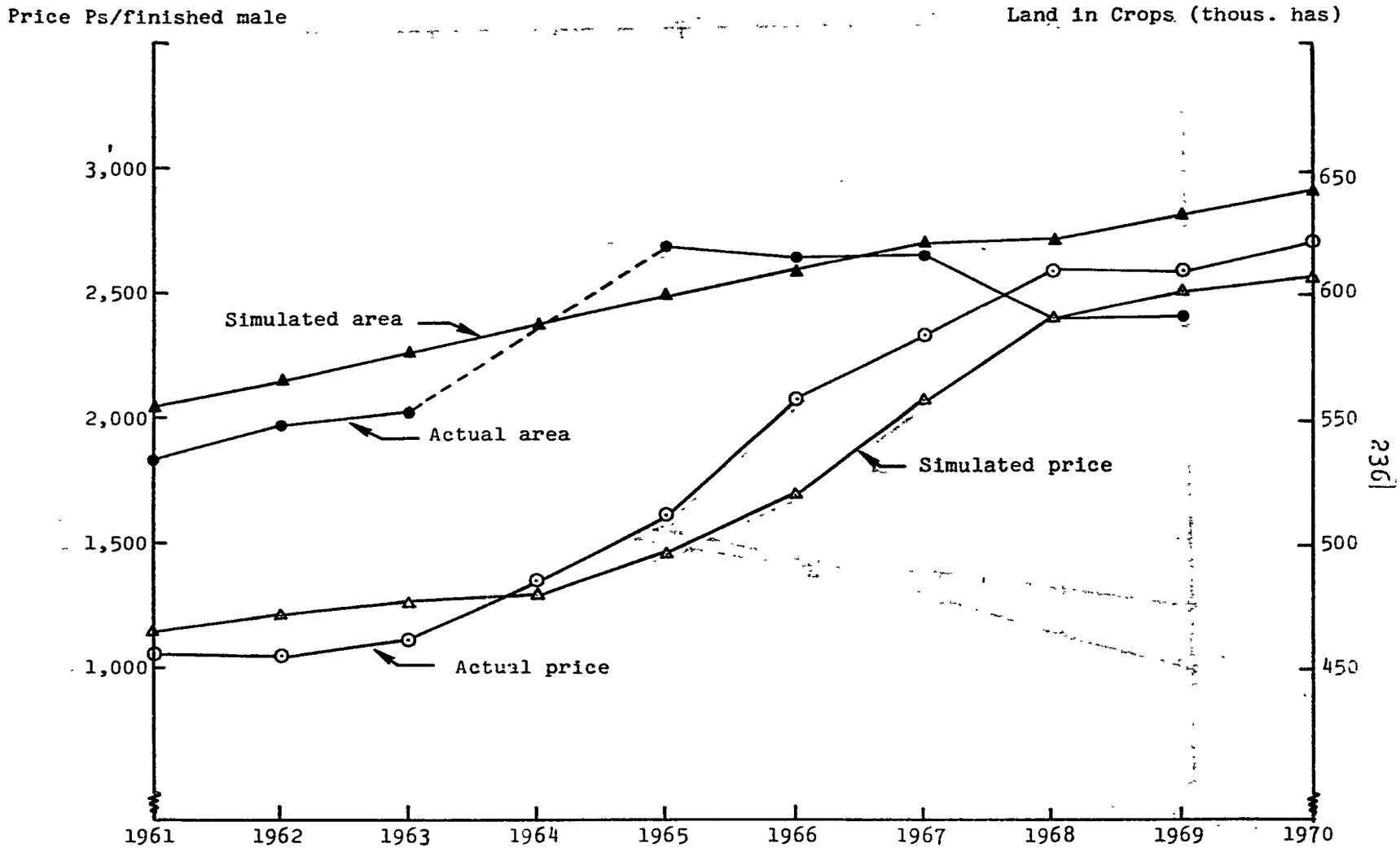

Figure III.2. Results of "coarse" model tuning--market price of finished males and land in crops time series against simulated series.

TABLE III.6. Time Series Tracking.

Year	Colombian Beef Supply (thous. animals/yr.) DATA	SIMULATED	Cattle Population in the Costa (thous. animals) DATA	SIMULATED	Land in Crops in the Costa (thous. has.) DATA	SIMULATED	Price of Finished Males (Pesos/animal) DATA	SIMULATED
1961	1,965	1,970	6,200	6,235	533.3	555.1	1,058	1,150
1962	2,145	2,123	6,400	6,356	548.2	565.9	1,054	1,236
1963	2,305	2,292	6,560	6,492	552.5	576.7	1,117	1,272
1964	2,418	2,350	6,680	6,656	n.a.	587.7	1,346	1,322
1965	2,469	2,324	6,800	6,856	619.4	599.0	1,629	1,459
1966	2,228	2,156	6,920	7,054	614.7	610.4	2,089	1,718
1967	2,205	2,006	7,160	7,181	616.7	620.6	2,345	2,097
1968	2,360	2,235	7,480	7,284	589.7	622.7	2,606	2,425
1969	2,624	2,485	7,800	7,403	589.6	633.4	2,599	2,523
1970	2,820	2,710	8,080	7,555	n.a.	642.4	2,729	2,567

n.a. = not available

Sources: As indicated on pp. 238-39.

development of the model more emphasis was placed on the general qualitative nature of particular interrelationships in the various model components that, in concert, produce the behavior that interests us in the actual system. Nevertheless, a close look at Figures III.1 and III.2 reveal a closeness between simulated and observed real-world data that increases confidence in use of the model as an experimental tool to study the effect of structural and policy changes in the actual system.

During the period 1961-1967, the observed prices plotted in Figure III.2 are the national average of current prices as reported by Garcia Samper [23]. But between 1968 and 1970, prices are a weighed average of finished males at the Medellin stockyard as reported by the Central Bank.[1/] Since Medellin prices for live animals are usually higher than in other markets, the average prices of finished males computed in Table III.6 for the period 1968-1970 are likely overestimated in relation to nationwide averages. This means that if national averages were used instead of Medellin averages for the last three-year period of observations, the match of the recorded and simulated price series in Figure III.2 would have been even closer. Estimates of cattle population and beef supply were obtained from DANE[2/] and

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[1/] Banco de la Republica, "Resumen de las Principales Ferias de Ganado en el Pais," Revista del Banco de la Republica, XL-XLIII (1967-1970), Bogota.

[2/] Departamento Administrativo Nacional de Estadistica, Pronosticos y Estimaciones Agricolas, (Bogota, 1971), p. 24.

those of land in crops from Caja Agraria.[1/] Cattle population in the Costa was assumed to remain at a constant 40 percent of Colombian cattle population.

Consistency Checks

Consistency checks are useful in evaluating the basic equations used to simulate real world behavior and to test the value of their associated parameters. Changes in parameter values and functional relationships may result after comparing the model's data with reliable data given by others. The demographic model with input data from alternative 2 was used to make comparisons with some of the productivity relationships given by the CIAT survey [9]. These relationships include average grazing rate, average daily per hectare milk production and average cows per hectare. As Table III.7 shows, the results of these checks indicate that, on the basis of data from actual records, the model's program is performing reasonably well in reproducing real world situations. In the following development of internal consistency checks, these definitions are used.

TOPOPR	= total cattle population in the Costa (animals)
TGLR	= total grazing land in the Costa (hectares)

[1/] Caja de Credito Agrario, "Calculos de Produccion Agricola de 1958 a 1963," Carta Agraria, Anexo al No. 144 (Sept. 1964), Bogota, I-IV.
Idem, "Estimativos Sobre Areas Cultivadas y Produccion Obtenida Para Los Principales Cultivos, 1965-1969," Carta Agraria, No. 244 (Nov. 1970), 5-14.

TABLE III.7. Results of Consistency Checks.

Productivity Index	Model (1970)	CIAT (1971)
Cattle head/ha.	1.46	1.45
Cows/ha.	.59	.56
Lts. milk/ha.-day	.6	.93

PFCT, PFCM = total traditional and modern cow population (producing and old females), respectively (animals)

QMCT, QMCM = total traditional and modern quantity of milk produced, respectively (liters/cow-day)

FERT, FERM = total number of traditional and modern fertile cows, respectively (animals)

PFLACT, PFLACM = proportion of traditional and modern lactating cows, respectively

CT202, CM202 = proportion of traditional and modern lactating cows which are milked, respectively.

The following equations define some of the productivity indices tested:

$$\text{Cattle head/ha.} = \frac{TOPOPR(t)}{TGLR(t)}$$

$$\text{Cows/ha.} = \frac{PFCT(t) + PFCM(t)}{TGLR(t)}$$

$$\text{Lts. milk/ha.-day} = \left[\frac{PFCT(t)}{PFCT(t) + PFCM(t)} * (QMCT(t) - QMCM(t)) + QMCM(t)\right] * \frac{(FERT(t) * PFLACT(t) * CT202 + FERM(t) * PFLACM(t) * CM202)}{TGLR(t)}$$

General Validation

Although the Costa model has been designed to experiment with four alternatives to traditional cattle management (see Chapter 4), manpower and time constraints required this policy experimentation be limited to one alternative. Briefly, alternative 1 considers the improvement of native and artificial grasses; alternative 2 considers the improvement of artificial grasses and the substitution of artificial for native grasses; alternatives 3 and 4 add the production of forages and silage to the improvement of range lands in alternatives 1 and 2, respectively. While alternatives 3 and 4 presented the problem of predicting the consequences of practices never done in the past, and alternative 1 implied little improvement over traditional practices, alternative 2 showed the ability to reproduce a pattern similar to the actual system. This ability was demonstrated during the process of tuning the model discussed earlier. It was fortunate that a modernization program was in effect in the region during the last five years of the period used to tune the model. This circumstance allowed evaluation of the reasonableness of the data and functional relationships employed in building the model, and increased confidence in alternative 2 as a predictor of the value of the real system over the future and as the "standard" or "base" run for policy experimentation.

Nevertheless, as part of the general validation of the model, the four alternatives were tested and compared under the same underlying general assumptions described in

Chapter 12 for the base run. As a first approximation, most of the system parameters and technological coefficients used in testing alternatives 1, 3, and 4 were the same adopted for alternative 2. However, new auxiliary equations and technological coefficients were introduced, and some system parameters changed as required by the nature of a particular alternative. While it is true that no strict statistical or econometric methods of verification and validation were used, less rigorous objectivity tests were applied repeatedly in assembling data, modifying and developing model components, combining smaller into larger model components and in evaluating model output. The objectivity of concepts or empirical theories requires that they be:

1. consistent with observed and recorded experience,
2. internally and logically consistent,
3. interpersonally transmissable, and
4. workable when used to solve problems.

Table III.8 summarizes the output of selected variables at the end of 25 years of simulation time. The results of this test suggested that more experimentation was necessary in order to better fit the behavior of the real system. This was especially true of all behavioral parameters and more specifically of those that control the modernization decisions in Equation 5.36.

As Table III.8 shows, no modernization takes place (TMPL = 0) when alternative 1 is considered as a means of improving cattle production. This result indicates that,

TABLE III.8. Selected Results of Alternatives to Traditional Cattle Production--1985.

Variables / Type of Modern Management	Cattle Population in the Costa	Land in Forages	Land in Cash Crops	Modern Pasture Land	Traditional Grazing Land	Accumulated Farm Income from Cattle	Accumulated Government Revenue from Cattle	Living Expenditures	Market Price of Finished Males	Beef Consumption Per Capita
	TOPOPR (thous head)	TLF (thous has)	TLCC (thous has)	TMPI (thous has)	TTGLR (thous has)	FARILA (mill Ps)	GOVREVA (mill Ps)	EXLIV (mill Ps)	PA (Ps)	PERCAP (Kgs)
Alternative 1	7,077	0	628.0	0	5,125	30,980	2,561	2,334	10,570	18.8
Alternative 2	9,211	0	625.7	725.0	4,375	32,280	2,721	2,750	9,916	19.96
Alternative 3	16,720	553.1	625.2	2,019	2,556	1,860	3,334	3,860	7,176	25.42
Alternative 4	15,010	225.6	625.7	1,512	3,390	18,910	3,364	3,404	7,274	24.34

given the model assumptions, the expected profitability of this alternative over the planning horizon does not produce the necessary incentive to induce farmers to change their traditional practices. We must remember that in the decision mechanism set in the model (Equation 5.36) modernization does not begin unless the perceived relative profitability (PDR) of the modern operation is larger than the value of the threshold parameter (E9). This and the response rate parameter (E8) are used to simulate farmers' attitudes toward the new methods of production, and as stated earlier, they have been assigned the same values as in alternative 2. But the minimum risk involved in alternative 1 suggests that farmers might react differently than they do when facing the more risky alternative 2. This consideration does point out the need of experimenting with other parameter values in the transition response function of alternative 1.

In alternatives 3 and 4 the transition response is the greatest as shown by the total modern pasture land (TMPL) and the cattle population (TOPOPR). However, these alternatives involve the greatest risk since they include the use of silage during the dry season which is a practice unknown in the region except for some experimental trials. In addition, they require the planting of large areas in forages that, in the case of alternative 3, almost equal that of cash crops. This implies a great effort on the part of both farmers and agencies supplying services--particularly in a region where cropping has not been the leading agricultural activity.

The effect of a too rapid rate of modernization in alternatives 3 and 4 is shown by the declining and lower value of the accumulated income from cattle (FARILA). As a matter of fact, income from the modern operation becomes negative in some years as a result of lower animal prices arising from larger supplies, increased operating costs from producing silage and larger expenditures on land improvement. The preceding discussion suggests that the simulated decisions of farmers in alternatives 3 and 4 have to be adjusted to a rational behavior more attuned with their profit and cash flow positions, and market situations.

Tuning the standard run to track four time series was a necessary but insufficient condition to validate the model. Confidence is confirmed by the correspondence of total model behavior to that of the actual system. And this is accomplished in a process of intuitive, theoretical, and empirical consistency analyses. This general process of model validation is very judgmental and should be viewed as an iterative and ongoing process of the model's development and application. Although different validation techniques have been applied to complex general systems simulation and econometric models used for decision making, the quest for better model evaluation methods continues among researchers. Detailed discussions of the methodological and philosophic issues involved in the process of validating and verifying complex models are found in Rossmiller, et al. [62], Johnson and Zerby [49], Fromm [22] and Shapiro [65].

CHAPTER 11

RESULTS OF SENSITIVITY ANALYSIS

The primary purpose of sensitivity tests is to indicate those areas of the model in which changes in parameter values or formulations have a significant impact on model results. Such information is useful, not only for model tuning and validation, but also for policy making and as a guide to data collection priorities. Sensitivity tests on an individual or combination of parameters are essential in model development since they enable us to check the internal consistency of the model against the theoretical and empirical knowledge we have on the real system. Additionally, they indicate those portions of the model which deserve the greatest additional research. Time and money can be saved by not studying parameters that have little or no effect on the results. Thus, the efficiency of both research and the decision-making process are improved. The preceding uses of sensitivity analysis have been explained in detail and exemplified by Abkin [1, Chapter 9]. An analysis of the results of a series of sensitivity runs of the Costa model is presented in the following section.

Analysis of Results

Methodology

The series of 17 sensitivity runs conducted with the Costa model investigate the effects of varying 45 selected coefficients. These 45 parameters are broken down into: (a) 12 production coefficients; (b) 12 land allocation coefficients; (c) 11 price and cost coefficients; and (d) 10 time lag or smoothing parameters. The production coefficients include proportion of cows milked, initial proportion of land in artificial pasture, initial cattle population, rate of transfer of animals from traditional to modern management, illegal cattle exports, and crop yields. Land allocation coefficients include initial land in the three agricultural regions, profitability response parameters of traditional cattle, internal transfer of capital from crop to cattle production, and consumption expenditures. Price and cost coefficients include price of crops and milk, cattle marketing margin, rate of inflation of farm inputs, and operating costs of crops and cattle. And finally, time lag or smoothing parameters include average lengths of time for averaging output, price and cost of crops, and cattle. Some of these parameters were tested individually while others were tested in combination in the same run; each run simulates agricultural production in the Costa over a 25-year period, 1960-1985.

A strict test of parameter sensitivity would require that all parameters be varied in the same way, e.g., plus

20 percent. The results could then be compared on the basis of a given deviation. This procedure would contribute nothing, however, to understanding the nature or overcoming the problem of the uncertainty arising from varying degrees of confidence in parameter values. If we increase a parameter value by 20 percent, we obtain a score value which may be either less than one standard deviation from the mean and have a small variance, or greater than one standard deviation and have a large variance. The resulting deviations in the output variables would be quite different in the two cases. Therefore, in statistical terms it would be meaningless to compare the relative consequences of 20 percent variations in each of two parameters whose means may be varied so differently.

The general rule followed, therefore, in defining the sensitivity runs described here was to vary each parameter by an amount which I felt covered most of its variability --two standard deviations. In the absence of informed judgments or other estimates of relevant distributions, the variations used were guesstimates on my part. They certainly do not imply the degree of precision suggested by the term "two standard deviations," but do reflect the relative width of subjective confidence intervals. But when estimates were available from several sources (for example CPLPT and MKM) their reported values were entered in the sensitivity runs. In this case sensitivity tests are helpful in establishing the confidence that can be placed on different sources of

information by checking the consistency of the output generated by a given estimate against the knowledge we have on the real system. Where possible, similar parameters were varied by similar amounts. For example, the cattle population cohorts were each decreased 25 percent, the lag parameters were each decreased 40 percent, and the initial land parameters were decreased by 10 percent each.

Output criteria, parameter deviations and results are tabulated in Table III.9. The output criteria include farm income from cattle (FARILA), farm income from crops (FARMICA) and government revenues from cattle (GOVREVA) accumulated over the 25-year simulation. In addition, effects of parameter variations are shown for cattle population in the Costa (TOPOPR), capitalized value of pasture land (VLAND), value of capital on cattle (VALCAP), and Colombian beef per capita consumption (PERCAP).

The discussion of results has been limited to the major explanations of the more appreciable output deviations. The test of some production parameters from Runs 2 through 5 indicates that the initial proportion of grazing land in artificial pasture is quite important in determining the performance of the model. Results of Run 3 are the same as those of traditional management under "worst" nutrition conditions.[1/] This means that farmers are not motivated to adopt the new production methods. The higher

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[1/] "Worst" and "best" nutrition conditions as used in this analysis are related to the initial proportion of land in artificial pastures.

TABLE III.9. Results of Sensitivity Tests on Selected Parameters of the Costa Model.

Run	Parameter Tested	Parameter Definition	Percent Change From Base Run	Test Run Value	Base Run Value	Performance Criteria[a/] TOPOPR	FARILA	FARMICA	GOVREVA	VLAND	VALCAP	PERCAP
						Base Run Value						
						9,211 thous. animals	32,280 mill. Ps	56,070 mill. Ps	2,721 mill. Ps	9,361 mill. Ps	68,300 mill. Ps	19.96 Kgs/person-year
						Percent Departure From Base Run						
2	CT202	Proportion of "traditional" cows milked	+25.0	.5	.4	-4.46	8.05	.12	.48	-16.5	-6.02	-2.3
	CM202	Proportion of "modern" cows milked	+25.0	.5	.4							
3	CPLPT	Proportion of initial (1960) grazing land in artificial pasture	-55.55	.2	.45	-28.5	-16.3	.09	-20.51	-68.52	-31.1	-9.7
4	C12	Effect of nutrition on animals transfer	-50.0	.5	1.0	-.36	-.22	0.	-.07	-27.6	-36.6	-1.05
5	UNEXPL	Illegal exports (thousand head/year)	-50.0	150	300	-11.8	-24.8	.2	-7.72	-74.4	-25.9	-.4
6	E8	Profitability rate of response of traditional to modern cattle	-33.33	.1	.1	-6.93	-.62	0.	-2.2	-31.11	-10.7	-3.01
7	E9	Profitability threshold of response of traditional to modern cattle	+100.0	1.0	.5	14.5	2.2	.04	-5.9	-48.5	-20.12	-5.81
	E91	Profitability threshold of response of disinvestment in modern cattle	+66.67	.5	.3							
8	DIR	Discount rate over the planning horizon (proportion/year)	+20.0	.18	.15	-5.7	-1.12	0.	-2.13	-25.9	-8.6	-2.61
9	C239	Proportion of internal transfer of capital from crops to cattle production	-50.0	.05	.1	-1.6	.74	0.	-.15	-.27	-1.6	-.15
10	C261	Value towards which ALPH2 tends as income gets large	-20.0	.2	.25	.2	-.46	0.	0.	-27.4	-3.3	-1.05
11	C263	Rate of response of consumption expenditures to changes in gross income from cattle	+16.67	.35	.3	0.	0.	0.	0.	0.	0.	0.
12	PRM	Producer price of milk (Ps/liter)	+50.0	1.5	1.0	-7.5	15.8	.3	-.48	-18.9	-9.21	-4.0
13	MKM	Marketing margin of finished males (proportion of price)	+60.0	.24[c/]	.15[b/]	-13.7	-34.7	.25	-9.41	-83.9	-34.01	-5.41

TABLE III.9. (continued)

Run	Parameter Tested	Parameter Definition	Percent Change From Base Run	Test Run Value	Base Run Value	Performance Criteria[a/] TOPOPR	FARILA	FARMICA	GOVREVA	VLAND	VALCAP	PERCAP
						Base Run Value						
						9,211 thous. animals	32,280 mill. Ps	56,070 mill. Ps	2,721 mill. Ps	9,361 mill. Ps	68,300 mill. Ps	19.96 Kgs/person-year
						Percent Departure From Base Run						
14	RCST	Rate of increase in farm costs (proportion/year)	-16.67	.1	.12							
	CSTHCU	Initial average cost of upland cash crops (Ps/ha-year) (1960)	+18.93	666	560							
	CSTHCL	Initial average cost of lowland cash crops (Ps/ha-year) (1960)	+18.51	1300	1097							
	CSTHCF	Initial average cost of food crops (Ps/ha-year) (1960)	+18.95	860	723	14.1	39.8	-50.4	10.5	147.4	31.3	3.51
	CTLBLT	Initial cost of labor in traditional sector (Ps/animal-year) (1960)	+19.02	21.9	18.4							
	VETRAC	Initial veterinary cost in traditional sector (Ps/animal-year) (1960)	+19.67	7.3	6.1							
	CLNDT	Initial average operating cost of traditional grazing land (Ps/ha-year) (1960)	+18.72	42.5	35.8							
15	CSTHCU	Initial average cost of upland cash crops (Ps/ha-year) (1960)	+13.57	636	560							
	CSTHCL	Initial average cost of lowland cash crops (Ps/ha-year) (1960)	-.46	1092	1097							
	PCROPU	Initial average price of upland cash crops (Ps/ton) (1960)	+6.03	668	630							
	PCROPL	Initial average price of lowland cash crops (Ps/ton) (1960)	+.67	898	892	-.03	0.	3.25	0.	.1	0.	0.
	YLDCU1	Initial average yield of upland cash crops (ton/ha) (1960)	+8.18	1.19	1.1							
	YLDCL1	Initial average yield of lowland cash crops (ton/ha) (1960)	+.64	1.57	1.56							

TABLE III.9. (continued)

Run	Parameter Tested	Parameter Definition	Percent Change From Base Run	Test Run Value	Base Run Value	Performance Criteria[a/]: TOPOPR	FARILA	FARMICA	GOVREVA	VLAND	VALCAP	FERCAP
						Base Run Value						
						9,211 thous. animals	32,280 mill. Ps	56,070 mill. Ps	2,721 mill. Ps	9,361 mill. Ps	[illegible] mill. Ps	[illegible] kgs. per-[illegible]-year
						Percent Departure From Base Run						
16	DEL5	Average length of time of exponentially averaged cattle producer price (years)	-40.0	3	5							
	DEL6	Average length of time of exponentially averaged traditional cattle sales (years)	-40.0	3	5							
	DEL7	Average length of time of exponentially averaged upland cash crops price (years)	-40.0	3	5							
	DEL8	Average length of time of exponentially averaged upland cash crop yields (year)	-40.0	3	5							
	DEL12	Average length of time of exponentially averaged per hectare taxes on traditional cattle (years)	-40.0	3	5							
	DEL13	Average length of time of of exponentially averaged per hectare traditional land tax (years)				21.3	4.3	-.16	9.33	18.1	17.7	8.5
	DEL19	Average length of time of exponentially averaged per hectare traditional cattle operating costs (years)	-40.0	3	5							
	DEL20	Average length of time of exponentially averaged operating costs per traditional animal (years)	-40.0	3	5							
	DEL21	Average length of time of exponentially averaged per hectare operating costs of traditional grazing land (years)	-40.0	3	5							
	DEL22	Average length of time of exponentially averaged per hectare upland cash crop costs (years)	-40.0	3	5							

TABLE III.9. (continued)

Run	Parameter Tested	Parameter Definition	Percent Change From Base Run	Test Run Value	Base Run Value	Performance Criteria[a/] TOPOPR	FARILA	FARMICA	GOVREVA	VLAND	VALCAP	PERCAP
						Base Run Value						
						9,211 thous. animals	32,280 mill. Ps	56,070 mill. Ps	2,721 mill. Ps	9,361 mill. Ps	68,300 mill. Ps	19.46 Kgs/person-year
						Percent Departure From Base Run						
17	PMGT	Initial size of growing male herd (thousand animals) (1960)	-25.0	880	1174							
	PFGT	Initial size of growing female herd (thousand animals) (1960)	-25.0	887	1183							
	PMPT	Initial size of producing male herd (thousand animals) (1960)	-25.0	707	943	-12.8	-8.33	-.16	-8.1	-49.8	-19.33	-5.31
	PFPT	Initial size of producing female herd (thousand animals) (1960)	-25.0	1818	2424							
	OLDFT	Initial size of old female herd (thousand animals) (1960)	-25.0	320	427							
18	TGLSF0	Initial seasonally flooded grazing land (thousand has) (1960)	-10.0	2824	3138							
	TLDRNL0	Initial drainable land (thousand has) (1960)	-10.0	2824	3138							
	TRAVL0	Initial flood-free agricultural land in lowland (thousand has) (1960)	-10.0	480	533.3	-6.35	9.73	-.39	-4.81	1.8	-1.33	-2.05
	TLAVU01	Initial agricultural land in subregion 1 (thousand has) (1960)	-10.0	1950	2169							
	TLAVU02	Initial agricultural land in subregion 2 (thousand has) (1960)	-10.0	1508	1676							

a/ Values are at the end of a 25-year simulation run (1985). All monetary values are in Colombian pesos and weight units are metric tons.
Variables are:
TOPOPR = cattle population in the Costa
FARILA = time integral of farm income from cattle
FARMICA = time integral of farm income from crops
GOVREVA = time integral of government revenue from cattle
VLAND = capitalized value of pasture land
VALCAP = value of capital on cattle
PERCAP = Colombian beef consumption per capita

b/ [Hector A. Sarmiento], Colombia as a Cattle Exporter, in Factors Affecting the Beef Cattle Industry's Return on Capital and Development Possibilities in Selected Areas in South America, by Roderich Von Oven (unpublished, 1966), 21.

c/ James E. Grunig, Information, Entrepreneurship, and Economic Development, (unpublished Ph.D. dissertation, University of Wisconsin, 1968), p. 336, quoting Supply Problems of Basic Agricultural Products in Colombia, Latin American Agricultural Marketing Institute (ILMA), (Bogota, 1964).

cost of planting a larger area in artificial grasses lessens the relative profitability differential of improved over traditional cattle production to a value that is below the minimum set in the model before farmers begin modernization (the threshold parameter of Equation 5.36). Although by 1975 this relative profitability differential is greater than .5, the absence of promotional activity from that year on precludes the adoption of improved management practices (see Equation 5.37). This seems to be an unrealistic behavior of the model that may require further consideration since this implies that ten years of campaign promotion do not produce any traceable effect in the region, or that farmers are unable to take advantage of profit opportunities by themselves. Increasing the proportion of cows milked (Run 2) increases cattle income but decreases the relative profitability differential of improved over traditional cattle production. Although this slows the adoption of improved management practices, the impact on the output variables is not significant. While controlling the rate of animal transfer from traditional to modern has no major effect on most of the output variables (Run 4), the volume of illegal exports has an important effect on the performance of the model (Run 5). In general, given the moderately inelastic price elasticity of demand for beef (-0.7), changes in domestic supply have an impact on prices which, in turn, significantly affect the overall performance of the model. This effect will be discussed in more detail in the next chapter as part of the policy experiments.

Runs 6-11 test the sensitivity of a number of land allocation coefficients. Of the land allocation coefficients the profitability response parameters are the most sensitive (Runs 6-8), particularly the adoption response threshold parameter (E9 in Run 7). Although in Run 7 the relative profitability differential of improved over traditional cattle production is greater than one after 1975, its output is the same as that of traditional management under "best" nutritional conditions. This performance experiences the same unrealistic behavior of Run 3 that was discussed earlier. The parameter controlling the response rate (E8) and the discount rate appear to be somewhat sensitive (Runs 6 and 8). A look at Figure II.1 in Chapter 5 will explain why increases in E9 have greater consequences on model output than decreases in E8. Since traditional and modern cattle profitabilities are not too far apart, the modern alternative is not too far out on the PDR axis, so the response is nearly at its asymptotic minimum. Increases in the threshold, i.e., shifting the curve to the right, has greater consequences than flattening the whole curve by decreasing the response rate. This is a fortunate circumstance since it is easier to determine the threshold than the response rate.

The parameters tested in the last three runs of this group (Runs 9-11) affect the transition response of grasslands by changing the cash flow position of farmers and their balances available for investment. Decreasing total cash balances in the cattle subsector by decreasing the

internal transfer of capital is of little consequence on the output of the criteria variables (Run 9). Decreasing consumption or living expenditures as in Run 11 leaves more capital for investment in the early years of the simulation, but its effect on the output of the model is nil.[1/] Since the modernization decisions are dominated by the profitability response and adoption rate parameters, an increased availability of capital for investment at the beginning of modernization does not have any effect on the model's performance. Later in the simulation period the consumption expenditures of the Base Run and Run 11 are equal as the coefficient determining the proportion of gross income that is consumed (C261 in Equation 9.12b) reaches its lower bound of .25 in both runs. Although the consequences of decreasing the lower limit to the proportion of income from cattle that is consumed (Run 10) is more conspicuous than changing the rate of response, its effect on the output of the criteria variables is not significant.

Despite the apparently low sensitivity of model output to changes in the consumption or living expenditures variable (EXLIV), this is an area that requires more careful consideration and refinement because of its welfare effects and its importance in making decisions at the farm level.

[1/] Since the exponential curve of Equation 9.12b is negatively sloped, any increase in C263 is reflected in a decrease in the variable ALPH2.

20 percent of the rice is grown in the uplands and average prices and yields have to be adjusted accordingly. Although income from crops is increased, this effect is of little consequence in the model.

The time lag constants tested in Run 16 appear to be quite sensitive. These parameters are used in the model in the exponential smoothing or averaging of prices, costs, and yields on which farmers base their expectations of future income streams. Reducing these time delays makes farmers respond more quickly to changing economic conditions and their decisions are then reflected in the model's output. Determining the length of smoothing time constants appears to be of utmost importance for plausible model behavior. In some instances during the validation and policy experiments we have been confronted with the paradox of farmers perceiving profitable conditions for modernization even when they are actually experiencing losses in the modern operation. This apparent noneconomic behavior points out the need for refining some formulations in the model in order to determine a more consistent response to situations of rising and declining profits. Changes in profits may lead to reorganization of the cattle enterprise by moving to different production functions.

The initial cattle and land parameters tested in Runs 17 and 18 appear to be quite sensitive. As might be expected, reducing the land base has a drastic effect on the animal population that can be supported in the region.

These results suggest the usefulness, for the purposes of this model, of obtaining accurate cattle inventories and land surveys.

Summary

In closing this chapter we can summarize some general observations and conclusions. Income from crops remains fairly stable throughout all runs with the notable exceptions of Runs 14 and 15. The major source of variation in Run 14 arises from changes in the relative profitability differential between cash crop and cattle production in the uplands (subregion 1). Through the land allocation mechanism of Equation 5.21 these changes have consequences on the total land in crops and consequently on their aggregated income. The policy implications of this effect will be discussed in the next chapter.

Cattle population in the region (TOPOPR) is, as expected, greatly influenced by the nutritional base. Nutritional conditions are affected, among other things, by the initial allocation of artificial pasture to grasslands and by the rate at which land modernization takes place, if any. The sensitivity tests suggest that the estimate of 20 percent of grasslands in artificial pastures provided by DANE in 1968[1/] is biased downward, and that the FAO[2/] estimate

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[1/] DANE, Encuesta Agropecuaria Nacional 1968, (Bogota, April 1970), p. 6.

[2/] United Nations, Food and Agriculture Organization, Livestock in Latin America: Status, Problems and Prospects-Colombia, 1962, p. 14.

is more consistent with cattle censuses. A comparison of DANE estimates on cattle numbers from Table III.6 on page 237 with the output of Run 3 indicates that the latter is 12 and 22 percent lower than DANE's for 1965 and 1970, respectively, while deviations of the base run which uses the FAO estimate (45 percent) from DANE's data are +.08 and -6 percent, respectively. Herd size greatly influences off-take and market prices which, through interactive effects in the model, determine farm income from cattle (FARILA), government revenues (GOVREVA), value of land (VLAND), value of capital in cattle (VALCAP), and Colombian beef consumption per capita (PERCAP). Feedback effects of price changes caused by variations in supply and demand, and/or by changes in marketing margins determine farmers' decisions on farm management and investments which, in turn, affect cattle numbers. When domestic beef supply is increased in Run 5 by reducing illegal exports 50 percent, all long run performance variables depending on cattle decrease; after short run price declines, consumers become worse off as the lower price curtails cattle population and output and raises price.

Changes in costs of production as shown in Run 14 have a major impact on farmers' income, their capability to carry on land improvements, and their attitudes toward modernization that must be taken into account when deciding on policies to improve cattle production. Subjective expectations of farmers toward future prices, costs, and yields also

have an important role in determining model output as shown in Run 16. In general, the capitalized value of land (VLAND) seems to be more sensitive than the other performance variables to changes in parameters value. This is, in part, explained by the response of VLAND to changes in annual income during the base year and not to its accumulated value. Accumulated income smoothes the annual oscillations of revenues from cattle and does not help in showing the cash flow position of farmers that affect their decisions on a yearly basis.

The preceding results show that the accuracy of the model will greatly be increased by improving the estimates on number of cows milked, proportion of land in artificial pastures, the marketing margin of animal sales, initial cattle inventories, land surveys, cattle traded at the border, and behavioral responses of farmers. In this chapter we have seen how sensitivity tests provide essential information for model building and validation by pointing out possible programming and modeling errors and by contributing to a better understanding of the model itself as well as of the system it is simulating. Sensitivity analyses may also be used to examine potential policies and to suggest priorities for data collection. The detailed analyses of the runs testing 45 selected parameters presented here illustrate these capabilities.

P A R T I V

MODEL APPLICATION IN DECISION MAKING

Introduction

The problems of planning for economic development are characterized by the uncertainty necessarily inherent in any process of planning for the future. This uncertainty arises both from the quantity and quality of available data and from the difficulties of forecasting how a large-scale system of complex interactive and feedback relationships will respond to policy inputs. With this in mind, the model developed in this dissertation, though restricted to a region and a subsector of the Colombian agricultural economy, sets up a workable and reliable alternative for dealing with these problems. The system approach used here, by modeling specific causal and structural relationships and by projecting time paths of behavior, provides at least some of the flexibility necessary to deal with the complexity and uncertainty of planning.

Chapter 12, in reporting and analyzing the results of a series of policy runs, illustrates how the model could be used in actual planning situations. Chapter 13 concludes the dissertation with a summary of results and a discussion of needed improvements and extensions of the current model.

CHAPTER 12

POLICY EXPERIMENTS ON THE NORTHERN COLOMBIA BEEF INDUSTRY

A system simulation model can be useful to policy makers in two principal ways: improving their understanding of the socioeconomic system they are concerned with, and formulating development policies. The model-building process and sensitivity tests, discussed in Chapter 11, can contribute substantially to an improved understanding of and sharpened intuitions regarding the development process, in general, as well as the particular socioeconomic system of concern.

The goals of development are part of a country's political process and, once established, policies must be defined for their attainment. Thus, the definition of policies is an important input to the policy-making process represented by the system simulation model. The computerized simulation model allows experimentation with alternative strategies of development under various assumptions, and then comparison of their likely outcomes. A set of plans or strategies are considered acceptable only if they are relatively effective in reaching the multiple goals under a wide variety of circumstances. During this planning exercise and through the interaction between

policy makers and researchers, goals may be set to more attainable levels or redefined toward the satisfaction of more urgent needs indicated by the simulation results. This chapter discusses a set of cattle development policies and presents an analysis of the results of a series of deterministic policy runs.

Policy Experimentation

The policies selected for this analysis are either currently in use or their implementation is being considered by the Colombian government as a means of attaining a diversity of objectives which are, more often than not, competitive.[1/] Examples of these objectives are: creation of incentives to increase production, measures to capture a larger surplus from cattle producers, cattle export incentives to increase foreign exchange earnings, and improved human nutrition through increased supplies. The policies tested include: disease control, taxes on land and cattle, credit for development, price and export targets, crops modernization, and cattle export incentives. With few exceptions, these issues have been unresolved controversial issues between the government and interested groups.

[1/] The analysis was made following very limited interaction with Colombian policy makers, though official policies were known through several published sources.

Although this dissertation is concerned with the Costa region, some of the policies tested have national implications since their implementation would not be restricted to this region. Furthermore, cattle production in the Costa weighs heavily in Colombian cattle output; therefore, any policy affecting production in this region will have an effect on the national cattle economy.

Run Definitions and Organization

Policy experiments were conducted with 21 simulation runs which cover the time period 1960-1985 (Table IV.1). The results analyzed here are for the period 1965-1985, with campaign promotion initiated in 1965 and policy implementation beginning in 1966 for cattle modernization, and in 1971 for disease control. There are two main reasons for including the period 1965-1973 in the policy analysis. First, this period, which is a part of the model's historical validation, includes the execution of both a cattle development plan as well as a disease control program. Second, we wanted to try a retrospective prediction of the likely consequences of starting the development plan in 1966 under a set of policies different from those prevailing at the time. Prospective predictions (forecasting) are considered after 1973 and projections are carried as far as 1985 to give the long-run diffusion response to the production campaign time to exert its major impact.

TABLE IV.1. Policy Simulation Runs.

Run No.	Run Sets	Run Definition
1	all	Standard Run--disease control; modernization of cattle production; normal land and cattle taxes; current credit terms; current export subsidy and fluctuating exchange rate; low export target and high world price; no modernization of crops or rest of national herd.
2	1	No disease control campaign for the traditional herd.
3	1	Increased government expenditures in foot-and-mouth disease control by 25 percent from year 1971.
4	2	Taxes on cattle cutoff at years 1970 and 1972.
5	2	Property tax increased at year 1970.
6	3	Reduced interest rate on development credits from year 1966.
7	3	Increased terms of repayment on development credits from year 1966.
8	3	Increased funding for development credit from 1966-1976.
9	3	Increased units of modernization promotion from 1965-1973.
10	4	Cattle exports set at intermediate target from year 1974.
11	4	Cattle exports set at high target from year 1974.
12	4,7	Run 11 with fixed exchange rate at Ps 25 and low world price, plus modernization of rest of national herd from year 1975.
13	5	Modernization of cash and food crops from 1972-1976.
14	6	Combines Run 4, Run 6 and Run 7.
15	6	Combines Run 8 and Run 9.
16	6	Combines Run 14 and Run 15 plus growth of rest of national herd at 5 percent from year 1975 and high export target.
17	7	Run 11 with low world price after year 1974.
18	7	Run 11 with moderate world price after year 1974.

TABLE IV.1. (continued)

Run No.	Run Sets	Run Definition
19	7	Run 17 with export subsidy cutoff at year 1975.
20	7	Run 17 with fixed exchange rate at Ps 25.
21	7	Run 17 with export subsidy cutoff at year 1975 plus modernization of rest of national herd from year 1975.

With simulation, it is possible to increase the complexity of the combination of policies tested and at the same time keep the output format flexible enough to permit analysis of aggregated macroeconomic variables or the investigation of responses at a more micro level. Experiments can start with runs to evaluate single policies or programs (e.g., cutting off taxes on cattle) and then other policies and programs (e.g., reduced interest rate and increased terms of repayment) can be added succesively to investigate interactive effects. The 21 policy runs are organized to take advantage of these capabilities and they are grouped into seven sets (Table IV.1). All seven sets include Run 1, the base run, as a standard point of reference. The base run projects likely performance of alternative 2 under current policies and assumes that the non-Costa cattle population grows at 2.85 percent annually.

The output measures selected for these experiments provide information about relevant parameters at both the macro- and micro-economic levels. Annual variations in private and government revenues, capital formation and beef consumption resulting from the implementation of different policies can be examined in each set of runs. But the more simple evaluations of run sets 1 and 7 each use only the criteria variables (described below) considered most relevant for this analysis.

The performance variables of Runs 4 through 16 (sets 2, 3 and 4) include cattle population in the Costa (TOPOPR), Colombian beef consumption per capita (PERCAP), annual farm income from cattle (FARIL), average per hectare capitalized value of land (VLANDH), and annual government revenues from cattle (GOVREV). In this analysis, annual value of revenues and per unit value of land were considered more meaningful than the accumulated and more aggregated values used in the sensitivity tests. Runs 2 and 3 (set 1) use as performance variables cattle population in the Costa (TOPOPR) and extraction ratio from the Costa herd (ERR). Finally, runs 17 through 21 (set 7) use as performance variables domestic market price of finished males (PA) and export margin (EXMAR). The performance variables used in the sensitivity tests and the policy experiments are those considered most useful in the analysis of results in this dissertation, but they are only a small sample of the many output variables actually produced or that can be produced in the model. The following sections analyze and graphically depict the results of the 21 policy experiments.

Policies Related to Disease Control

Disease control, particularly for foot-and-mouth disease, have a major impact on the good health of cattle and the corresponding size and productivity of the Costa beef industry. In the first set of runs, Run 1 shows the results of a foot-and-mouth control program budgeted for

Ps 224 million over the period 1971-1985 (an annual treatment cost of Ps 4.50/animal is assumed). Run 2 explores the effect of maintaining precampaign disease control practices in the traditional herd. Run 3 investigates the results of increasing government expenditures on foot-and-mouth control by 25 percent up to Ps 280 million over the period 1971-1985. Although control of foot-and-mouth disease is highlighted here, improved practices include control of brucellosis as well as other diseases (black leg, anthrax and septicemia) and parasites.

The effect of upgrading disease control in the traditional herd (Run 1) is to increase cattle population and sales faster than under traditional control practices (Run 2). This effect is reflected in the different time path projections of Runs 1 and 2 as illustrated in Figures IV.1 and IV.2. But this is a short-term effect; if modernization proceeds steadily in the long run, output from Run 2 will approach that of Run 1 since the modern herd, treated with improved control practices, increases both absolutely and relatively. But this is not to say there should not be a disease control program. The advantages of starting this program early are many. On one account, eradicating brucellosis will increase not only the output of calves and milk in the traditional herd but in the modern herd as well since more females free from the disease are transferred to the latter.

Run Definitions

1. Disease control, modernization of cattle production and continuation of present trends and policies (base run).
2. No disease control campaign in the traditional herd.
3. Increased government expenditures in foot-and-mouth control by 25 percent from year 1971.

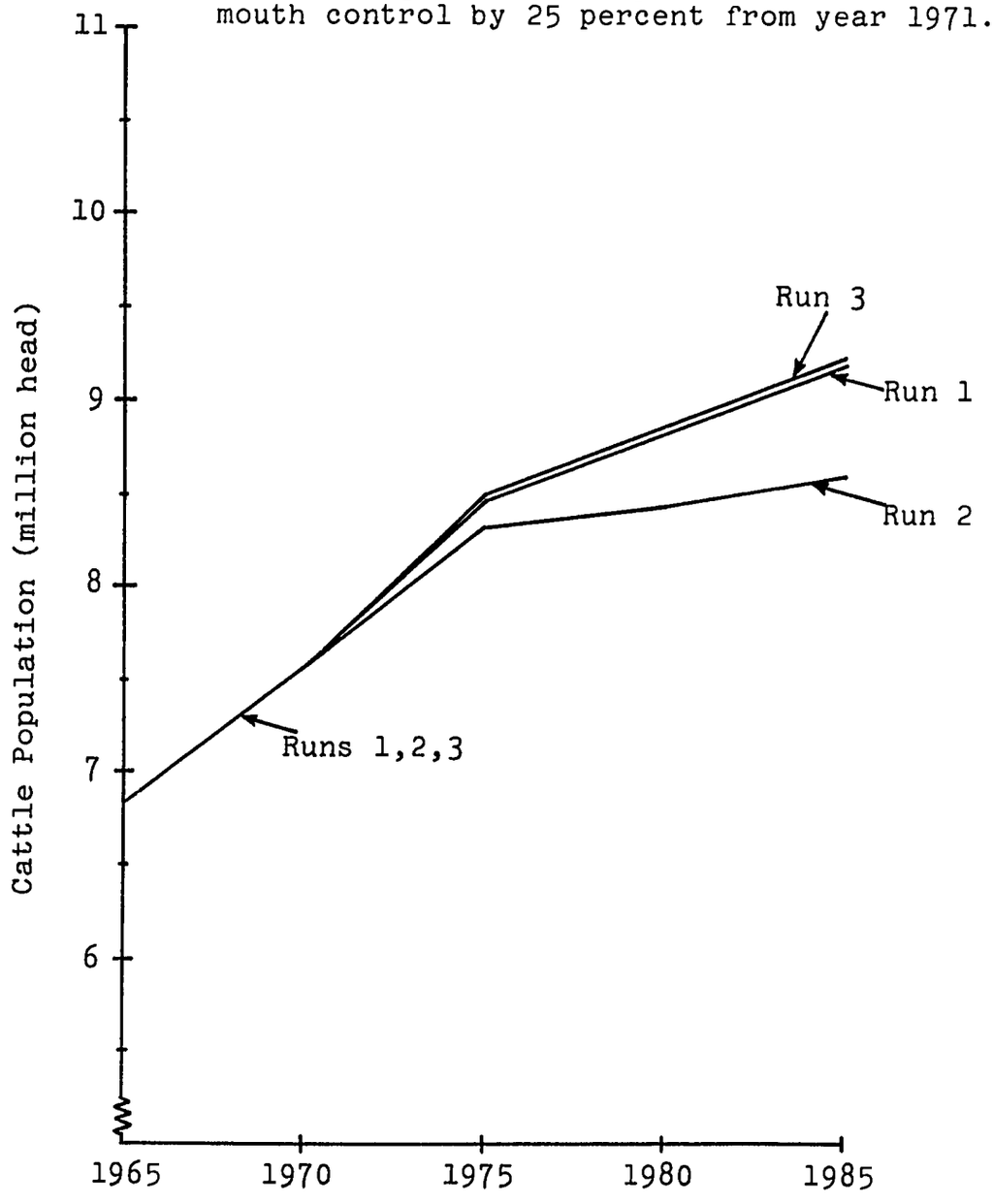

Figure IV.1. Cattle population in the Costa with and without a disease control program, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production and continuation of present trends and policies (base run).
2. No disease control in the traditional herd.
3. Increased government expenditures in foot-and-mouth control by 25 percent from year 1971.

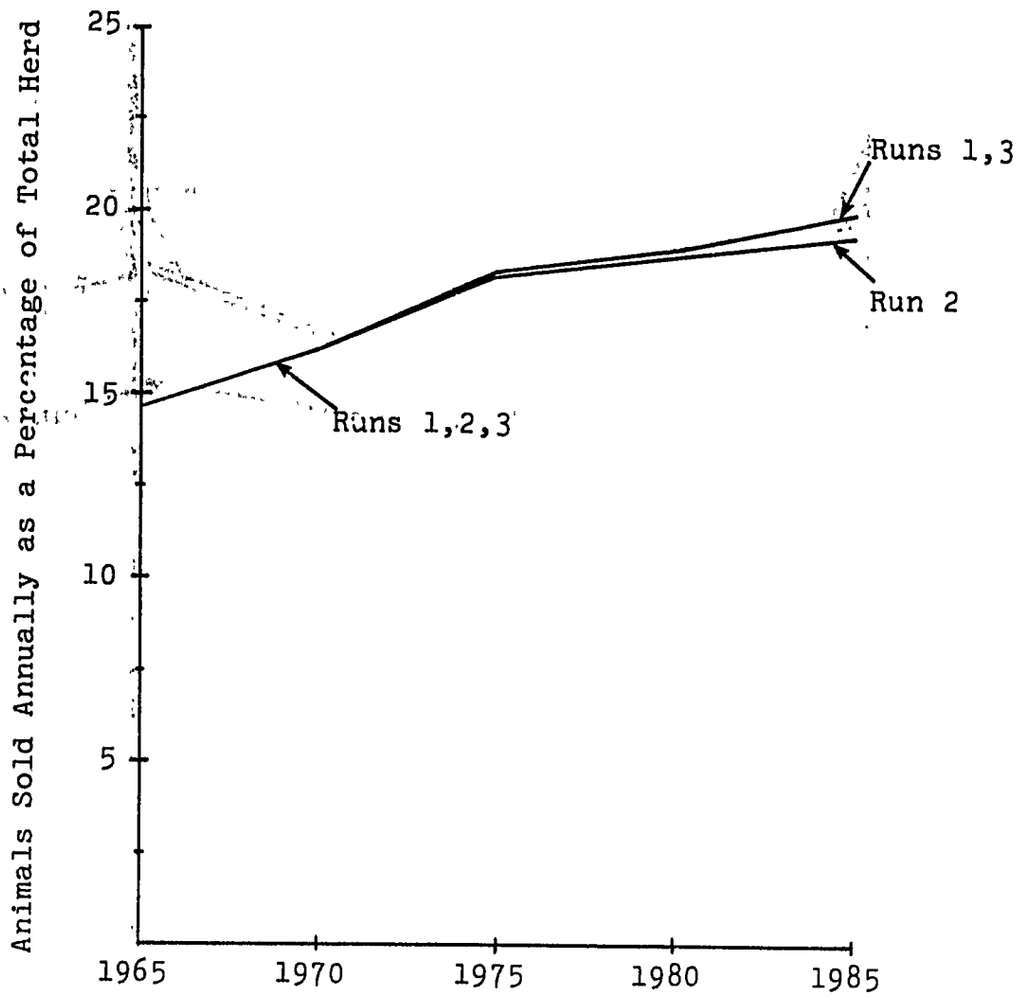

Figure IV.2. Extraction ratio from the Costa cattle herd with and without a disease control program, 1965-1985.

In addition, the control of foot-and-mouth disease in the whole herd will have the double advantage of increasing cattle numbers and output, and easing sanitary barriers against Colombian beef exports in world markets.

Yet increasing government expenditures on foot-and-mouth control by 25 percent have a negligible impact on cattle population and sales as shown by Runs 1 and 3. Run 3 (with increased expenditures) shows a faster increase in population early in the campaign, but after 1975 this run assumes the same trend as Run 1 although population levels are slightly higher.

Increased government expenditures have the initial effect of accelerating the annual rate at which animals in the traditional herd are treated, but this slows down and almost equals that of Run 1 after the first five years of the campaign. Thus, its long-run effect on the traditional herd is small, and increases in population depend more on the rate at which grasslands are modernized and animals are transferred accordingly.

The projected cattle population is slightly higher in Run 3 because of differences in the long-term modernization responses of farmers which result from the varying expectations about future income streams. Such expectations are higher in Run 3 than in Run 1 throughout the planning horizon. This results in a higher rate of land modernization in Run 3 than in Run 1 which, in turn, affects the size of the modern herd.

Policies Related to Cattle and Land Taxes

Taxes on cattle and land are investigated in the second set of runs, Runs 4 and 5. Since the cattle sector is considered hard to tax, with its contributions to governmental revenues greatly out of proportion to the sector's importance, a special scheme has been devised for the purpose of taxing the industry more effectively. These taxes (described in detail in Chapter 2) include a consumption tax, a selective inventory tax, and a general inventory tax. Although Law 26 of 1959 enacted the general inventory tax until 1970, Law 42 of 1971 made it effective through 1980. Run 1 assumes that further extensions will take place and this will continue in effect through the period of the simulation. Run 4 examines the effect of cutting off the general inventory tax in 1970 and the remaining special taxes after 1972.[1/]

Run 5 compares the consequences of increasing the land or property tax from the current level of 4.2 mills to 14.2 mills. The property tax is the main source of municipal revenues, and it has remained at 4.2 mills since 1948. Although in recent years there has been a large number of proposals and laws to utilize the property tax, both as a measure to increase government

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[1/] The 1972 proposed legislation on presumptive taxation of agriculture intends to alleviate the tax burden of ranchers by eliminating the selective inventory tax.

revenues as well as to encourage improved land utilization, they were either never implemented or never put into effect [30]. In 1968, when the Musgrave Mission [11] presented its proposal for tax reform, the Colombian government again considered a change in the structure of the property tax, and in 1969 a surcharge of 10 mills (1 percent of the assessed value of land) was proposed for the purpose of financing public education.[1/] Although this tax surcharge has not yet been levied on landowners, Run 5 attempts to evaluate the likely consequences of an early implementation by assuming that its collection started in 1970, one year after legislation was proposed.

Run 4 (cutting off special cattle taxes) results in values of all five performance variables below those of Runs 1 and 5. Cattle population, government revenue and per capita consumption in Run 4 remain below the other two runs for the period 1975-1985.

Maintaining the special cattle taxes in Run 5 while increasing by 3.4 times the tax rate on the assessed value of land results in a 29 percent increase in government revenue over the base run by 1985. But when the land tax remains at its current rate of 4.2 mills in Run 4 while the special cattle taxes are cut off after 1970, government revenue falls 80 percent below the base run in 1985 (Figure IV.7).

[1/] Rodrigo Llorente, El Desafio de un Pueblo en Desarrollo, (Bogota: Editorial Andes, 1972), p. 273

Although the tax revenues examined here need to be considered with caution due to probable estimation inaccuracies, a comparison of annual government revenues attained with Runs 1, 4 and 5 suggests that taxing cattle inventories and sales is a major regional source of government income from the cattle subsector (not considering income and net worth taxes). We can conclude that eliminating the special taxes on cattle would likely produce a big loss in government revenue unless this loss is compensated by other fiscal policies designed to tax more effectively the income, net worth and property of ranchers.

There are two unrealistic assumptions in the model affecting the output of all runs. First, because of inadequate information and accounting difficulties in computing the general inventory tax as a proportion of the net investment on cattle (Law 26, 1959), this is computed at a constant Ps 3.1 per head throughout the simulation. Thus, revenues from this tax change with the cattle population and not with the net worth of farmers. Second, the property tax is computed from the assessed value of land which is set at 50 percent of the capitalized value of land. Yet the use of the capitalized value of land as a tax base introduces a destabilizing effect on government revenues since this value changes with net returns and the rate of interest resulting in an unlikely automatic adjusting mechanism in the value of land and the related value of the property tax.

Total cattle population and per capita consumption follow the same rank of government revenues, i.e., Run 5 at the top and Run 4 at the bottom (Figures IV.3 and IV.4). Per capita consumption is used here as a measure of the effect of increasing cattle output from the Costa herd on the availability of beef to the Colombian population. We estimate that domestic consumption equals the residual of the total supply of beef after accounting for official and illegal exports; therefore, the program producing the largest cattle population and off-take will result in the highest supply to the domestic market. The cyclical pattern of consumption per capita is produced by the long-term (7 years) cycle of beef supply from the rest of the country which is forced into the regional model. Lower prices arising from increased supplies have the effect of improving the consumer's situation and worsening the producer's. Consumers are better off in the short run, but they may be worse off in the long run, since low prices reduce incentives to increase output through modernization and may eventually cause a reversion of land to traditional management which would curtail output more drastically. Such welfare effects must be faced when policy makers consider alternative strategies for development.

Annual cattle populations for the various runs depend on their projected composition as traditional and modern. As stated, differences in herd size are produced by varying rates of land modernization caused by differences in the farmers' long-term modernization responses. While it is

true that cutting off the special taxes increases income and leaves the farmer with more capital available for investment in farm improvements, (and possibly a higher rate of modernization) the actual rate is smaller. This paradox can be explained by examining the dynamic nature of the farmers' decision-making process. We have conceptualized that the rate of land modernization cannot be higher than the rate at which land enters modernization due to promotion and diffusion, and that this rate depends upon the farmers' perception of the relative profitability of the modern operation and the response rate parameters.

Since eliminating the special taxes makes profits proportionally higher in the traditional than in the modern herd, the perceived relative profitability of the modern operation throughout the planning horizon declines, and as a result the rate of land modernization in Run 4 is lower. This effect has its greatest impact after 1975. On the other hand, increasing the property tax reverses the situation described above, causing the perceived relative profitability of the modern operation and the resulting rate of land modernization to be higher in Run 5. Although these results apparently give support to those advocating increased land taxes in order to encourage an improved land utilization, no definite conclusions can be drawn at this point.

Aggregate farm income from cattle[1/] sharply increases in all cases from 1965 to 1975 showing the effect of modernization and rising prices. It then decreases rapidly (Figure IV.5). From 1966 to 1980 the time paths of the three runs are parallel with Run 4 at the top and Run 5 at the bottom as expected. But after 1980, Runs 1 and 5 reverse the trend while that of Run 4 continues downwards. The behavior of this performance variable is responsive to the interaction of several other variables in the model. As stated, the sharp increase in income from 1965 to 1975 coincides with a period of rising beef prices and increasing sales from a larger herd. But the long-run effect of increased supply slows the rate of increase in price from 1975 to 1980, and this, coupled with rising costs and the debt burden after 1976 (when payments of development credit cease) causes a decline in income from 1975 to 1980. After 1980, increases in total demand more than offset the initial impact of increased supplies and prices regain the upward trend of the period 1970-1975. Rapid rising prices and decreasing indebtness from development credits cause income to become an upward trend after 1980 in Runs 1 and 5. Furthermore, given the structure of the model, land modernization stops altogether

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[1/] Farm income includes both sale of traditional and modern animals and milk as well as credits paid, but is net of operating costs, debt service and interests.

between 1975 and 1980 in these runs, eliminating all costs on land improvement. This happens in the model when costs and living expenditures exceed the value of sales and transfers from the crop sub-sector, cutting off the availability of capital for investment. In this case, commercial credit makes up the difference to cover operating costs and/or living expenditures.

Although Run 4 experiences the same trends in price and indebtness, it takes longer to slow down and reverse its downtrend. Since higher incomes leave the farmers with more capital for investment, more private resources are committed to land improvement, and modernization proceeds for a longer period in this run, though at a lower rate, before it ceases. This results in lower acreage in modern land, but extended establishment costs throughout the period 1980-1985. This behavior may suggest that, after 1985 when modernization stops, the downtrend of Run 4 could be tapered off or even reversed. Only by making projections after 1985 will this behavior be known with certainty.

Finally, the per hectare capitalized value of land follows very closely the pattern of farm income (Figure IV.6). Although the value of a hectare in modern grazing (based on its amortized annual average returns) is much higher (about double) than a hectare of traditional grazing, the relative proportion of the former in the total grazing land is so small during the simulation that changes in the composition of acreage in grazing have less effect on the capitalized land value of

Run Definitions

1. Disease control, modernization of cattle production, current land and cattle taxes and continuation of present trends and policies (base run).
4. Taxes on cattle cut off at years 1970 and 1972.
5. Property tax increased to 14.2 mills at year 1970.

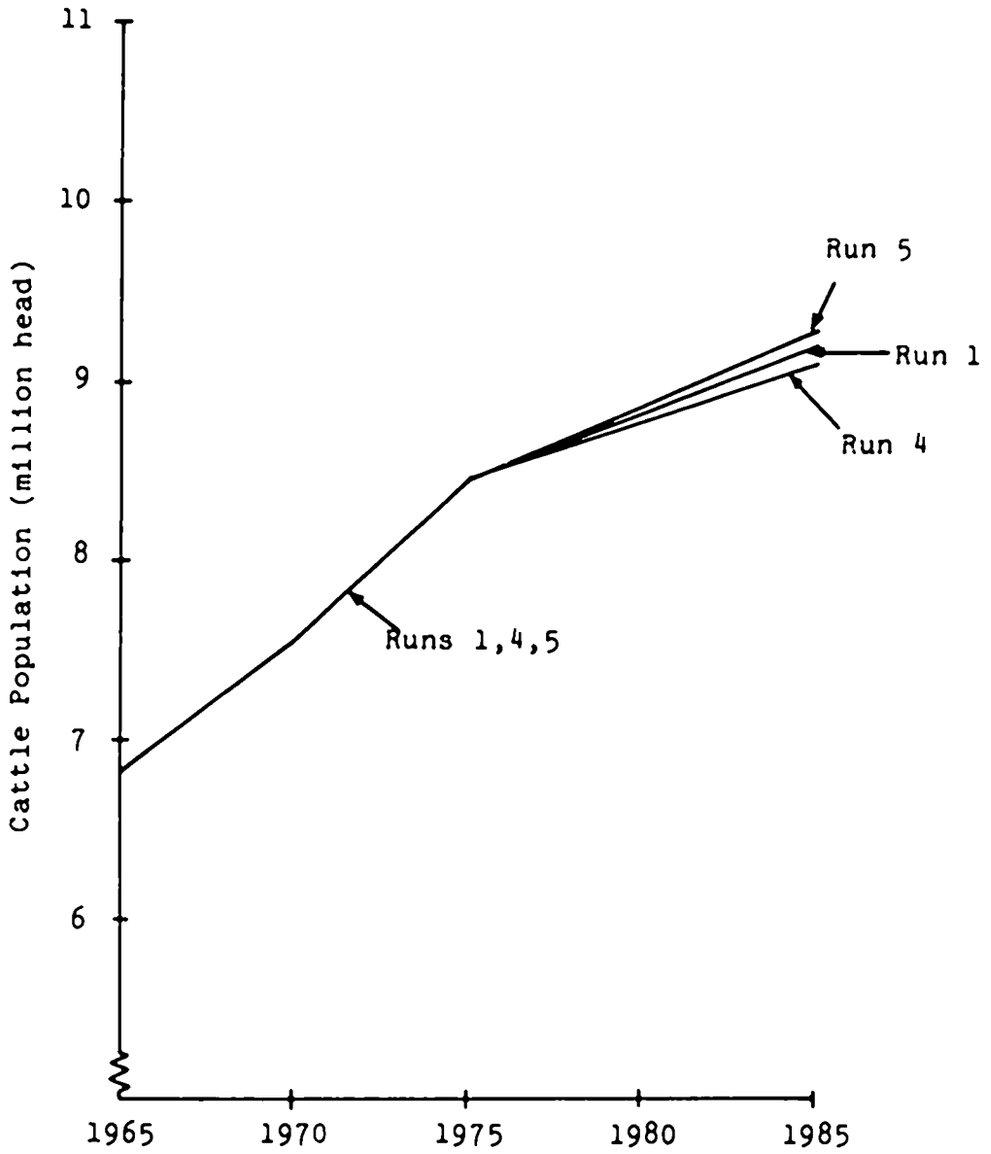

Figure IV.3. Cattle population in the Costa under various taxing policies, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, current land and cattle taxes and continuation of present trends and policies (base run).
4. Taxes on cattle cut off at years 1970 and 1972.
5. Property tax increased to 14.2 mills at year 1970.

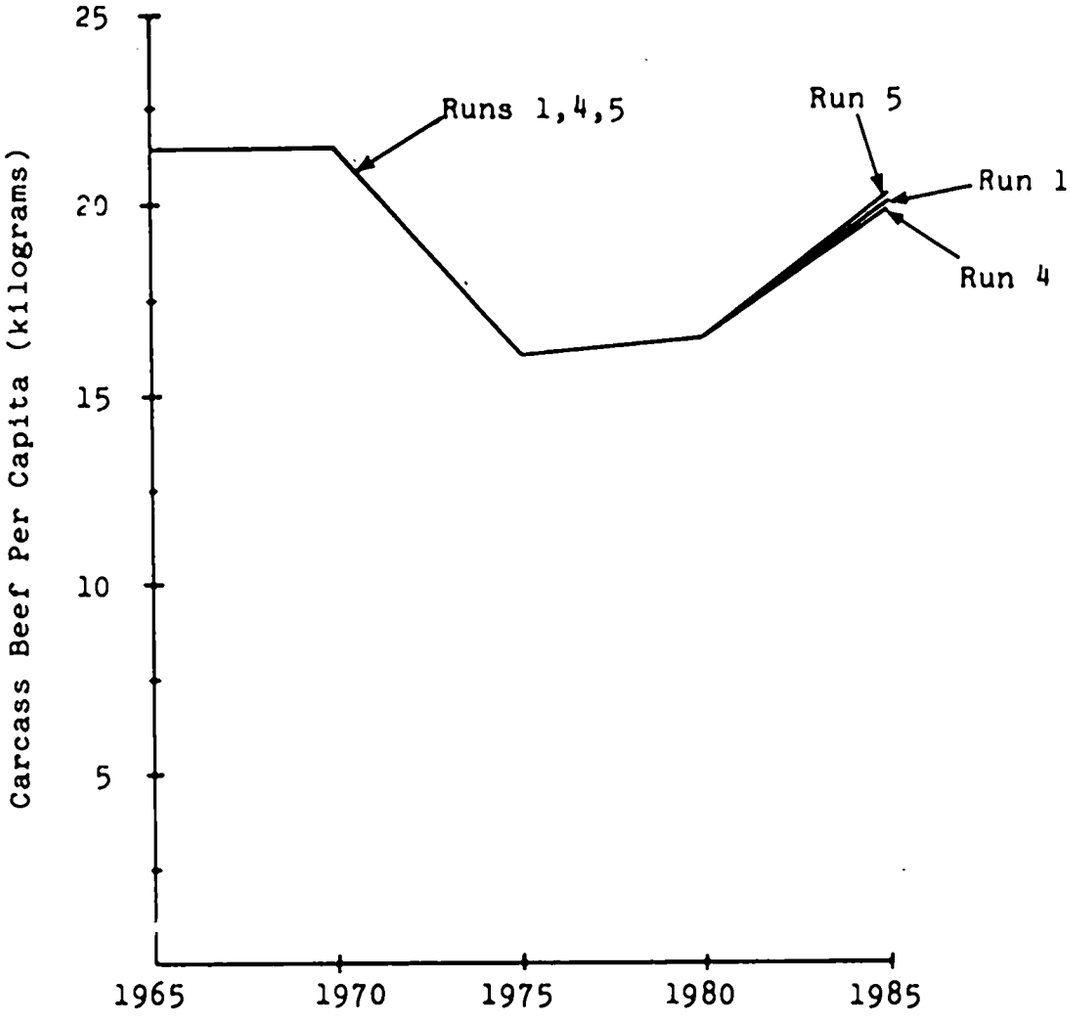

Figure IV.4. Beef consumption per capita of the Colombian population under various taxing policies, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, current land and cattle taxes and continuation of present trends and policies (base run).
4. Taxes on cattle cut off at years 1970 and 1972.
5. Property tax increased to 14.2 mills at year 1970.

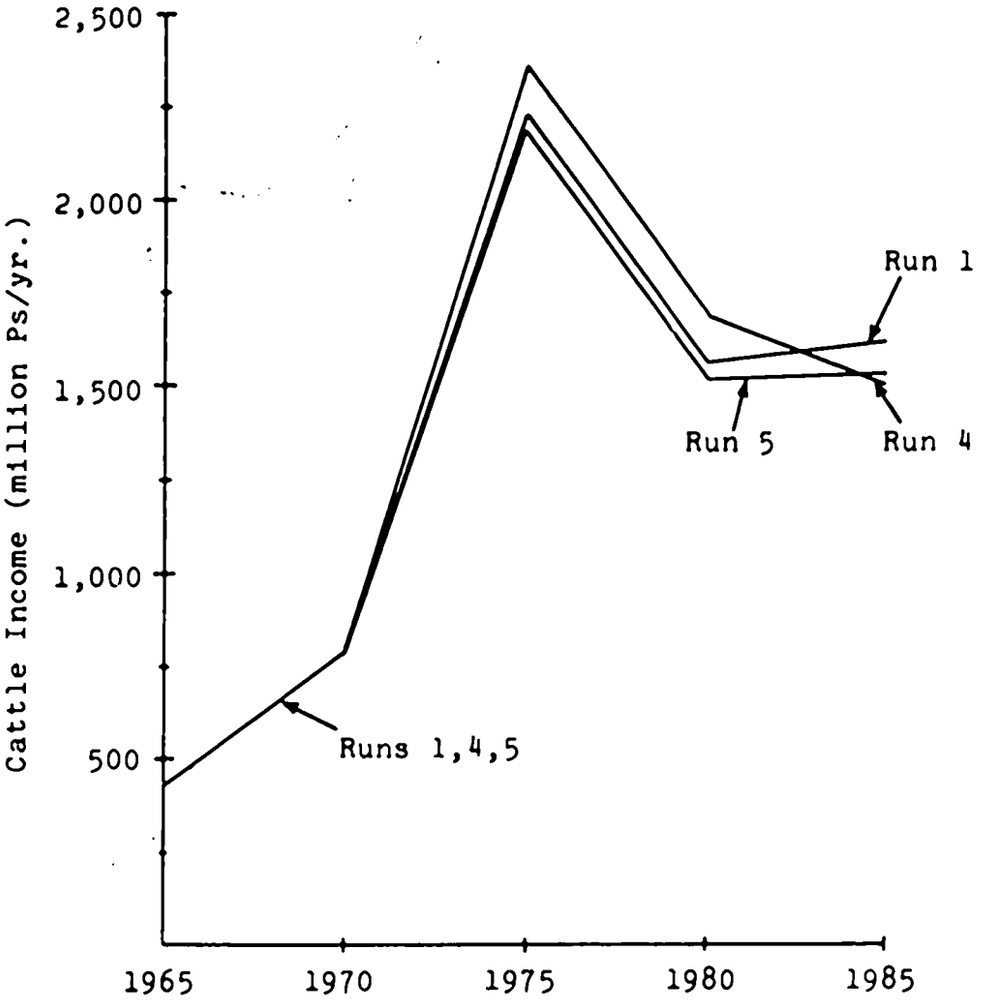

Figure IV.5. Aggregated farm income from cattle production in the Costa under various taxing policies, 1965-1985.

Run Definitions

1. Disease control modernization of cattle production, current land and cattle taxes and continuation of present trends and policies (base run).
4. Taxes on cattle cut off at years 1970 and 1972.
5. Property tax increased to 14.2 mills at year 1970.

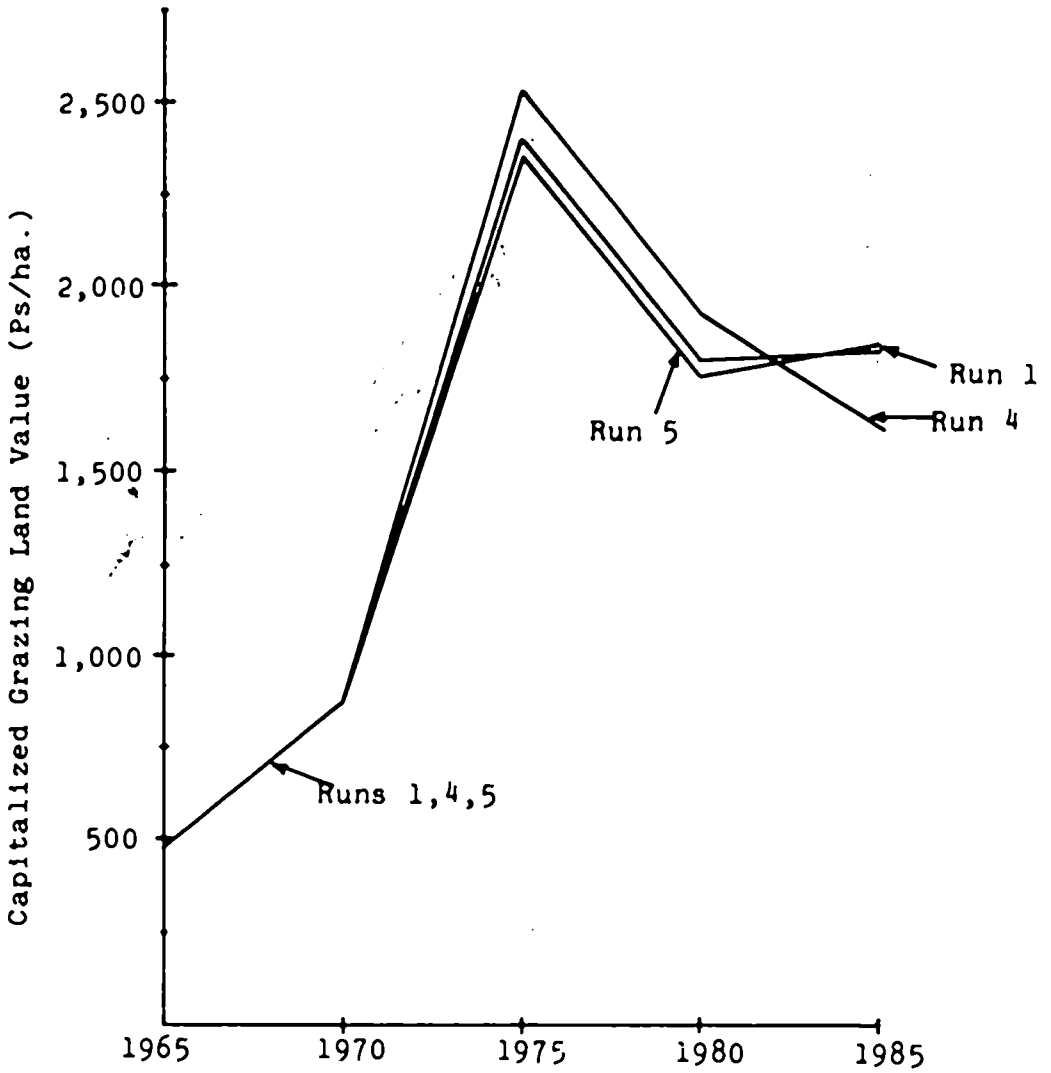

Figure IV.6. Average per hectare capitalized value of grazing land in the Costa under various taxing policies, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, current land and cattle taxes and continuation of present trends and policies (base run).
4. Taxes on cattle cut off at years 1970 and 1972.
5. Property tax increased to 14.2 mills at year 1970.

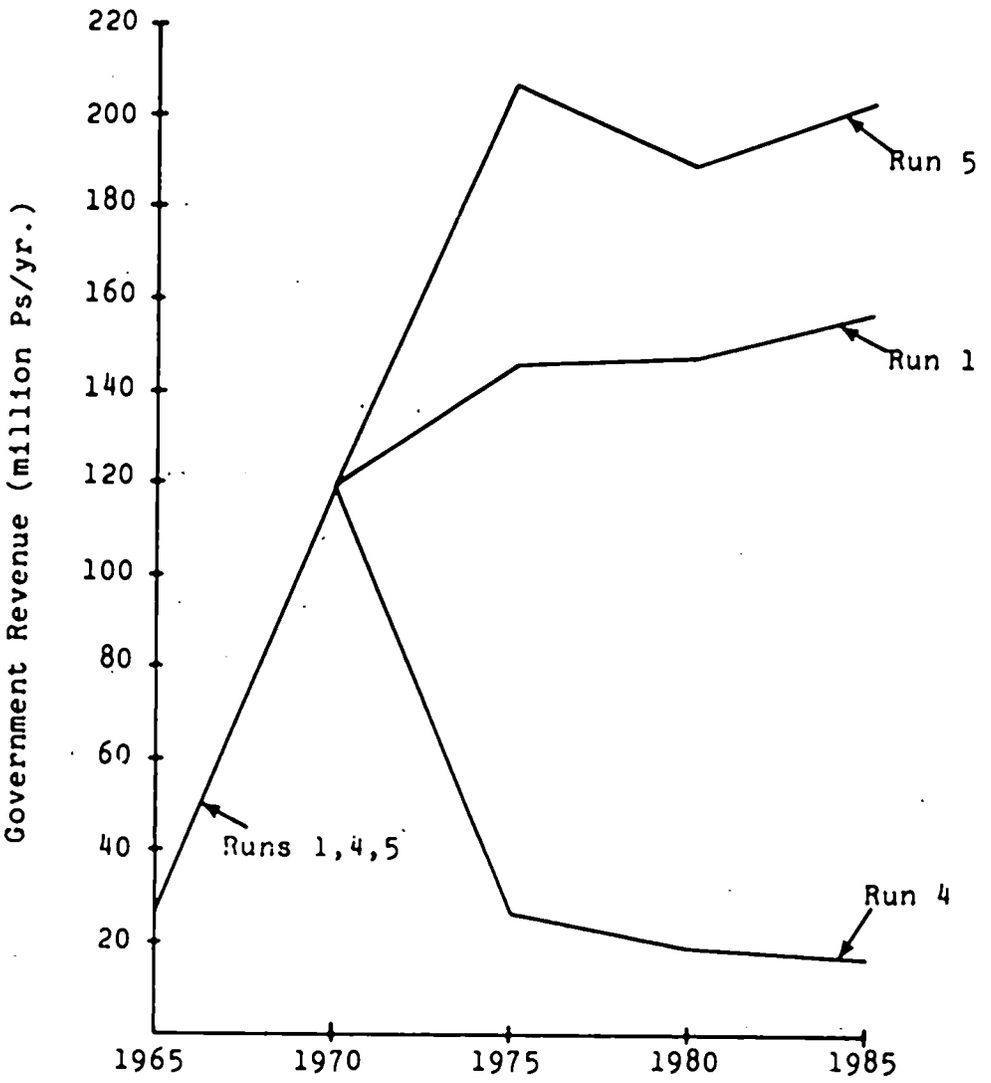

Figure IV.7. Annual government revenues from cattle production in the Costa under various taxing policies, 1965-1985.

the region. Yet as modernization proceeds and the area in modern land increases (both absolutely and relatively), its impact on the average value of land will be greater. While it is true that the special annual land tax burden will be amortized in the form of lower land prices, thus reducing the net worth of farmers, its long-run allocative effect could result in increased land values and government revenues as more traditional farmers are encouraged to improve their lands and herds.

In general, increasing the land tax greatly increases government revenues without impairing farmers' income and wealth to a great extent. Probably the best strategy would be one of combining increased land tax and eliminating some of the special taxes on cattle. These results suggest that, when proper policies are implemented, more surplus could be taken from cattle producers in the form of higher taxes without greatly curtailing farm capital formation and output.

Policies Related to Promotion and Development Credit

Policies and programs related to promotion and credit for cattle modernization are examined in simulation Runs 6, 7, 8 and 9. Current arrangements for development credit assumed in Run 1 are those set by the Caja Agraria project: interest rate of 14 percent, a four-year grace period, eight years for repayment, and borrowing ranchers participating with 20 percent of the estimated cost. The total budget for the credit program is assumed to be Ps 750 million spread over

a ten-year period (see Figure II.8). And precampaign promotion is assumed to be 3,000 units of promotion spread over an eight-year period (see Figure II.8).[1/] Run 6 compares the effect of reducing the interest rate to 10 percent during the life of the program. Run 7 explores the effect of increasing the grace period to five years and the repayment period to ten years.

The remaining runs of this set examine policies of a more macroeconomic nature. Run 8 explores the effect of increasing the allocation of credit funds up to Ps 1,125 million over the same ten-year period. And finally, Run 9 investigates the effect of increasing the units of campaign promotion to 4,500 man-year equivalents over the same eight-year period.

The most striking observation that can be made about this set of runs is that Run 8 (increased funding for development credit) produces results practically identical with those for the base run, and that results from Runs 7 and 9 (improved terms for repayment and increased units of promotion, respectively) are very close. Results from Run 6 (reduced interest rate) are consistently higher than for the other runs with the exception of the period 1965-1971 for farm income and value of land and the last three years of the run for farm income only (Figures IV. 8, 9, 10, 11 and 12).

[1/] One unit is equivalent to one man-year with annual cost of Ps 20,000.

The almost identical results (differences are so small they can't be detected in the graph) for Runs 1 and 8 indicate that allocating 50 percent more funds for development credit over a period of ten years has practically no effect on the output of the model. While it is true that farmers use more credit when it is available and that more of their cash balances are used to complement credit payments, the total area in modern land is not affected. It is the same in both runs. Runs 1 and 8 generate the same rate of land modernization which means that, given the present model's structure, more available credit does not affect farmers' decisions. This is to say that more available credit does not change farmers' perception of relative profitability nor their threshold and response rate parameters. Recalling the modernization mechanism in the model, we see that these parameters are used to simulate a wide variety of responses to environmental situations (social, political and economic). Therefore, we can see that, unless the environmental conditions are such as to make new investments attractive, increasing government funds for modernization do not have major impacts on development.

As stated above, the projected time paths of Runs 7 and 9 are very close and produce virtually the same results. Initially, the rate of modernization is dominated by the relatively higher net returns expected throughout the planning horizon when the debt burden is spread over a longer period, but, after a few years, the promotion effort builds and its

effect outweighs that of the relative profitabilities to produce a higher rate of modernization in Run 9 than in Run 7. Yet after 1973 when promotion ceases, the modernization decisions are based exclusively on the relative differences of the net present values and the other behavioral parameters, and as a result more land is modernized in Run 7 than in Run 9.

As discussed in the previous section, the projected time paths of the five performance variables respond to the interactive effects of changes in use of modern land. This interactive effect is more easily seen in the changing order of cattle numbers in Runs 7 and 9 which follow the varying rates of land modernization discussed above (Figure IV.8). Farm income behavior is more complicated since there are more factors involved. From 1965 to 1973 it is higher in Run 7 than in Run 9 as a result of the extended grace period on the development credit and less expenditures on land modernization by the end of the period. Then follows a period when increased modernization demands more expenditures in Run 7 than in Run 9 and aggregate income in the former drops below the latter (Figure IV.10). The increasing and decreasing trends in this variable have been discussed. The capitalized value of land is a reflection of farm income although, in the final period of the run, larger values of traditional land increase average assessed land value in Run 7. This is the effect of the capitalized higher price of cattle in Run 7 resulting from lower supplies as shown in Figure IV.9. Finally, government

revenues follow from cattle inventories, sales and assessed land values (Figures IV.11 and 12).

When outputs of Runs 1, 6, 7, 8 and 9 are compared, reducing the interest rate on development credits in Run 6 shows the greatest impact on all variables. Cattle population, consumption per capita and government revenues are consistently higher in Run 6 than in the other runs. Farm income, however, is the lowest in Run 6 from 1966 to 1971, and then is the highest until approximately 1983 when it is below Runs 7 and 9 but above the base run (Figure IV.10).

Reducing the interest rate greatly increases the net present value of the expected income stream from modern relative to traditional cattle, and the resulting higher profitability accelerates modernization in Run 6 above the other runs. The initial effect of this enhanced rate of modernization is to decrease farm income relative to the other runs as more resources are committed to farm improvements and more cattle are retained in order to build up the herd. Although total cattle off-take is reduced, the supply of beef is increased as a larger proportion of heavier animals from the modern herd are slaughtered. Yet this enlarged beef supply, in turn, lowers the price of cattle and reinforces the decline in income. At this juncture, it should be remembered that all cattle prices in the model are related to the market price of finished males, disregarding conditions of demand for different animal categories. For

a more precise accounting of cattle prices and income this part of the model needs more refinement.

After this initial impact, increased sales in Run 6 outweigh the decline in price and as a result income becomes larger until 1983 when expenditures in modernization continue at a faster rate than in the other runs, and income becomes lower. The capitalized value of land reflects the varying pattern of farm income while government revenues follow in relation to cattle inventories, sales and assessed land values. The average value of land at the end of the run is greatly influenced by a higher proportion of modern land in the total grazing land which is 34 percent in Run 6 compared with 15 percent in Runs 1 and 7, and 22 percent in Run 9 (Figure IV.11).

Policies Related to Domestic Supply

Pricing policies are investigated in Runs 10, 11 and 12. Retail prices have been under control at various times but have never been efficiently enforced. Therefore, coercive controls are ruled out here and the only price adjusting mechanism allowed is through control of domestic supply via the export market and/or increased off-take from the national herd. Cattle exports will come mostly from the Costa herd but excess supplies from other producing regions, if ever attained, will also be exported. Exports are exogenously determined according to targets set by the government. Low target projections are included in all runs between 1972 and 1974 (see Table I.1, p.19) but thereafter three different

Run Definitions

1. Disease control, modernization of cattle production, current credit terms and continuation of present trends and policies (base run).
6. Reduced interest rate on development credits from year 1966.
7. Increased terms of repayment on development credits from year 1966.
8. Increased funding for development credit from 1966 to 1976.
9. Increased units of modernization promotion from 1965 to 1974.

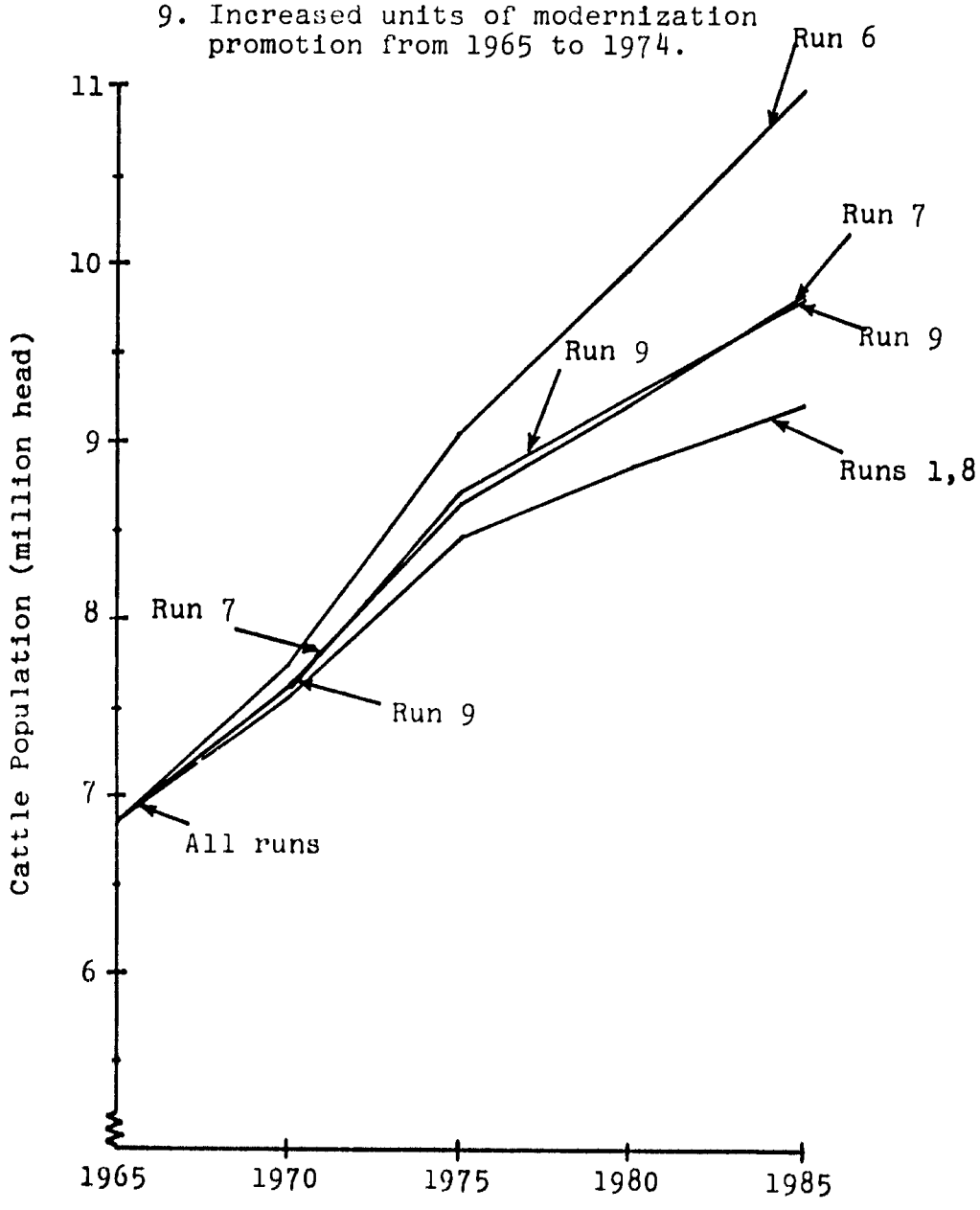

Figure IV.8. Cattle population in the Costa under various promotion and credit policies, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, current credit terms and continuation of present trends and policies (base run).
6. Reduced interest rate on development credits from year 1966.
7. Increased terms of repayment on development credits from year 1966.
8. Increased funding for development credit from 1966 to 1976.
9. Increased units of modernization promotion from 1965 to 1973.

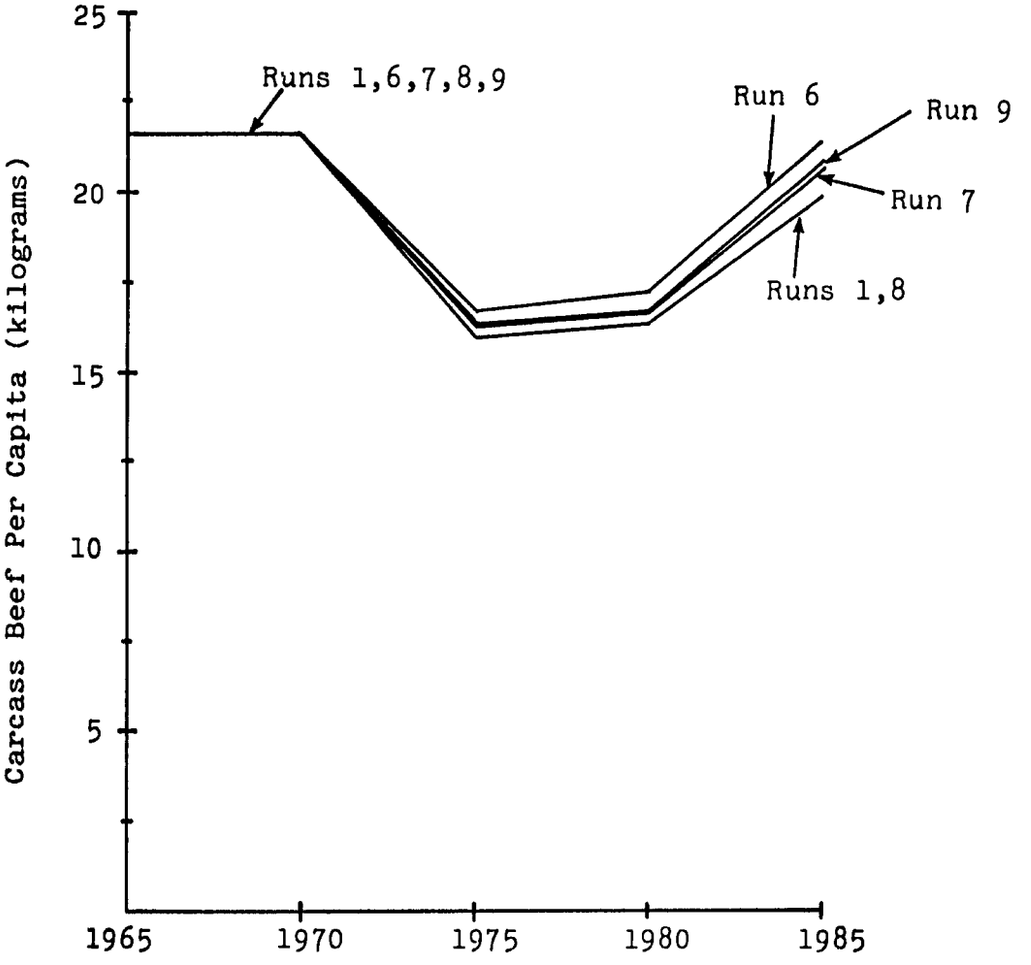

Figure IV.9. Beef consumption per capita of the Colombian population under various promotion and credit policies, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, current credit terms and continuation of present trends and policies (base run).
6. Reduced interest rate on development credits from year 1966.
7. Increased terms of repayment on development credits from year 1966.
8. Increased funding for development credit from 1966 to 1976.
9. Increased units of modernization promotion from 1965 to 1973.

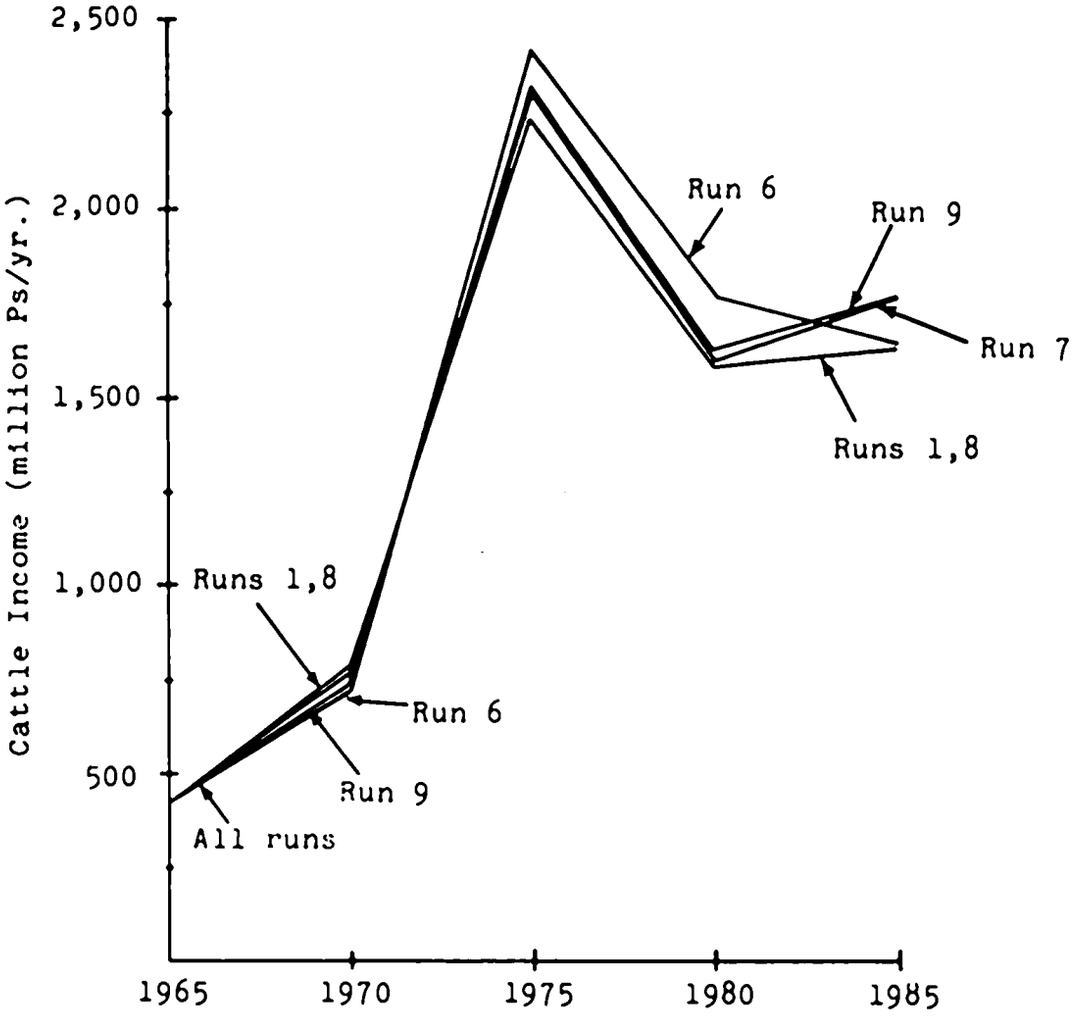

Figure IV.10. Aggregated farm income from cattle production in the Costa under various promotion and credit policies, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, current credit terms and continuation of present trends and policies (base run).
6. Reduced interest rate on development credits from year 1966.
7. Increased terms of repayment on development credits from year 1966.
8. Increased funding for development credit from 1966 to 1976.
9. Increased units of modernization promotion from 1965 to 1973.

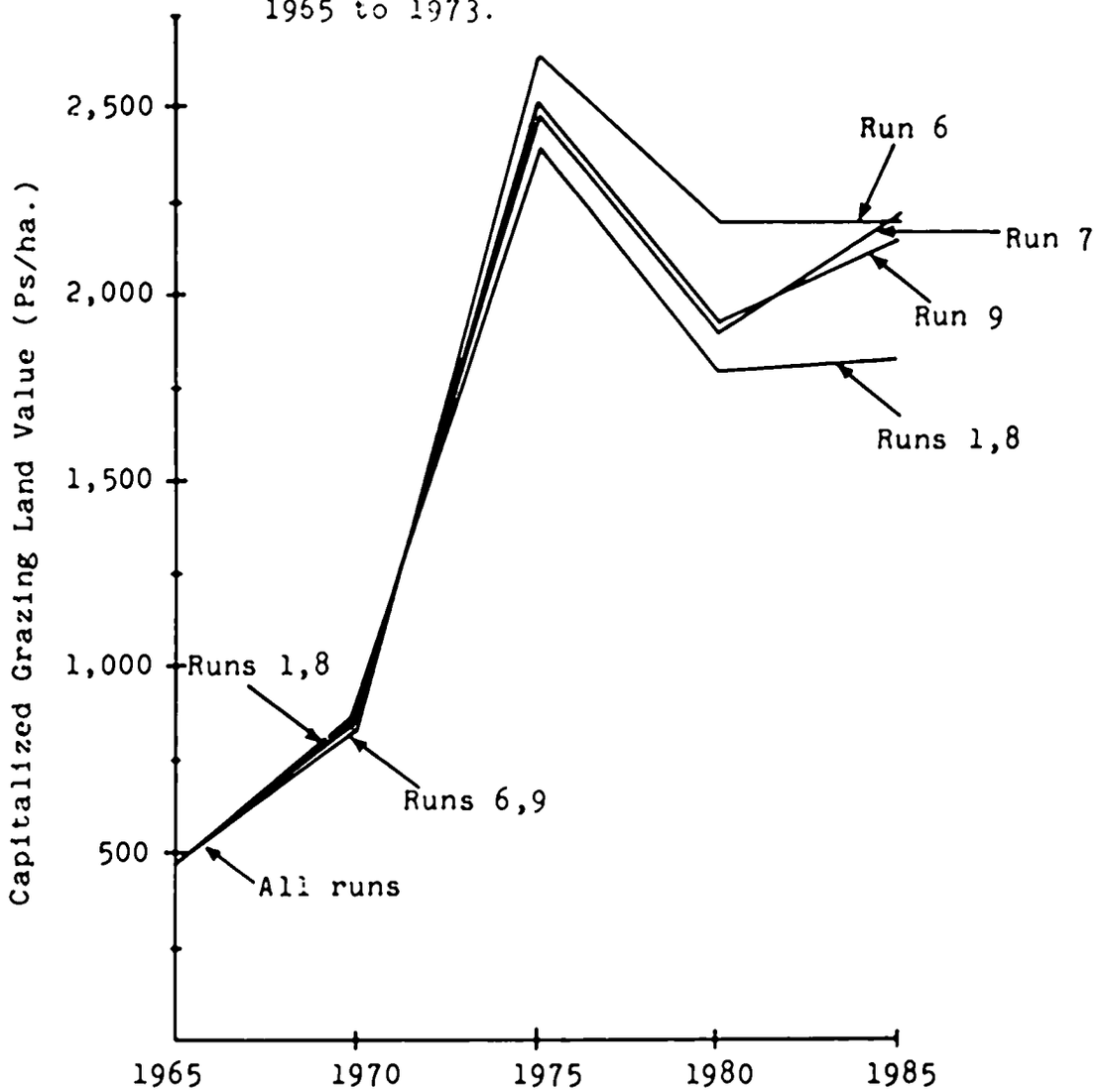

Figure IV.11. Average per hectare capitalized value of grazing land in the Costa under various promotion and credit policies, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, current credit terms and continuation of present trends and policies (base run).
6. Reduced interest rate on development credits from year 1966.
7. Increased terms of repayment on development credits from year 1966.
8. Increased funding for development credit from 1966 to 1976.
9. Increased units of modernization promotion from 1965 to 1973.

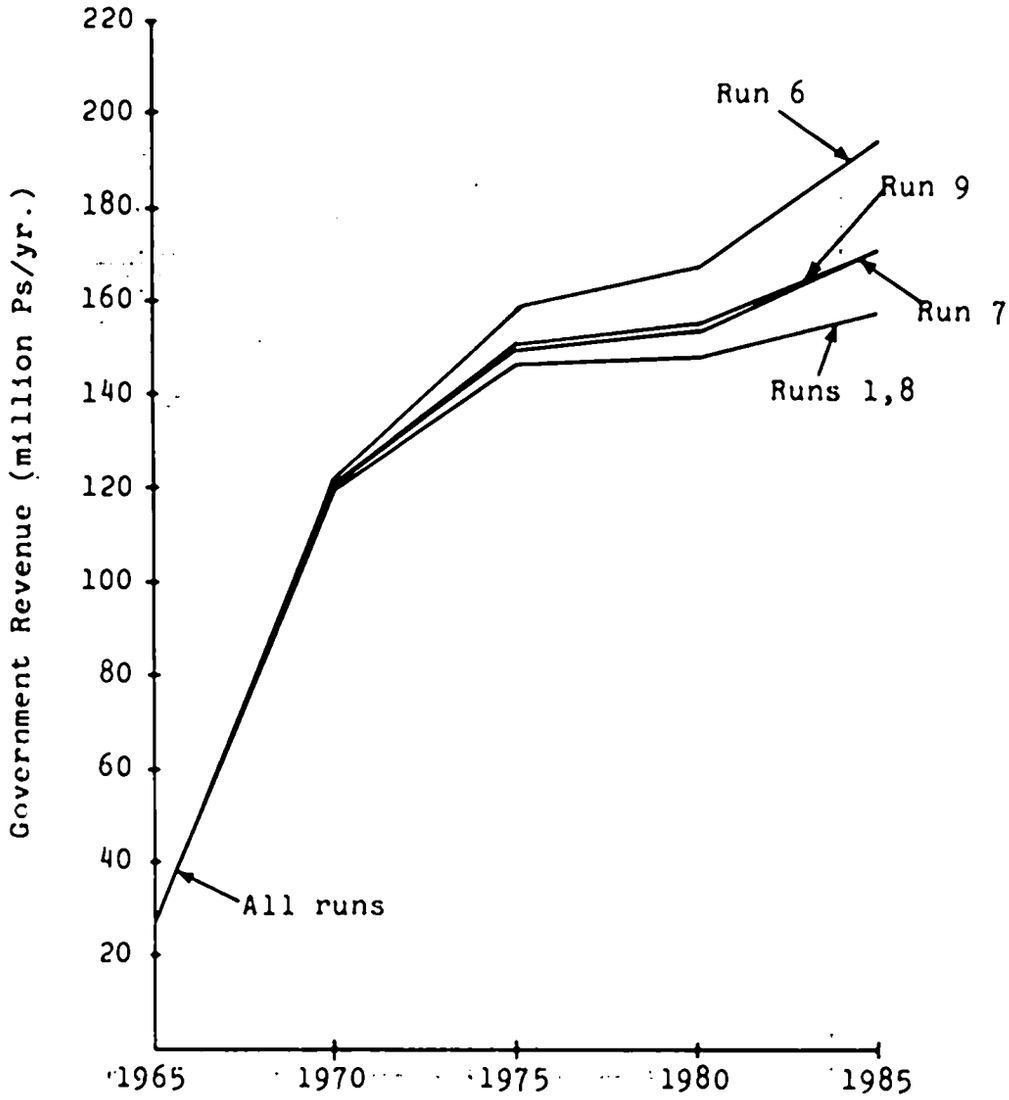

Figure IV.12. Annual government revenues from cattle production in the Costa under various promotion and credit policies, 1965-1985.

targets are tested in the model. The base run continues projecting exports at a low level (329 thousand head annually), Run 10 makes projections at an intermediate level (496 thousand head annually), and Run 11 at a high level (692 thousand head annually) [35]. Run 12 compares the effect of attaining a high export target at the same time that the cattle herd in the other four producing regions is growing at 5 percent annually. At the time the simulation runs were completed, details of the new cattle development plan were released setting a revised export target at one million head annually by 1990, but due to time constraints this was not included in the study.[1/] Illegal exports are kept constant in all runs at 300 thousand head annually.

The effect of setting up low, intermediate and high export targets accompanied or not by programs to develop the cattle herd in the rest of the country results in striking differences in outputs. In Figure IV.14 we see that the major contributor to high consumption per capita is the development of the cattle herd in the rest of the country beginning in 1975, even after sustaining the export of 692 thousand head annually. The lowest consumption per capita is attained in Run 11 with high export target and "normal" growth of the non-Costa herd.

[1/] El Espectador, (Bogota), July 8, 1973.

Total (national) cattle population is the highest in Run 12 as expected, despite a substantial decline in the Costa inventories after 1975 (Figure IV.13). Yet, the non-Costa cattle projections for this run reveal unrealistic internal inconsistencies. In one account, the same conditions that discourage cattle production in the Costa might exist in the other producing regions, resulting in a lower or even zero rate of mcdernization. Likewise, the 5 percent annual rate of growth assumed in the government plan seems to be unrealistically high since the growth of the Costa herd in the base run has been about 1.6 percent for the period 1960-1985, and about 2.2 percent annually during 1960-1975, the period of the fastest growth.

The rising trend in the Costa cattle population of Run 12 (Figure IV.13) tapers off after 1975 and turns down after 1980 ending the projection with 8 percent fewer cattle than the other runs. The substantial increase in beef supply after 1975 causes a sharp decline in cattle prices (price of finished males are 45 percent lower in Run 12 than in Run 1 by 1985) that first reduces the comparative advantage of the modern operation and later turns it into a loss. At this point land and cattle are transferred back to traditional practices, and the nutritional imbalance caused by these shifts fosters sales that further depress prices. We must recall that the modernization mechanism in the model will return land to traditional management when the perceived relative profitability (net present values) becomes negative

indicating that the discounted returns at the base year for traditional cattle are higher than those of modern throughout the planning horizon. Therefore, the declining profitabilities discussed above, through their interactive effects in the model, result in reduced and early cessation of modernization, reversion of land and animals from modern to traditional, and firally in lower cattle inventories.

Despite larger incomes from higher cattle prices in Runs 10 and 11 than in Run 1, the projected rates of land modernization are very close and, as a result, the Costa cattle population is virtually the same in these runs. The reason for this is twofold: (1) discounted net returns in each base year from traditional and modern cattle experience about equal proportional increases for higher prices apply to sales from both operations. Consequently, the perceived relative profitabilities that are part of the modernization's decision mechanism remain very close in their time paths, and (2) the final rate of modernization is dominated by the behavioral responses of farmers despite the greater availability of investment capital arising from higher incomes, especially in Run 11. This effect is the same as that of having more credit available for modernization. Yet we can speculate that projections after 1985 might show a higher population in Run 11 as modernization expands because of the increased liquidity of farmers at a time when that of the other runs has been reduced. It is also worth noting that the higher average discounted returns from cattle in Runs 10 and 11 also have an effect on land use, reducing the area in crops in

the region. This estimated effect, through the land allocative mechanism in the model, and its possible inaccuracies will be discussed in the next section on crop modernization.

The most dramatic effects of regulating prices through domestic supplies are seen in the other three performance variables. Aggregated farm income from cattle (Figure IV.15) is the highest when the high export target is attained, followed in order by Runs 10, 1 and 12. Farm income in Run 12 not only falls sharply after 1975 when increased cattle outputs from non-Costa regions are marketed, but also becomes negative during the run's last five-year period. As income drastically drops, farmers have to resort to short-term credit to cover their operating costs and living expenditures. As short-term indebtedness increases, debt service expenditures further reduce farmers' liquidity. Although under these circumstances farmers reorganize their business, returning land and cattle from modern to traditional management, the model does not provide adequately for reorganizing production by reducing expenditures or, more drastically, going out of business. Contrarily, the upper bound on sales and the dominance of nutritional factors built into the sales mechanism preclude a liquidation of the herd and force farmers to stay in business even at a loss. This behavior points out the

need to refine the model so as to better handle this investment and disinvestment.[1/]

The capitalized value of land (Figure IV.16) follows the projected time paths of farm income. However, Run 11 shows the effect of a higher value of traditional land on the weighted average of land in the region. The value of land in Run 12 decreases sharply after 1975 until it reaches the salvage value of one peso assumed in the model when income becomes negative.

Government revenues (Figure IV.17) are again the highest in Run 11 and the lowest in Run 12. Higher government revenues in Runs 10 and 11 than in the base run arise from higher assessed land values since cattle inventories and sales remain about the same. The loss in revenues in Run 12 is produced by reduced cattle inventories and mostly by lower assessed land values.

Policies Related to Crop Modernization

Run 13 attempts to highlight the interactive effects of increasing the production of cash and food crops via extension efforts to introduce new seed varieties and improved cultural practices, improving average cash crop yields in lowlands and uplands to 2,900 and 1,650 kg./ha., respectively, and average food crop yields to 10,000 kg./ha. This run

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[1/] In turn, this need indicates a disciplinary need for economists to develop a user cost theory as a basis for improved modeling of investment and disinvestment.

Run Definitions

1. Disease control, modernization of cattle production, low export target and continuation of present trends and policies (base run).
10. Cattle exports set at intermediate target from year 1974.
11. Cattle exports set at high target from year 1974.
12. Cattle exports set at high target from year 1974 plus modernization of rest of national herd from year 1975.

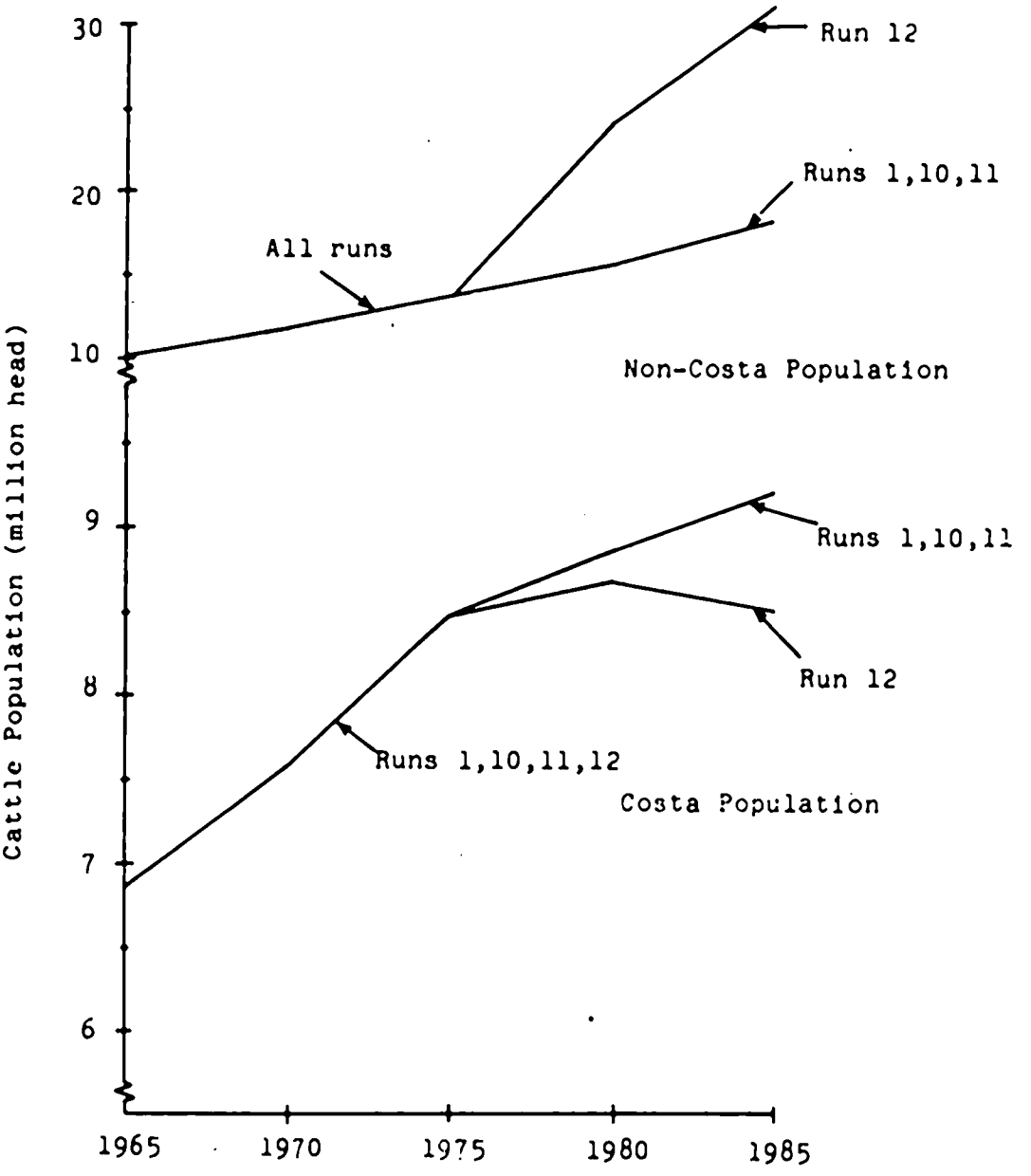

Figure IV.13. Cattle population in the Costa and the rest of Colombia under various domestic supply policies, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, low export target and continuation of present trends and policies (base run).
10. Cattle exports set at intermediate target from year 1974.
11. Cattle exports set at high target from year 1974.
12. Cattle exports set at high target from year 1974 plus modernization of rest of national herd from year 1975.

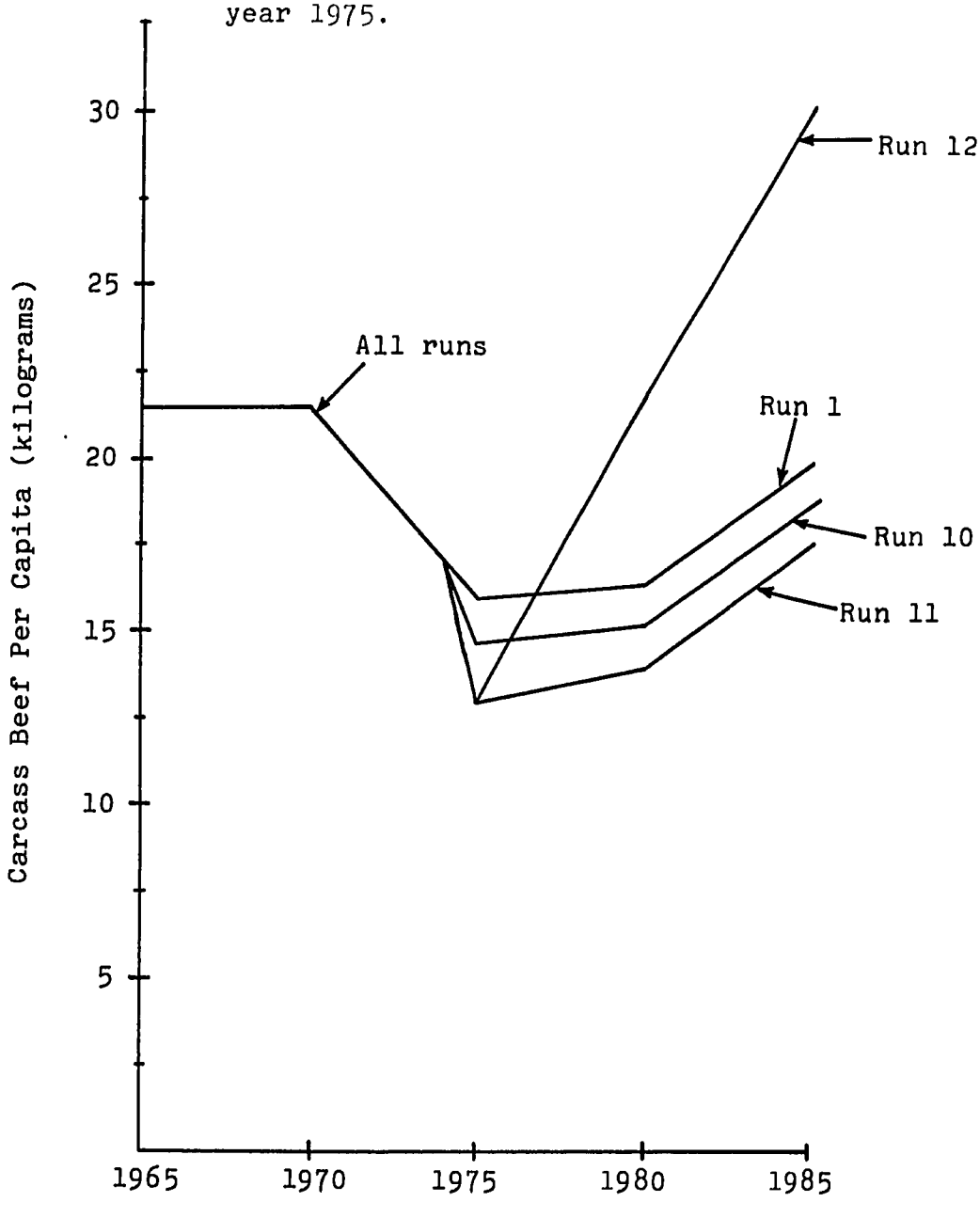

Figure IV.14. Beef consumption per capita of the Colombian population under various domestic supply policies, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, low export target and continuation of present trends and policies (base run).
10. Cattle exports set at intermediate target from year 1974.
11. Cattle exports set at high target from year 1974.
12. Cattle exports set at high target from year 1974 plus modernization of rest of national herd from year 1975.

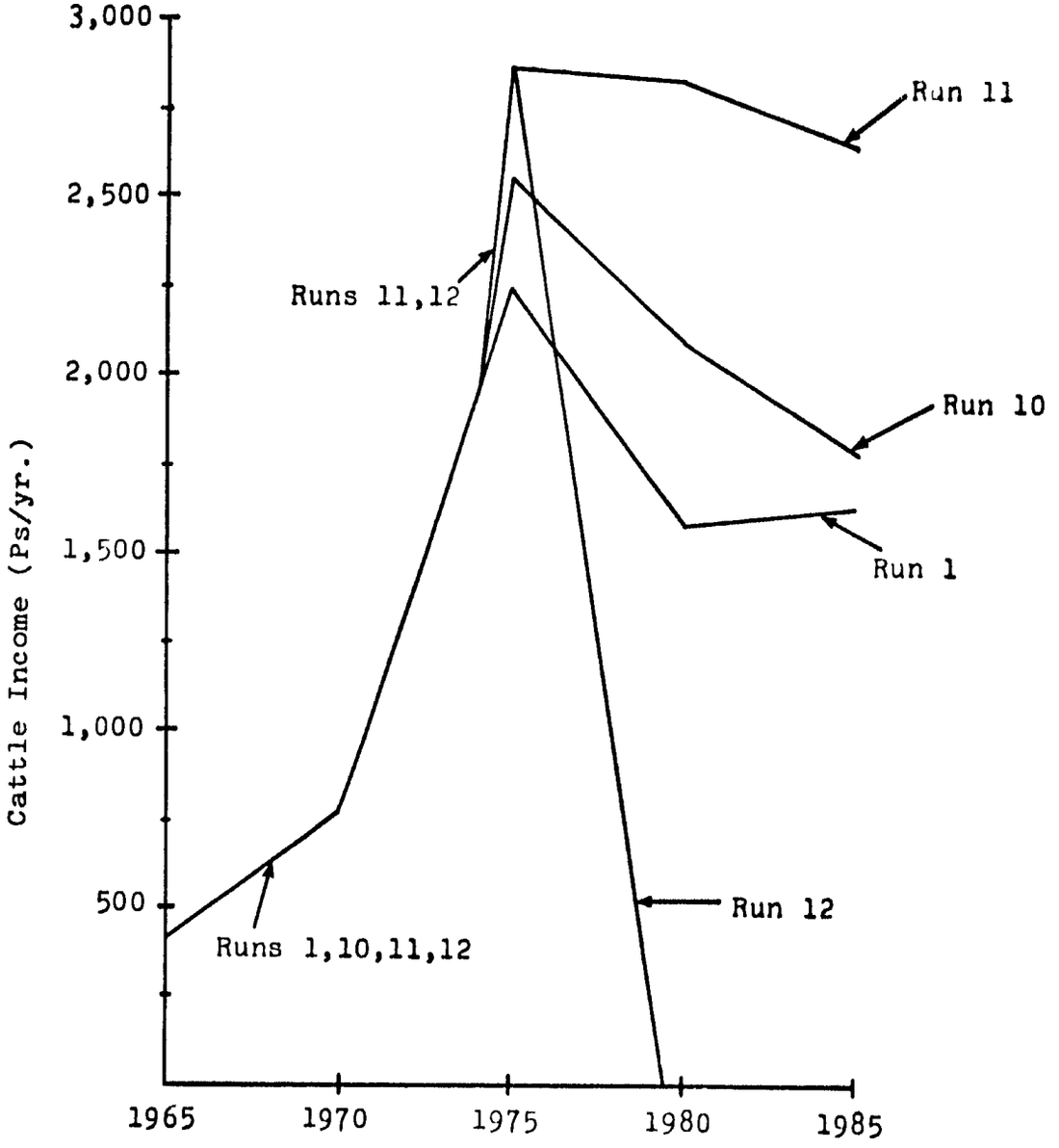

Figure IV.15. Aggregated farm income from cattle production in the Costa under various domestic supply policies, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, low export target and continuation of present trends and policies (base run).
10. Cattle exports set at intermediate target from year 1974.
11. Cattle exports set at high target from year 1974.
12. Cattle exports set at high target from year 1974 plus modernization of rest of national herd from year 1975.

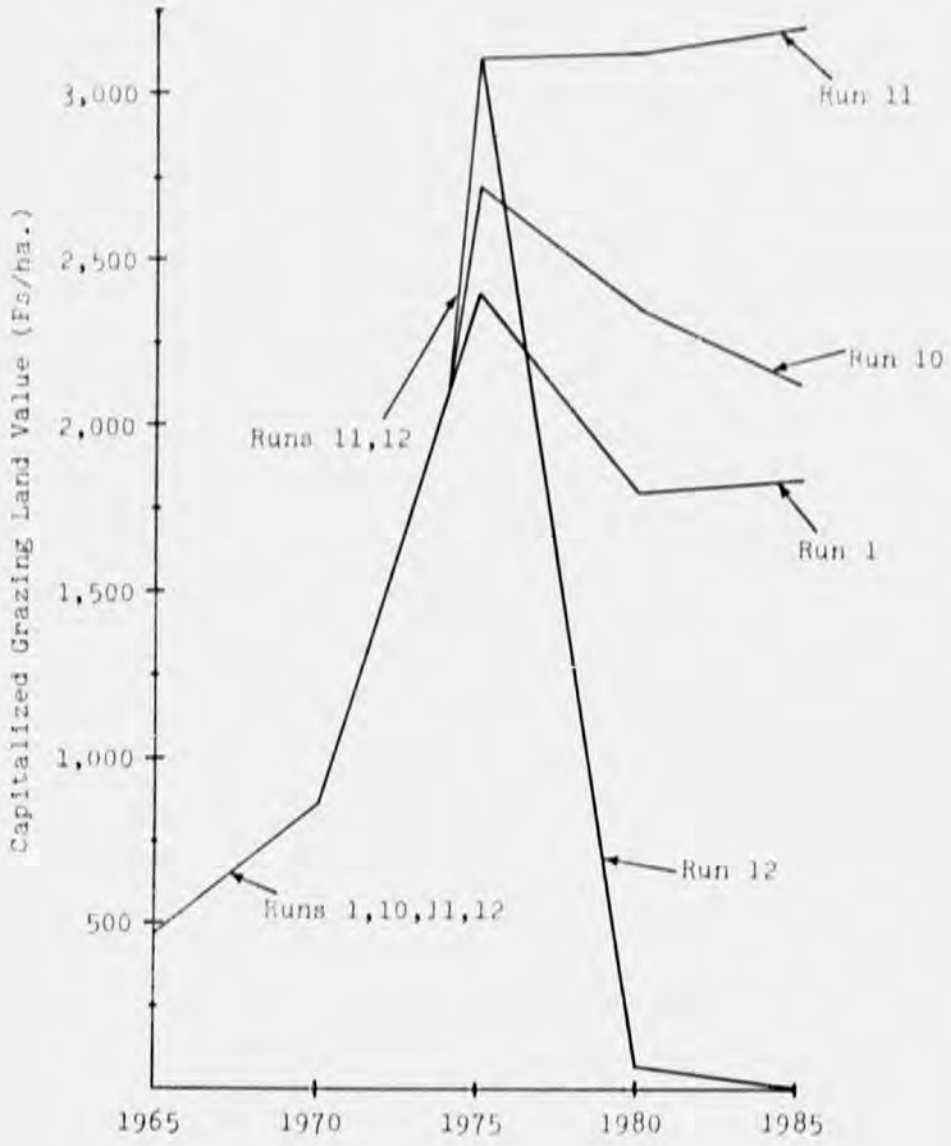

Figure IV.16. Average per hectare capitalized value of grazing land in the Costa under various domestic supply policies, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, low export target and continuation of present trends and policies (base run).
10. Cattle exports set at intermediate target from year 1974.
11. Cattle exports set at high target from year 1974.
12. Cattle exports set at high target from year 1974 plus modernization of rest of national herd from year 1975.

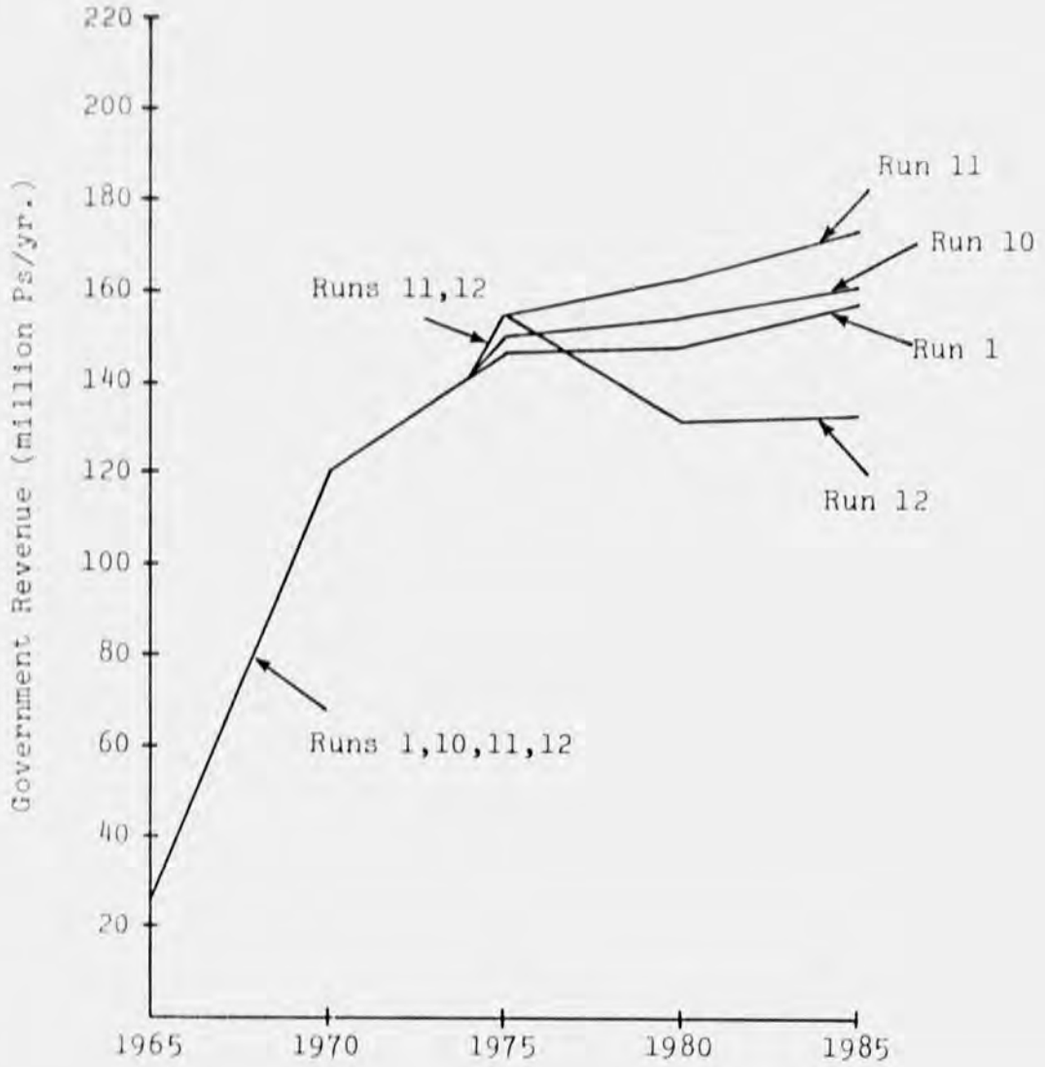

Figure IV.17. Annual government revenues from cattle production in the Costa under various domestic supply policies, 1965-1985.

assumes that yield targets are attained at the end of five years with the crop modernization effort starting in 1972 while cattle improvement programs are still in effect.

Run 13 examines the effect of a program to modernize cash and food crop production on the performance of the cattle industry. In general, the modernization of crops has an adverse effect on all performance variables but cattle population which shows a slightly higher trend in Run 13 than in the base run between 1980 and 1985, although for practical purposes the results can be considered the same (Figure IV.18). When cash crops are modernized, their profitability increases relative to that of cattle and more land is transferred from cattle production to crop production. As a result, total grazing land declines over time. But the land allocation and modernization mechanisms in the model interact to step up the proportion of modern land in total grazing land. The effect of the land allocative mechanism is to take out land from the least profitable cattle activity--the traditional in this case--and transfer it to the most profitable cash crop activity. Meanwhile, the modernization decision mechanism continues to shift land from traditional to modern cattle management. If the latter effect outweighs that of the land allocation, as in Run 13, this results in a higher proportion of modern pasture land relative to total pasture land that compensates any loss of grazing area. Yet it is likely that, in the long run, differences in cattle population will widen as more grazing land is

modernized in Run 13 after 1985 at a time when modernization has ceased in the base run. The reason for this is the greater availability of capital for investment brought about by larger revenue transfers from crops to cattle production as total income in the crops subsector increases. We should remember that the model assumes a 10 percent[1/] internal transfer of net revenues from crops to cattle; and that, for the period 1972-1985, net crop income is greatly increased, being 190 percent higher in Run 13 than in the base run in 1985. While this effect has its major impact in the absence of development credit and when the liquidity of farmers is low the projected rates of land modernization are very close in the two runs, despite larger internal capital transfers in Run 13. As discussed, this result indicates that the final rate of modernization is dominated by similarities between the way farmers' behavioral responses are modeled in both runs.

Although in Run 13 there are conditions for a larger and faster shift of land from cattle production to crop production, the assumptions underlying the land allocation mechanism prevent profit incentives from exerting a greater impact on land use. It is assumed that cash crops in the lowlands expand at a constant 4,500 hectares annually throughout the simulation; this seems to be an unrealistic assumption since it is likely this rate would increase as the profitability

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[1/] The accuracy of this estimate is highly uncertain. The rational for using a low proportion of capital transfer at this point is the current low level of reinvestment in cattle raising.

of crops relative to cattle becomes greater. In the uplands (subregion 1), however, we have reasoned that farmers' decisions to expand (or contract) their cash crop acreages are based on their perceived differences in net present value of future income streams from land in different uses, and on a response rate parameter. In the land allocative mechanism, we see that the effects of revenue differences between the allowed land uses are reduced by the response rate parameter which is assumed constant in the projected time paths for the two runs. This also seems to be an unrealistic assumption since it is likely that farmers will accelerate the rate of land transfer from pasture to crops as their perceived relative profitability becomes larger. As a result, the impact of relatively greater returns from crops on land allocation is minimized and the final estimate of land in crops is biased downwards. However, this transfer could be tapered off or even reversed if the average returns from cattle approximate or outweigh those from crops.

Although cattle population is slightly higher in Run 13 than in Run 1, the resulting per capita consumption is lower during the last five years of the run (Figure IV.19). This apparent paradox is explained by a higher pasture-to-animal ratio toward the end of Run 13 that results in a lower extraction ratio. In the sales mechanism of the model, the short-term response in off-take is dominated by nutritional conditions. Yet it is likely that the off-take in Run 13 will increase in the long run when modernization is completed

and the cattle herd is in equilibrium with the forage available.

As expected, aggregate farm income from cattle and the resultant capitalized value of land follow the same pattern. Income from cattle (Figure IV.20) follows almost the same time path in the two runs until 1980 indicating, again, the behavior and interactions discussed in previous sections. But after 1980, the two runs diverge widely and, while Run 1 reverses its downtrend, Run 13 continues to fall sharply. The reason for this is found in the greater availability of capital for investment brought about by increased revenue transfers from crop to cattle production--which enables farmers to continue investing in farm improvements for longer periods after the credit program has been cut off. This downtrend could be tapered off or even reversed if modernization slows down or stops altogether either for lack of incentives, lack of outlay balances for modernization, or lack of traditional land.

The capitalized value of land per hectare is a reflection of what happens to farm income (Figure IV.21). However, it is worth noting that in Run 13, after 1980 the decrease in land values is less than that of farm income. This is explained by the increased weight of modern land in the average capitalized value of land in the region resulting from the expansion of modern pasture and the contraction of traditional one. Finally, government revenues are lower in Run 13 after 1980 as a result of lower tax collections from cattle sales and assessed land values (Figure IV.22).

Run Definitions

1. Disease control, modernization of cattle production, no modernization of crops and continuation of present trends and policies (base run).
13. Modernization of cash and food crops from 1972-1976.

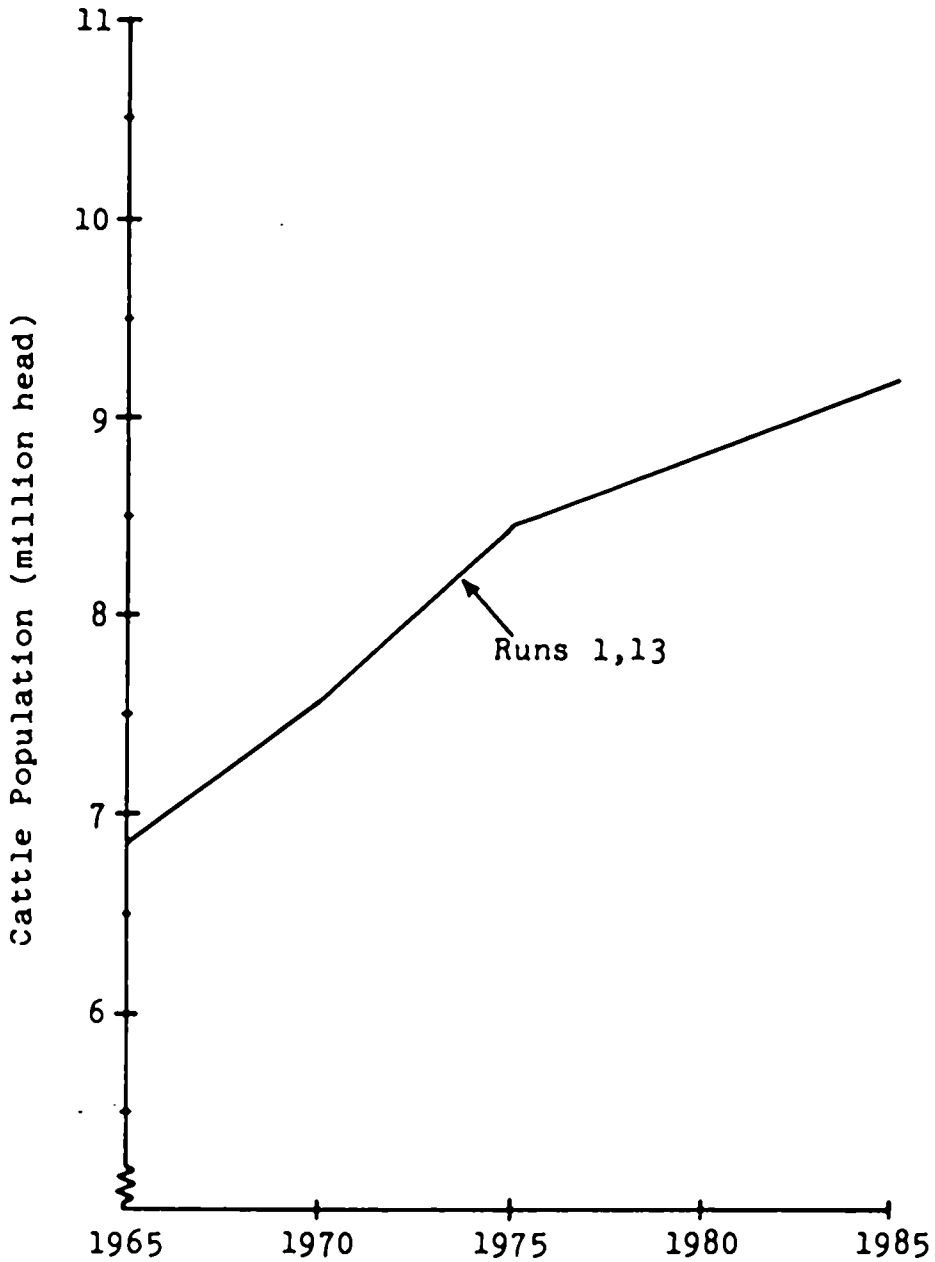

Figure IV.18. Cattle population in the Costa with and without a crop modernization program, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, no modernization of crops and continuation of present trends and policies (base run).
13. Modernization of cash and food crops from 1972-1976.

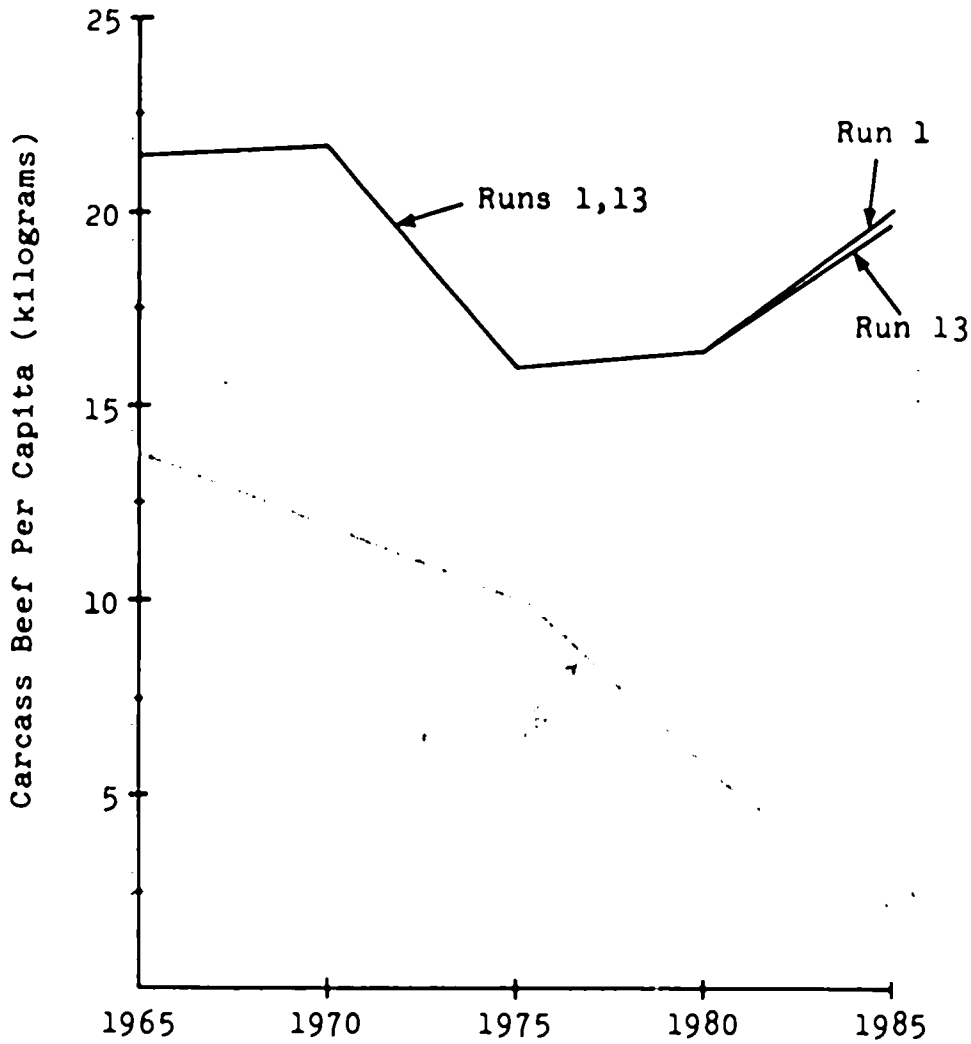

Figure IV.19. Beef consumption per capita of the Colombian population with and without a crop modernization program 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, no modernization of crops and continuation of present trends and policies (base run).
13. Modernization of cash and food crops from 1972-1976.

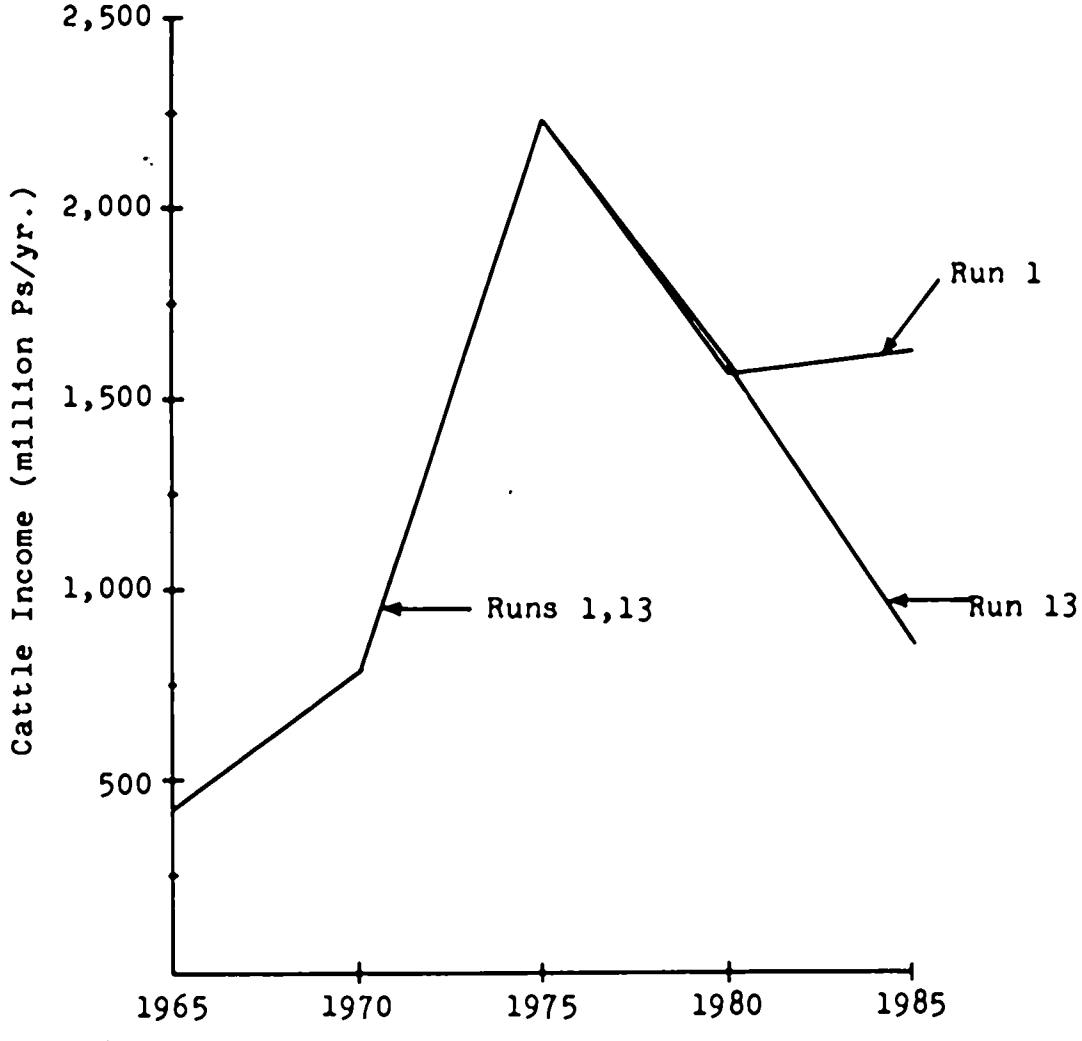

Figure IV.20. Aggregated farm income from cattle production in the Costa with and without a crop modernization program, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, no modernization of crops and continuation of present trends and policies (base run).
13. Modernization of cash and food crops from 1972-1976.

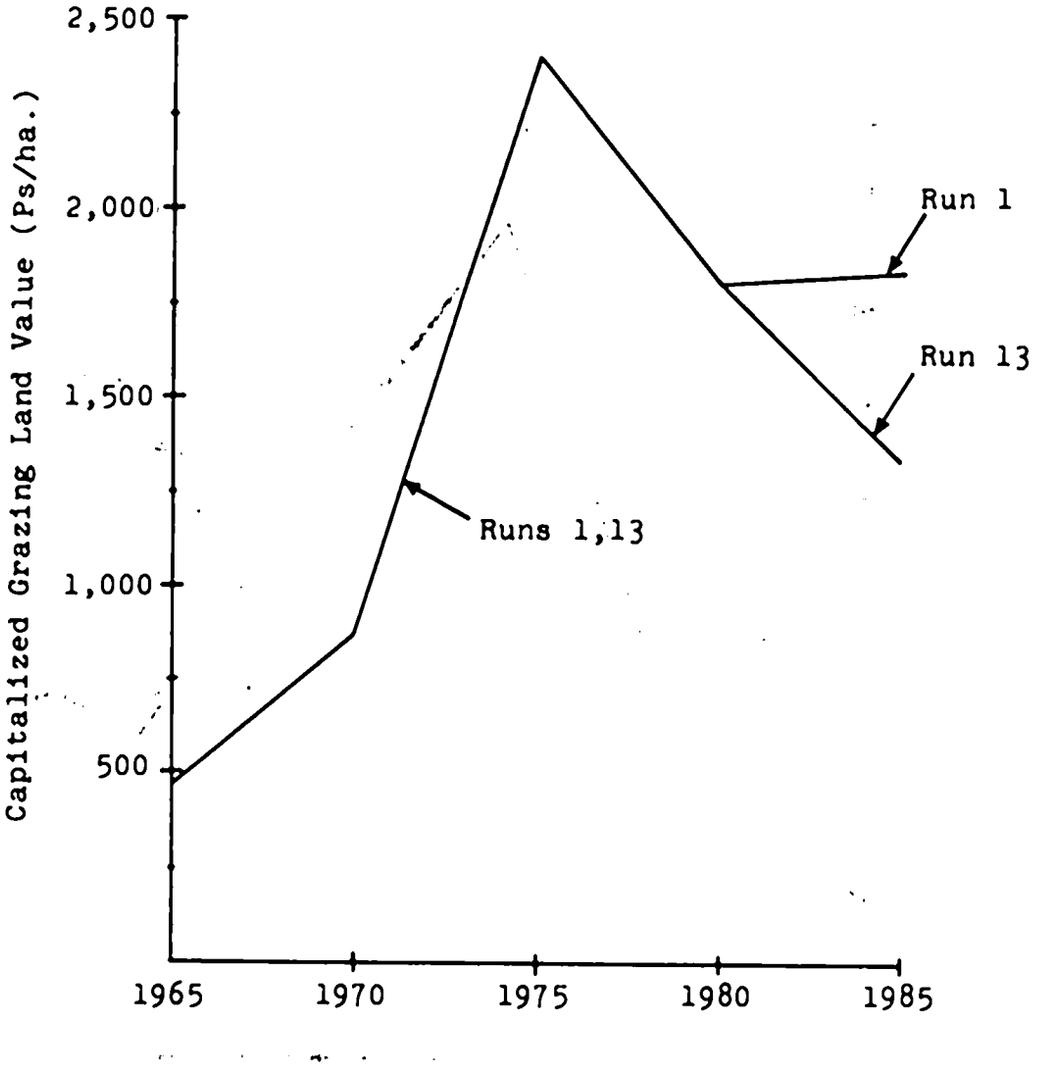

Figure IV.21. Average per hectare capitalized value of grazing land in the Costa with and without a crop modernization program, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production, no modernization of crops and continuation of present trends and policies (base run).
13. Modernization of cash and food crops from 1972-1976.

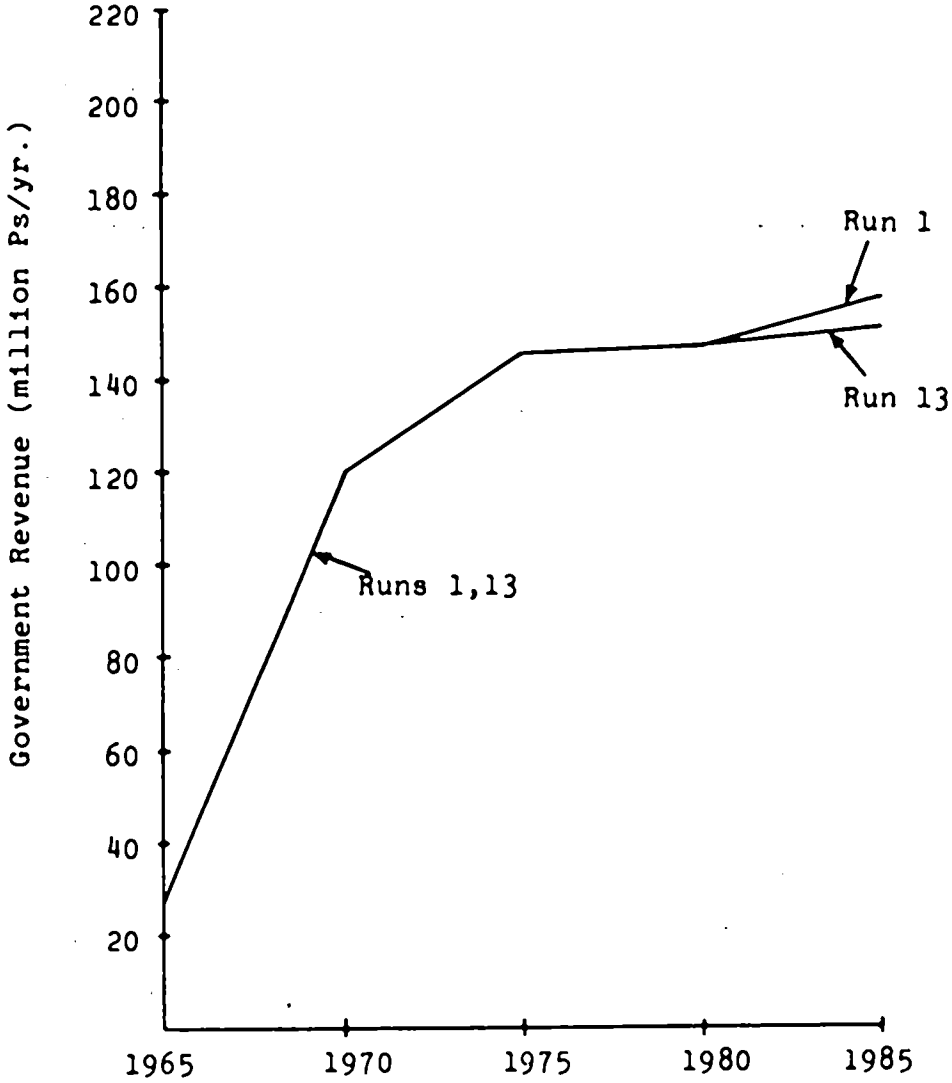

Figure IV.22. Annual government revenues from cattle production in the Costa with and without a crop modernization program, 1965-1985.

Effect of Various Policy Combinations

The set of runs which investigates the consequences of various combinations of policies and programs includes Runs 1, 14, 15 and 16 as defined in Table IV.1. Briefly, Run 1 projects present trends and policies (the base run); Run 14 implements the taxing policies of Run 4 with the credit policies of Runs 6 and 7; Run 15 investigates the effects of increasing the funds for development credit coupled with a 50 percent increase in the promotion effort; and Run 16 implements the programs of Runs 14 and 15 concomitantly with the development of the non-Costa cattle herd and the increase of beef exports from a low to a high target.

In general, the more micro-economic oriented policies of Run 14 have the greatest long-run impact on the performance variables in the model, followed by those of a more macro-economic nature (Run 15). The combination of these policies in Run 16, coupled with a program of expanding exports and growth of the cattle herd in the rest of the country, produce varying results that go from a steady increase in consumption per capita to a gradual decline in cattle population in the Costa and a sharp decline in farm income, land value and government revenues.

By 1985, total (national) cattle population is 42 million head in Run 16, about 50 and 40 percent higher than in the base run and Run 14, respectively. The cattle population in the Costa in Run 16 at first experiences a faster rate of growth than in the other runs, but this tapers off

after 1975 when the development of the cattle industry in the rest of Colombia begins, and in the long run the growth rate will likely turn down (Figure IV.23). Although the negative effects of increased beef supplies from the rest of Colombia on land modernization and cattle population in the Costa have been discussed earlier, further discussion is necessary at this point to better understand the changes in cattle inventories in Run 16. Between 1975 and 1985, cattle population continues to grow at a decreasing rate although no more traditional land enters the process of modernization and conditions exist for a reversion of land from modern to traditional management. The reason for this is found in farmers' delayed response to falling prices and income which is built into the model. Since the perceived relative profitabilities are based on exponentially averaged costs and prices of the preceding five years, it takes several years before the decline in price has its full effect on expected returns. Increasing prices before the turning point in 1975 (see Figure IV.28) have the effect of increasing or maintaining averages in the following base years. Since the perceived relative profitability in 1985 continues to be positive and higher than the threshold parameter, it prevents the operation of the land reversion mechanism although modernization of new land is stopped by the other constraints imposed on the modernization decision mechanism. Nevertheless, the land in process of modernization from previous years (the land "stored" in the modernization delay)

completes its development and enters full modern production a few years after modernization of new traditional land has been stopped; as a result, the area in modern land increases beyond 1975 and with it the more productive modern herd. However, it is to be expected that in the long run this process would reverse as discussed earlier in the section on domestic supply policies in connection with Run 12. It is highly unlikely that farmers would wait ten years before changing their expectations from profit to loss and start reorganizing production. This weakness of the model should be considered more carefully and corrected.

Run 14, which combines the incentives provided to modernization only, shows a steady uptrend in cattle population as a result of a higher and sustained rate of land modernization (Figure IV.23). Run 15, which combines the credit funding and promotion policies of Runs 8 and 9, results in virtually the same cattle population of Run 9 alone (about 9.8 million head in 1985) indicating that adding increased availability of development credit to the promotion effort does not affect the output of the model. This result was explained in the section on promotion and development credit policies.

Consumption per capita is the highest when the cattle herd in the rest of Colombia is developed, even after sustaining a high level of exports. When the cattle development program is limited to only the Costa region, Run 14 yields the highest domestic supplies (Figure IV.24).

As depicted in Figure IV.25, aggregated farm income from cattle is greatly influenced by export policies and development programs which affect cattle prices and costs as well as expenditure commitments for farm improvement. Initially, farm income is inversely related to the rate of land modernization with Run 1 at the top followed by Runs 15, 14 and 16 respectively. But between 1970 and 1975, this order is completely reversed by the effect of the various policies followed. Run 16 shows the effect of increased prices because of high exports coupled with increased sales and cost reductions arising from the development programs. When the export target is low and domestic price drops as in Runs 1, 14 and 15, the production incentives provided in Run 14 result in the highest farm income. The changing trend in farm income in Runs 1, 14 and 15 after 1975 is explained by different levels of expenditures on land modernization at the end of the credit for development program. Farm income in Run 16 sharply decreases after 1975 and becomes negative after 1980 when increased supplies from the rest of the country greatly depress prices--more than offsetting the positive effect of the other policies implemented in this run.

In general, the capitalized value of land (Figure IV.26) follows the projected time paths of farm income. In the initial period 1965-1970, the order differs from that of farm income because of varying proportions of traditional and modern land in the total grazing land that affect the average value of land in the region. Although farm income

in 1985 is lower in Run 14 than in Runs 1 and 15, the capitalized value of land is higher because of the larger value of traditional land which has the greatest weight in the average value of land. The value of land in Run 16 decreases sharply after 1975 until in 1985 it reaches the salvage value of one peso per hectare assumed in the model when income becomes negative.

Government revenues (Figure IV.27) are the highest when development is promoted while maintaining the special taxes on cattle (Run 15). When the special taxes are cut off, government revenues are sharply reduced even though the other policies implemented in Run 14 substantially increase revenues from the property tax. But government income is the lowest in Run 16 because of the lost revenues from cattle taxes and very low assessed land values.

Policies Related to Export Promotion

Policies aimed at the promotion of beef exports are examined in the last set of runs, Runs 12, 17, 18, 19, 20 and 21. Although the present structure of the model does not provide a feedback linkage between the export sector and the domestic market except for the simple effect of increasing the total number of animals demanded, the output of the study is appropriate for exploring the likely outcome of some world market conditions and/or domestic policies on the competitiveness of the Colombian cattle industry.

The export promotion policies now in operation were introduced in 1967 under Decree-Law 444, and those examined

Run Definitions

1. Disease control, modernization of cattle production and continuation of present trends and policies (base run).
14. Combines Run 4, Run 6 and Run 7.
15. Combines Run 8 and Run 9.
16. Combines Run 14 and Run 15 plus modernization of rest of national herd from year 1975 and high export target.

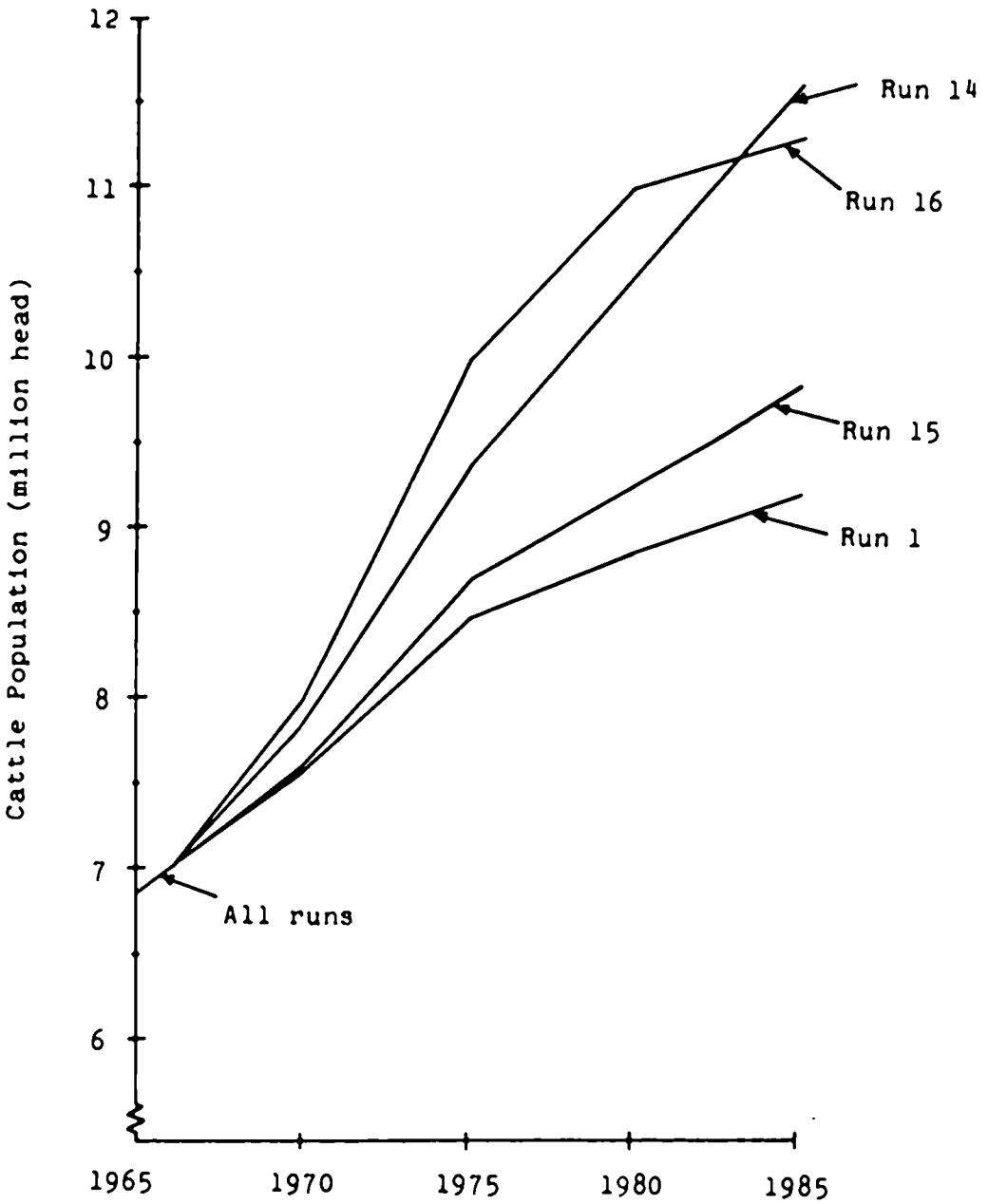

Figure IV.23. Cattle population in the Costa under various policy conditions, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production and continuation of present trends and policies (base run).
14. Combines Run 4, Run 6 and Run 7.
15. Combines Run 8 and Run 9.
16. Combines Run 14 and Run 15 plus modernization of rest of national herd from year 1975 and high export target.

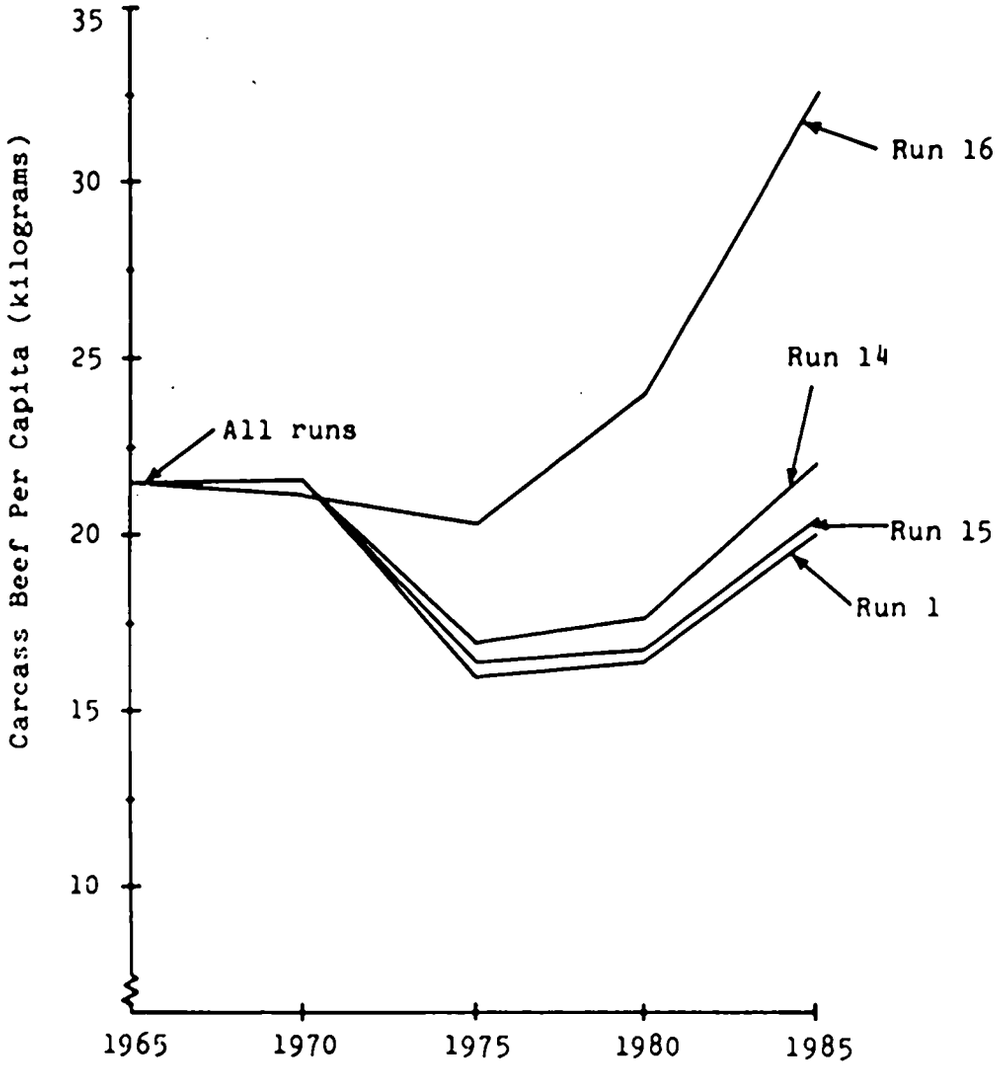

Figure IV.24. Beef consumption per capita of the Colombian population under various policy conditions, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production and continuation of present trends and policies (base run).
14. Combines Run 4, Run 6 and Run 7.
15. Combines Run 8 and Run 9.
16. Combines Run 14 and Run 15 plus modernization of rest of national herd from year 1975 and high export target.

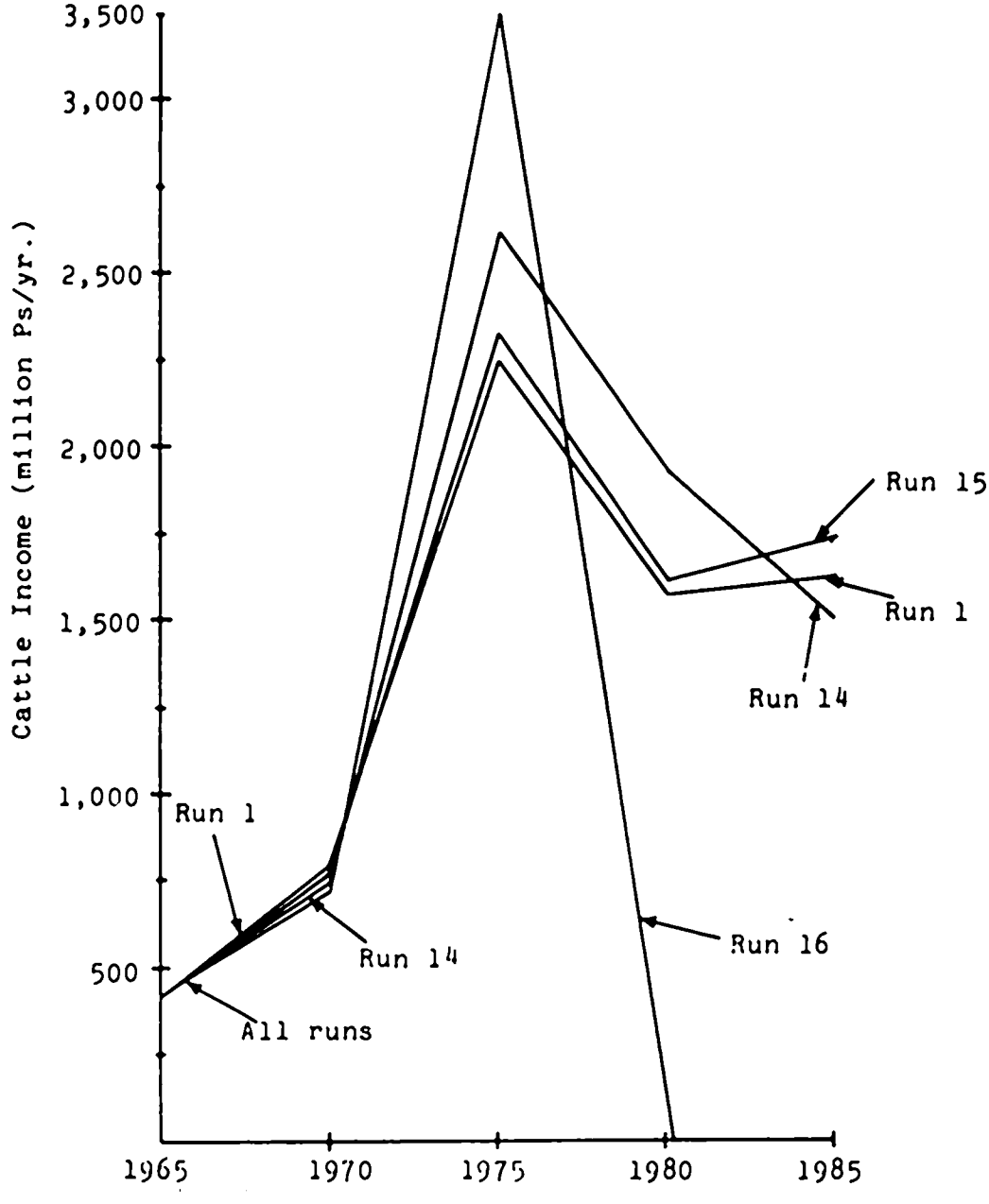

Figure IV.25. Aggregated farm income from cattle production in the Costa under various policy conditions, 1965-1985.

Run Definitions

1. Disease control modernization of cattle production and continuation of present trends and policies (base run).
14. Combines Run 4, Run 6 and Run 7.
15. Combines Run 8 and Run 9.
16. Combines Run 14 and Run 15 plus modernization of rest of national herd from year 1975 and high export target.

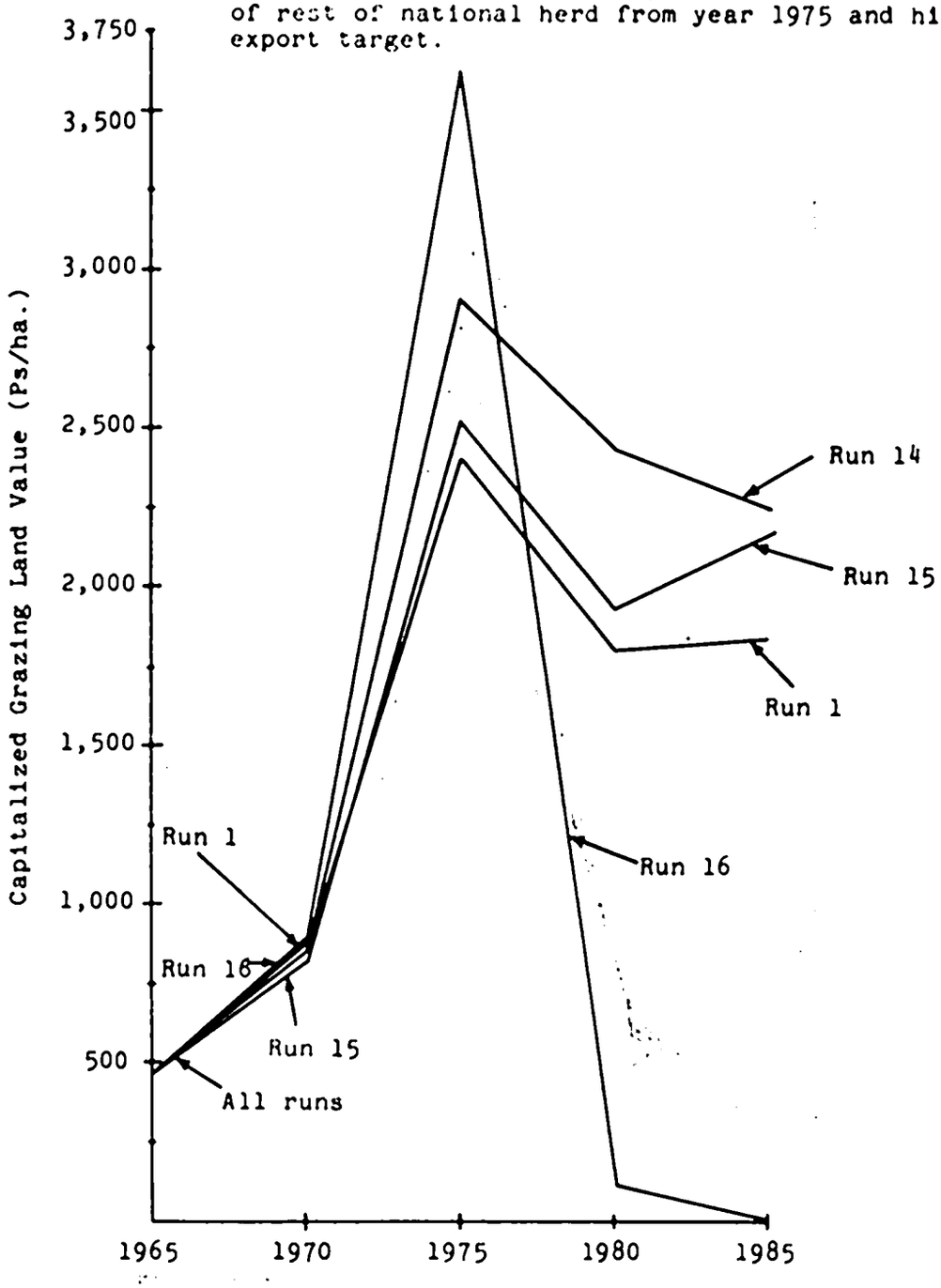

Figure IV.26. Average per hectare capitalized value of grazing land in the Costa under various policy conditions, 1965-1985.

Run Definitions

1. Disease control, modernization of cattle production and continuation of present trends and policies (base run).
14. Combines Run 4, Run 6 and Run 7.
15. Combines Run 8 and Run 9.
16. Combines Run 14 and Run 15 plus modernization of rest of national herd from year 1975 and high export target.

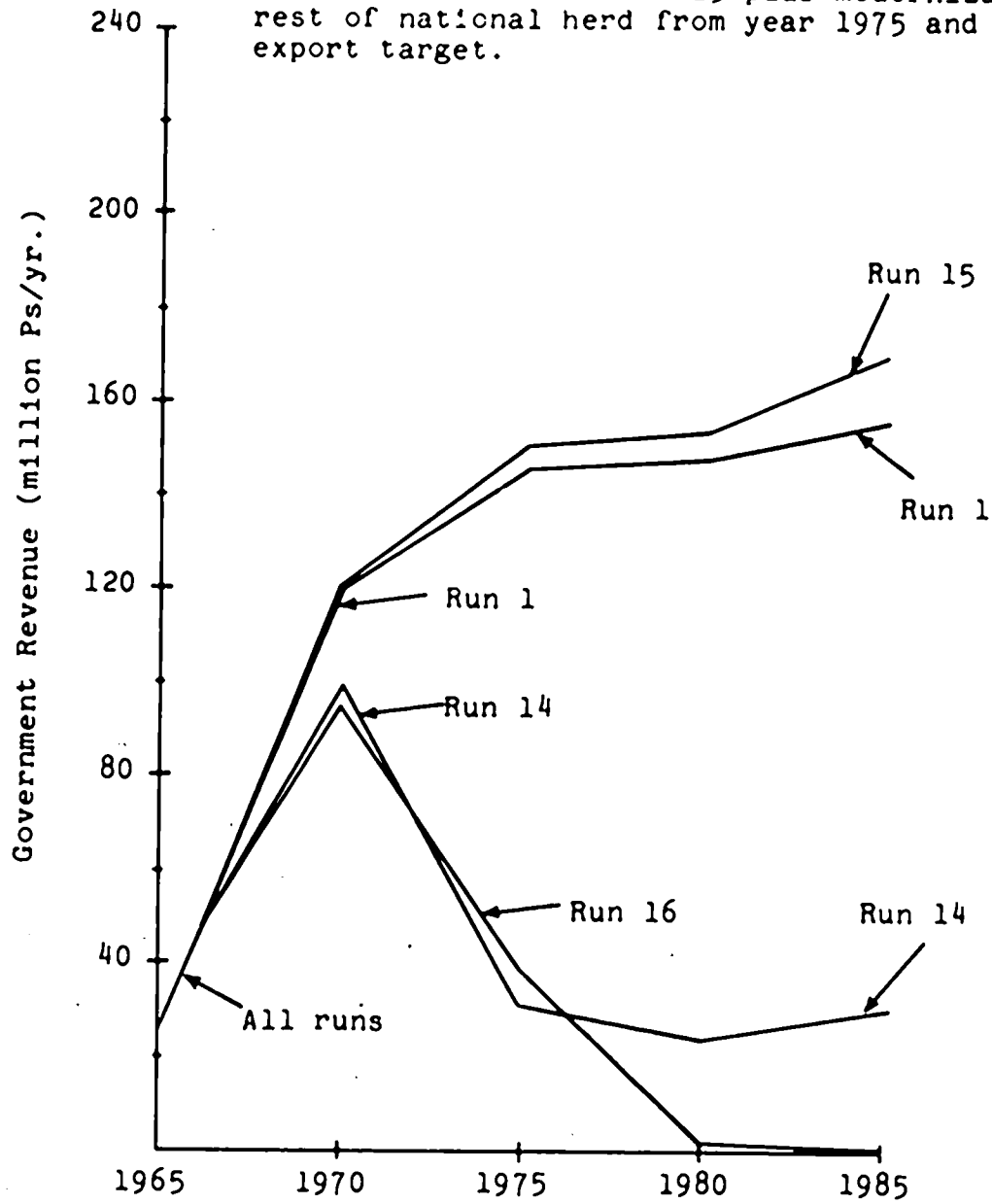

Figure IV.27. Annual government revenues from cattle production in the Costa under various policy conditions, 1965-1985.

here at the tax credit certificate (CAT) discussed in Chapter 2, and a fluctuating exchange rate. The present 15 percent rate of return accruing to exporters through the CAT scheme is subject to annual adjustments depending on the competitive position of Colombian exports in foreign markets.

Although sales of live cattle have dominated Colombian exports, it is assumed that after 1974 only dressed animals will be exported in the form of frozen carcasses. Therefore, the three levels of world price considered here are for frozen beef. The high price assumes that after 1974 the world price will continue the trend for the period 1970-1972, one of rapid rising prices (during this two-year period, the price of Colombian frozen beef increased 38.4 percent on a yearly basis). The low price assumes that after 1974 the rising trend in world price will be approximately one-eleventh of the 1970-1972 period. And finally, the moderate price assumes a rising trend in the world price of about three-eights of the 1970-1972 period. In all cases the per ton price of carcass beef has been converted to a live animal equivalent by a factor of 4.3. Runs 17 and 18 investigate the effect of low and moderate world prices, respectively. In the remaining runs, Runs 12, 19, 20 and 21, policies related to exchange rate, export subsidy and promotion of cattle production in the rest of the country are examined under conditions of low world price. Run 19 investigates the effect of cutting off the export subsidy

after 1975 while maintaining a flexible exchange rate. Run 20 speculates on maintaining export subsidies while returning to a fixed parity against the dollar when this reaches an approximate value of Ps 25. Run 12 combines the effect of maintaining export subsidies and fixing the exchange rate with an increased growth of the non-Costa herd at 5 percent annually after 1975. And finally, Run 21 combines the effect of cutting off export subsidies after 1975 and maintaining a flexible exchange rate with an increasing cattle population in the rest of the country.

In general, the international competitive position of Colombian beef is investigated assuming the least advantageous conditions in both the domestic and world markets. In the domestic market we always assumed high export targets which are reflected in higher domestic prices, and in the world market we assumed low prices in all cases but in Run 18. In the study, export margins, defined as the difference between the pesos equivalent of the world price per animal increased by the export subsidy and the domestic price per animal, are used as a proxy for competitiveness in world markets. The subsidy to exports considered in the study is that enacted by Decree-Law 444 of March 22, 1967. Although Decree 444 also introduced a fluctuating exchange rate, the study assumes a return to fixed parity against the dollar when this reaches an approximate value of 25 pesos (Runs 12 and 20). Exchange rate values are trend-like projections computed exogenously in the model by Equation 9.18a on page 213.

As Figure IV.28 shows, the domestic market price per finished male is greatly affected by policies related to exports and production expansion. When exports are at a low level and modernization is limited to the Costa, policies to increase production (Run 14) result in lower prices than the base run. If modernization is carried out only in the Costa with the same development policies as in Runs 1, 10 and 11, the larger export target in Run 11 results in the highest price. The major contributor to lower prices is the expansion of cattle population in the rest of the country as depicted by Run 12.

Although Runs 1, 10, 11 and 14, show a steadily rising trend through the period 1965 to 1985, the varying time path at each five-year interval shows the effect of the seven-year cycle of beef supply from the rest of the country. Run 12 experiences a sharp drop in price after 1975 when the increased production from the rest of the country herds is marketed. But an upward trend follows after 1980 which coincides with a declining path in the long-term supply cycle. Since cattle production is discouraged in the Costa by low prices and domestic demand is always increasing, it is likely that in the long run the price cycle in Run 12 will have a raising trend.

From Figure IV.29 we can see that export margins are consistent with world prices and with policies affecting domestic

prices and the pesos equivalent value of exports.[1/] Since Colombia's current and projected share of the international beef market is relatively small (the high export target sustained after 1975 is equivalent to approximately 161 thousand metric tons or about 10 percent of the total beef traded internationally),[2/] we assume an infinitely elastic demand for Colombian exports. This means that Colombian sales to the world market do not have an impact on world prices and that beef exports will be traded at the going world price. However, if Colombia greatly increases its share of the world market in the future, the above assumption would not hold and conditions of world supply and demand would have to be more carefully considered. When domestic price is high (because of high exports) and world price is low as shown in Run 17, export margins are negative for a period of about ten years, even if export subsidies are paid and the pseo gradually depreciates against the dollar. But further depreciation of the peso, to the point when the exchange rate reaches a 1985 value of Ps 53.98 for each dollar, results in a rising export margin that becomes positive during the last three years of the run. If world prices are moderate, export subsidies are paid, and the exchange rate is flexible, as shown in Run 18, export

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[1/] One way of looking at export subsidies is by changing the effective exchange rate at which certain commodities are traded.

[2/] Australian Bureau of Agricultural Economics, "World Production and Trade," The Beef Sutiation, No. 15 (May, 1971), 12-14.

margins are always positive and by 1985 could be as high as Ps 15,160/head.

Runs 19 and 20 project the effect of two alternative policies for export promotion under conditions of high domestic price and low world price. Run 19 shows that if export subsidies are cut off in 1975, a flexible exchange rate is not enough to produce positive export margins, although the upward trend of the last ten years suggests that in the long run the margin will be positive as the peso further depreciates. Yet, as shown in Run 20, exporters are worse off when a subsidy is paid but the exchange rate is fixed at about Ps 25 to the dollar. The downward trend in this case indicates that the negative margin will continue to widen as increases in domestic demand bid up the price. Run 21 shows that under conditions of low domestic prices resulting from increased supplies from the rest of the country and low world prices after 1975, a flexible exchange rate alone is sufficient to cause export margins to change the downward trend and become positive. And finally, Run 12 shows that if a fixed exchange rate is used in combination with an export subsidy the export margin takes an upward trend from 1975 to 1980, but after 1980 it again shows a downtrend when domestic price rises after increases in demand more than offset the impact of an enlarged supply. It is clear in this run that export margins follow a reciprocal pattern to that of domestic prices, and therefore the margins are affected by the long-run supply cycle as well (see Figure IV.28).

Run Definitions

1. Disease control, modernization of cattle production, low export target and continuation of present trends and policies (base run).
10. Cattle exports set at intermediate target from year 1974.
11. Cattle exports set at high export target from year 1974.
12. Cattle exports set at high target from year 1974 plus modernization of rest of national herd from year 1975.
14. Combines Run 4, Run 6 and Run 7.

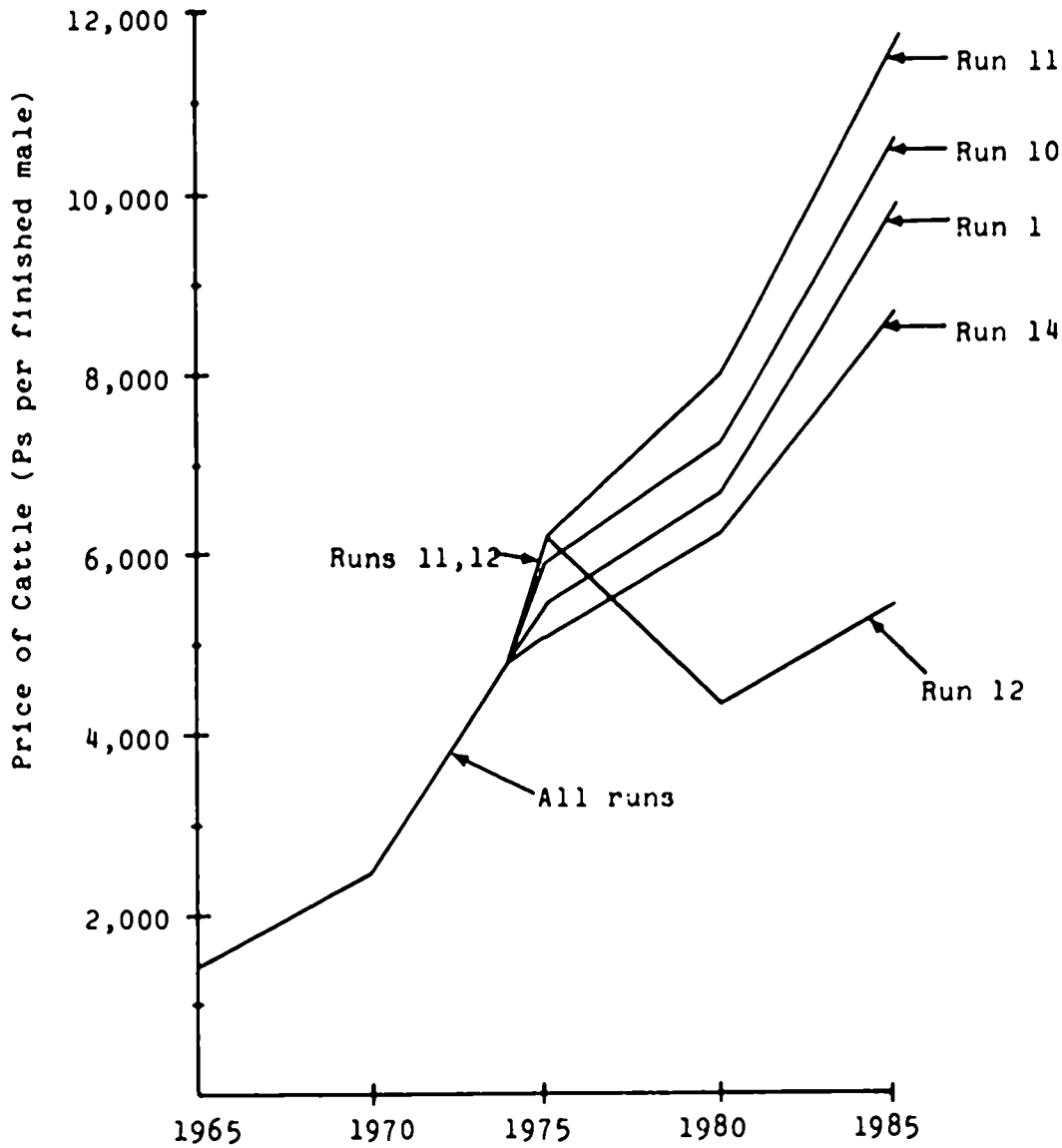

Figure IV.28. Domestic market price of finished males under various policy alternatives, 1965-1985.

Run Definitions

12. Same as Run 1 with high export target and low world price after 1974 plus fixed exchange rate at Ps 25 and modernization of rest of national herd from 1975.
17. Same as Run 1 with high export target and low world price after 1974.
18. Same as Run 1 with high export target and moderate world price after 1974.
19. Same as Run 1 with high export target and low world price after 1974 plus export subsidy cut off at year 1975.
20. Same as Run 1 with high export target and low world price after 1974 plus fixed exchange rate at Ps 25.
21. Same as Run 1 with high export target and low world price after 1974 plus export subsidy cut off and modernization of rest of national herd after 1975.

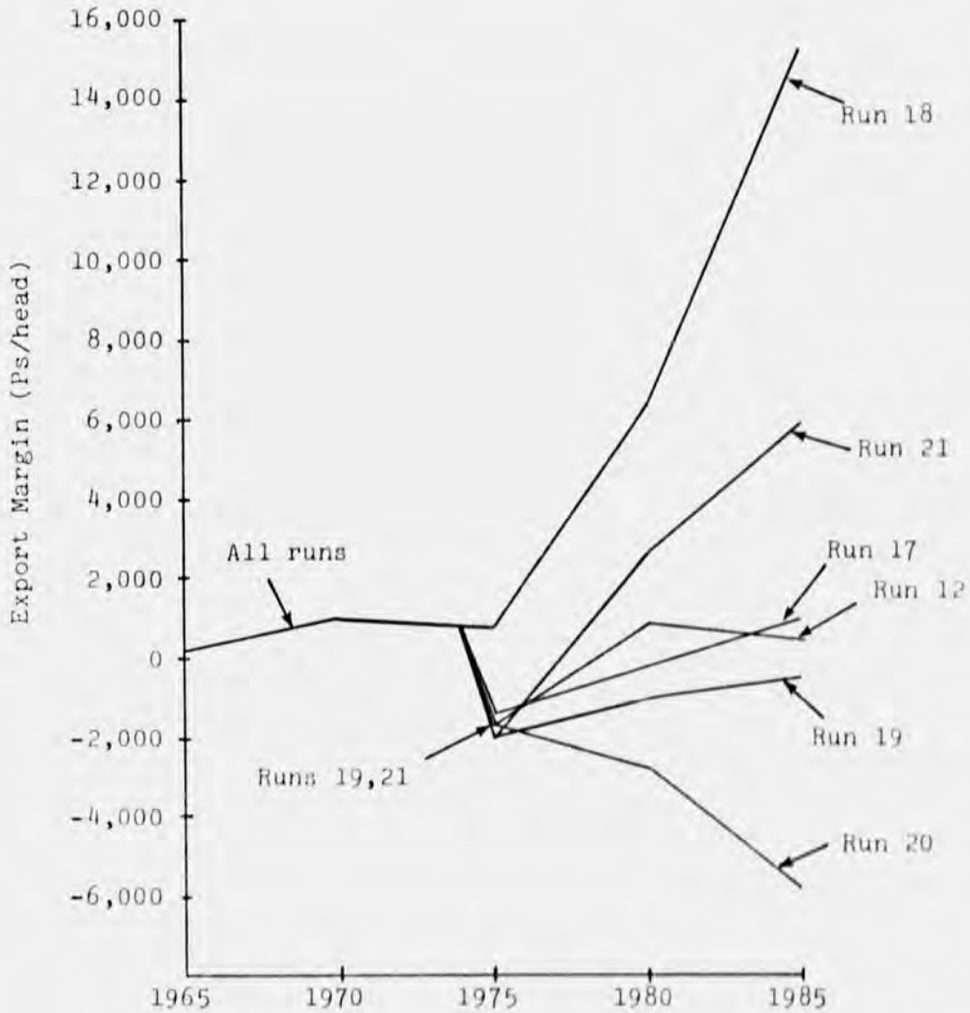

Figure IV.29. Competitive position of Colombian cattle in export markets under various policy alternatives assuming high export target and moderate and low world beef prices, 1965-1985.

Two comments on the assumptions about the exchange rate are relevant to this analysis. First, when the exchange rate is flexible or fluctuating, it is assumed to depreciate at 7.28 percent annually precluding any acceleration or tapering off of this rate over time. Second, when the exchange rate reassumes its fixed parity against the dollar it remains at about Ps 25 from approximately 1973 until the end of the run in 1985. This extended period of fixed parity is likely to result in an overvaluation of the peso that would eventually affect Colombian foreign trade leading to balance of payment problems and eventual further devaluation. The above considerations make the assumptions related to exchange rates in the model likely unrealistic.

The annual value of the subsidy paid to exporters will depend on the volume of exports, the world price and the exchange rate. Given the same world price, the higher the exchange rate the higher the subsidy per animal exported. Although annual payments vary from year to year, at the end of the simulation in 1985 they are the highest when the world price is high, the exchange rate flexible and the export target high (Run 11) and amount to Ps 5,179 million. But subsidy payments drop to Ps 1,168 million when world price is low (Run 17) while exports and exchange rate are the same as above. If world price is high, the exchange rate flexible, but the export target is low as in the base run, subsidy payments are Ps 2,462 million. And finally, subsidy payments are the lowest amounting to Ps 546 million when the

exchange rate is fixed and the world price is low even though exports are high (Run 20).

The value of foreign exchange earnings will depend on the volume of exports and the world price and, therefore, its annual projection will experience a changing pattern that will also differ among the various runs according to their underlying assumptions. If exports are sustained at a high level, the projected value of foreign exchange earnings in 1985 will be $144.3 million when the assumed world price is low; $307.5 million when world price is assumed moderate; and $639.7 million when world price is assumed high.[1/] If world price is assumed moderate, the projected value of foreign exchange earnings in 1985 will be $146.2 million when exports are maintained at a low level; and $220.4 million when exports are intermediate.

The foregoing examples indicate that changes in world price provide the government with more latitude in the choice of policies for the attainment of foreign earning targets without greatly impairing other desirable goals. Recalling earlier discussions we see that increasing the level of exports reduces consumption per capita unless other measures are taken to increase domestic beef supply (see Figure IV.14). Yet it is also true that higher prices brought about by

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[1/] At the end of the run, the projected world prices per live animal based on the price of frozen beef are: low $208.5; moderate $444.4; and high $924.4.

enlarged exports could create the incentives for farmers to expand cattle production with the long-run effect of increasing the number of animals marketed for slaughter. Likewise, government revenues from the domestic sector are enhanced as profits, cattle inventories and land values are increased.

Conclusions

We have made eight major inferences from our cattle policy experiments.

First, given the assumptions behind the model, the availability of credit for development does not seem to be as crucial as originally thought. Although farmers use credit whenever it is available, there are substantial unused credit balances at the end of each year between 1966 and 1976. Furthermore, the model indicates that, in the aggregate, farmers could cover establishment costs of the land being modernized with resources generated internally in the agricultural sector. This is shown in the model by the allowable rate of modernization depending on the farmers' capability to meet the total establishment costs without credit support (ARM3 in Equation 5.42c) being higher than the combined rate of modernization due to promotion and diffusion (RLMI in Equation 5.40). As seen throughout this analysis, farmers' response to economic opportunities determine their use of private and public savings for farm improvement. However, cash flow problems developing late in the simulation suggest the need for a comprehensive credit

policy. These outcomes are seen more explicitly here when increasing the competitive edge of the modern over the traditional operation; in such cases, easing the credit terms, as in Runs 6 and 7, encourages modernization more than increasing development credit funding as in Run 8. And the sharp decline in annual income in all runs after 1975 is an indication of farmers' unbalanced cash flow. The preceding results imply that providing credit assistance for a longer period might be more effective than increasing the volume of funds within the ten-year period (1966-1976) set in the model.

Second, the model's output indicates that the performance indices depend heavily on farmers' attitudes toward adoption and continued use of the new production methods. This behavior is simulated in Equations 5.36 and 5.47 using principles of diffusion theory. But modeling farmers' decisions to expand or contract production on the basis of diffusion theory is a poor proxy to sound economic principles explaining such processes. Until more adequate user cost, investment, and disinvestment theory is developed for use in modeling expansion and contraction of agricultural production, the model would benefit from more research and experimentation on farmers' response patterns under the diffusion theory used in this study.

Third, the benefits of long-term output responses in modern pasture acreage expansion are reinforced by policies directed toward the modern sector only. Otherwise, the

relative profitability differential of improved over traditional cattle production is decreased and the adoption rate of improved management practices is reduced accordingly. The effect of production incentives and the production campaign, particularly promotion, are highly complementary in encouraging the farmers to modernize their system of cattle production.

Fourth, cattle inventories and output in the Costa depend decisively on controlling diseases in the traditional sector. But at the national level, the major effect is obtained when cattle production is also modernized in the other producing regions.

Fifth, the cumulative effects of policy combinations (Runs 14, 15 and 16) on the model's output are, in general, greater than those of single policies. Positive effects of single policies are reinforced by complementary measures when simultaneously applied. Reinforcing and offsetting policy effects are important characteristics to be considered by policy makers when designing strategies for economic development.

Sixth, the competitive position of Colombian cattle in world markets is decisively dependent on world price and policies concerning domestic supply and export incentives. In this analysis, a negative export margin indicates that domestic price is higher than world price as viewed by Colombian exporters and implies that they cannot compete in world markets at the price beef is being internationally traded. The results shown in Figure IV.29 suggest that the

need for and the amount of transfers from the rest of the economy to cattle exporters in the form of export subsidies can be examined and determined in the face of both domestic and world prices and exchange rate policies.

Seventh, an alternative course to policy makers' active participation in the model was to assume certain policy changes during the period 1966-1973. In this period various programs were implemented (cattle development and animal disease control), legislation was proposed (increased property tax, presumptive taxation of agriculture and elimination of cattle selective inventory tax), and important decisions were made (extension of general cattle inventory tax after its expiration in 1970). Or, using another interpretation, retrospective policy experimentation is a demonstration of how the model could have been used as a planning and decision-making tool had it been designed at the time decisions were made and/or policies proposed. Quick legislative action, assumed in some cases in the model, could possibly have been obtained by the use of the model. Models designed to predict the outcome of alternative policies have the additional application of prompting government officials and legislators to action. The Costa model attempts to evaluate the effects of an early implementation of various proposed policies and the likely effects of having started cattle development programs applying different measures to those used at the time of their introduction. Initial time of alternative policy implementation can easily be changed to 1973 or any other future year. The model's

structure is flexible enough to allow these changes. Given the structural relationships and assumptions behind the model, it can be expected that its output variables will experience the same trends as shown for the period 1966-1973. Changes in initial time of policy implementation were planned in additional experiments with the model but were not accomplished because of time constraints. Meanwhile, it is believed that extrapolating results from policy implementation during the period 1966-1973 will produce legitimate predictions for another future period, say 1973-1992.

Finally, throughout this study we have demonstrated that a simulation model provides a useful experimental setting in which policy makers and researchers can interact at different stages in model creation and developmental planning. This interaction is instrumental in redefining goals and policies, and reformulating parameter values and interrelationships. With different and improved sets of goals, policies, parameter values and interrelationships, new experiments can be carried on and new outcomes analyzed. This interactive, iterative process can and should continue until results are judged to represent the real system reasonably well and until decision makers are satisfied with their goals and the display of projections indicating the effects of following their various development strategies.

In our case, each of the policy runs have projected different outcomes at different time phases of the planning horizon. These projected differences provide policy makers

with some basis for selecting a prefered policy option on the basis of tradeoffs among perceived values for the economy. For example, if the perceived dominant values for the cattle subsector during the next 20 years are farmers' income and the foreign exchange generated from cattle exports, Run 11 (which has the high export target) may be preferred. On the other hand, if a perceived paramount value is government revenue, Run 5, which gives the highest annual revenue and accumulated funds for government, is the logical option. However, if the dominant value is to ensure consumers a higher availability of beef, without impairing farmers' and government revenues, Run 6 (with the reduced interest rate feature) would be recommended. If the objective were to increase per capita consumption of beef up to or above the recommended nutritional requirement of 28 kilograms, the selected option would be Run 16 (with the non-Costa cattle modernization feature). But this run, even though it maximizes foreign exchange earnings from cattle exports, seriously impairs farmers' and government revenues. Hence, in this particular situation, the tradeoffs are between a loss in government revenue and an increase in output and personal income of farmers in the cattle economy; and between an increase in beef consumption and a loss in foreign exchange generated from cattle exports, government revenue and farmers' income.

CHAPTER 13

SUMMARY AND CONCLUSIONS

Introduction and Summary

Colombia, as many other developing nations, is facing a new pattern of food scarcity in the decade ahead. The increased demands of her rapidly expanding population are added to the impact of rising affluence on demand for food. To meet domestic needs and take advantage of world market opportunities to increase foreign earnings required to support development, Colombia must make a great effort to encourage agricultural production, particularly the output of the protein-rich food which is in greatest demand.

With vast natural resources suitable for cattle production, this industry has the potential for becoming a leading sector in the Colombian economy. To this purpose the Colombian government has committed resources for preparing and implementing a nationwide plan aimed at the development of beef cattle production. With about half the cattle population and with a regional comparative advantage for grazing, the Atlantic or Caribbean plain of Northern Colombia is receiving most of the development effort.

With the preceding considerations in mind and realizing the experienced usefulness of the systems simulation approach in overcoming many of the complexities of development

planning, this dissertation developed a simulation model which: (1) focused primarily on the production of cattle in the six departments of Northern Colombia (the Costa) that include most of the Atlantic plain, and (2) included only rudimentary considerations on the related production of crops. The model thus developed is capable of exploring the ramifications of the proposed government strategy and their resultant interactions and feedback effects.

This study is divided into four parts incorporating basic background information and material relevant to the model building and analysis. Part I describes the general problems of producing cattle in Colombia and the physical and economic setting of the Costa region, discusses the justification for using the systems simulation approach, and finally sets the model's specifications and procedure. Part II details the five components used to simulate the production of cattle which: (1) allocate land use according to the farmer's perceived profitabilities of cattle and crops subject to land and capital constraints; (2) calculate the yield and output of cattle and crops and their respective producer and market prices; (3) provide the instrumental linkages for the government revenue, export trade policies, and production campaign policies; and (4) generate the performance criteria necessary to evaluate the impacts of alternative programs on the cattle economy through time. Three major policy entry points are considered; production campaigns can be specified, cattle and property taxes can

be levied, and export targets and incentives can be regulated. Part III discusses data needs and methods used in dynamic system models to determine the correspondence between the model and the system being represented. These methods include sensitivity analyses, tuning the model to track recorded time series and general validation procedures. Sensitivity analyses not only reveal logical or theoretical inconsistencies but also can provide an indirect way to test policy options and suggest data collection priorities.

Part IV demonstrates the model's applicability to policy formulation. Chapter 12 analyzes the results of 21 runs that examine combinations of policy options which have recently been considered in Colombia.

Salient Features of the Costa Model

In this summary some of the salient features of the Costa model are discussed. Then some policy implications and areas for additional research will be discussed.

First, the model is mathematical. With a mathematically formulated model, assumptions about behavior, technology and institutions are translated into the universal and precise language of mathematics which makes them relatively explicit and open for examination.

Second, the model is operational. That is, it is a computerized model and can be operated without much difficulty and at very low cost. Using an operational model is a major step forward in the task of modeling sectorial and/or regional economics. Experiments can be performed and

new improvements in the model introduced if needed. Repeated runs using refined data and structural relationships improve the model's representation of reality and its overall performance. Without an operational model, it would be difficult, if not impossible, to accomplish these ends.

Third, the model to a large extent is data based. That is, many of its relationships have been formulated and tested using actual data. The model's outputs can be checked against actual data. These points are important because the degree of confidence we have in a model depends to a great degree on the extent to which it is able to explain past variation of variables and to predict future variation. As discussed in Chapter 10, when regional data are poor in quality and quantity, vast data requirements make the task of formulating and implementing a model with measurable quantities particularly difficult. Although models can be built even when information is poor, the system simulation approach provides means for dealing with the data problem by indicating where improved regional information would yield high returns in terms of a better understanding of regional phenomena and superior models.

Fourth, significant steps forward are made in the modeling of cattle demography. Three age cohorts for females and two for males with age-specific birth rates and age-sex-specific death rates, sale rates, transfer rates, and disease treatment rates have been employed which make the model's outputs change in extremely significant ways in

response to changes in the age and sex distribution of the cattle population. Such changes feed back in the cattle demographic component through time delays and induced behavioral effects to influence the pattern of cattle population development that produces further changes, and so on. Those endogenous interactions between cattle demography and performance appear to be vital elements in the process of regional economic growth.

Fifth and last, although the model as presented here needs further work and is not ready for implementation, it affords a good example of how the system simulation approach provides an analytical framework within which researchers and policy makers can interact while formulating alternative cattle policies. We were specifically interested in evaluating the long-term economic impact of modifying cattle prices through exports, revising tax policies, and the proposed government production campaigns to expand cattle production in Northern Colombia. Crop improvement and export policies were included as a secondary objective.

To this end, the computerized cattle simulation model provided a very useful and a convenient means of predicting and comparing the outcomes of various combinations of cattle programs and policies. Based on the predicted time paths of the various performance indices of the cattle subsector, the merits of various policy alternatives were discussed. This capability of the model to project the time paths of various performance indices can be used to give the policy

maker a clear picture of the range of possible outcomes of each proposed policy.

In addition, policy makers not only benefit from the analysis of potential policy results but also from the process of formulating the simulation model itself. Planning officials taking part in the model development process are forced to specify, examine and study their assumptions, data sources, underlying interrelationships and impact of each policy upon the model structure and parameters. Thus the planners may refine and improve their decision process and the information used in it. As the process of simulation model development and experimentation proceeds, both researchers and planners gain greater insight into the mechanisms and likely patterns of change within the system being modeled. Further, the decision maker can play a more active role in the experimental system by making exogenous policy decisions at the end of any time period and allowing immediate feedback on the results of alternative decision patterns and policy choices. This iterative process involving close interaction among decision makers and system analysts engages decision makers in investigation activities that lead them to perform as researchers as well. Hence, the simulation model becomes not only a valuable analytical tool in helping decision makers in their planning, policy formulation, and program development activities, but also an educational tool that enhances their planning capacities [28].

Policy Implications from Simulation Experiments on the Costa Cattle Economy

There are six major inferences from the simulation experiments which may throw light on questions of public policy concerning a cattle development program. First, investments in government disease control programs are justifiable since the projected cattle output, given the same model assumptions, was higher when improvements in range and herd management were accompanied by disease control in the traditional sector. Nevertheless, long-run assessments of the pay-offs to "traditional" farmers require a more accurate accounting of costs with and without the extended treatments.

Second, measures aimed at improving the profitability of modern cattle alone are the most effective in encouraging cattle output and increasing farmers' incomes and government revenues. Easing the debt burden, particularly interest payments, had the greatest long-run effect on all performance variables. Although credit has been considered crucial for development, the results point out that farmers' attitudes constrain the use of capital resources to a point that increased credit funds went largely or totally unused. The pay-offs of "educating" the farmer, demonstrating the profit opportunities of the new practices and creating a socio-economic environment amenable for investments seem to be very high. Further, the profitability of the cattle sub-sector relative to other sectors in the economy must be carefully considered if capitalization of the former is a

preferred goal. Otherwise capital will likely be diverted from the cattle subsector to more profitable sectors of the economy.

Third, increasing the domestic price level of cattle by increasing exports from low to high targets is not by itself an effective tool for expanding cattle modernization and output. While it is true that higher prices greatly increase farmers' income and wealth, they also have the effect of curtailing the incentive to modernize by reducing the profitability differential between traditional and modern practices. Consequently, if modernization is to be enhanced by taking advantage of the farmers' expanded revenue, it is necessary to implement other policies that would increase the profitability of the modern operation relative to traditional. Yet, when total Colombian cattle output is greatly expanded because of developmental efforts in the non-Costa regions, the simulation analysis indicates that a pricing policy through the export market is crucial for sustaining modernization and preventing farmers from incurring heavy income and capital losses. Likewise, government revenues would not likely be improved because of farmers' higher income unless there are more effective ways of taxing farmers.

Fourth, special taxes on cattle are the main sources of government revenue (not including income tax). Cutting off cattle taxes, in addition to removing this source of revenue, has the same counteracting effect on modernization as price increases (discussed above). However, any loss

in government revenue that might occur from cutting off special cattle taxes could be compensated by more effectively taxing the farmers' increased income and the asset value of their land; or by taxing their increased purchases of producer and consumer goods. Although increasing taxation on land has, from the point of view of government revenue, an equivalent effect to levying taxes on an expanded cattle population, the likely allocative effect of land taxation makes it a more preferred policy option. These results suggest the need for a careful reassessment of the taxing policies toward the cattle subsector and the consideration of alternative policies that will not impair government revenues and will not interfere with the allocation of resources on the farm.

Fifth, if improved cattle production is to be used to bring some sort of redistribution of income in the region, it is a requisite that the medium and small farmers are not left behind in the modernization effort. Alternatively, modernization might be accompanied by a change in the pattern of land ownership that prevailed in 1960. According to the agricultural census of that year, three-fourths of the cattle farms were less than 100 hectares; they controlled one-fourth of cattle and had an average inventory of less than 50 head of cattle [14].

Finally, the world price of beef greatly affects foreign earnings. It is, therefore, very important that the government secure the highest world price for exports.

This can be attained by exporting high quality dressed and/or processed beef to bring higher prices in international markets. In addition, this measure might increase the Colombian value added of exports with spill-over effects on the economy. The policy experiments show that the profit margin of cattle exporters varies according to domestic and world price conditions and measures affecting the effective rate of exchange. The combination of a fluctuating exchange rate and an export subsidy seems to give an ample profit margin to exporters. This suggests that the subsidy could be adjusted periodically based on cattle and foreign exchange market conditions. An appropriate exchange rate could maintain a competitive edge in international markets, thereby eliminating or reducing the need for large transfers from public revenues to exporters. Since cattle exporters compete with suppliers to the domestic market, the foreign earning targets set by the government may affect the nutritional levels of the Colombian population. By the same token, exports have a regulatory effect on domestic prices that in turn affect incentives to produce.

Improvements and Extensions of the Model

The simulation of dynamic human systems is a process of trial and invention that can never be completed. Each simulation result teaches and prompts additional questions leading to an iterative procedure that helps sharpen data and verify structural and causal relationships. It

also may disclose problems in the original formulation of goals, feasibility and methodology that might need refinement and reformulation. Revisions may also be required by the changing needs of planners and policy makers. The extent of these experiments and changes demand costs that must be weighed against the expected returns of increased model accuracy, flexibility and relevance before a decision is made to proceed with the modifications.

A number of areas in the current Costa model need further attention in order to improve its performance. These are discussed below. Experiences with other regional models [1, 27, 53, 62] have suggested possible extensions to enable it to better address some of the major problems of economic development. These will also be discussed.

Needed Improvements in the Model

There are several aspects of the Costa model which need further development and verification. First, it is not certain that the model of the domestic cattle price mechanism (Equations 6.39a and 7.2) adequately or even realistically represents the actual operation of that market. In particular, the pricing of cattle other than finished males is an oversimplification of supply and demand for the various sale groups. Furthermore, the link between the Colombian market price and the regional market price is not clear since regional prices are sensitive to short-term fluctuations caused by seasonal changes in pasture yields.

In addition, the supply response to price changes is not yet very well understood. Since the model is fairly sensitive to cattle prices, further research and eventual modification of this aspect of the model may be indicated.

A second area that could call for further work is the simulation of cattle demography. Although the use of different demographic groups is an improvement over previous regional cattle models [51, 53, 55] a further step could be to calculate the productivity of each age group relative to the feed resources consumed. This will permit more precise computation of feed requirements and total herd productivity (kilograms of gain per animal-year). The latter will enable the model to estimate the nutritional contribution to the Colombian population more accurately.[1/] If policy makers and planners feel this is an area they would like to investigate more fully, revisions of the model will be necessary.

A major feature of the model which needs theoretical and empirical verification is the modernization decision mechanism (Chapter 5), particularly the value of parameters that determine the adoptors' behavior. A development program taking place currently in the region and resembling that described by alternative 2 (improvement and substitution of artificial pasture for native pasture) provided both an empirical base for assigning values to these and other model parameters as well as justification for focusing the simulation

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[1/] A detailed demographic model of this sort is discussed by Johnson et al., in [48].

experiments on this alternative. Yet other alternatives including forage crops, though with greater impact on the model's output and performance, were disregarded because of inconsistencies probably arising from the simulation of farmers' behavior in the face of the higher risk and uncertainty involved in these alternatives. Additional research is necessary to better understand the nature of this problem before further modeling work can be done on it.

Another unrealistic aspect of the decision mechanism is the assumption that capital is employed at a low opportunity cost in cattle production. This does not effectively represent the capital market in Colombia where transfers of capital out of cattle farming are certainly occurring with the subsequent effect of impairing the farm improvement effort. It also seems unrealistic that the private capital constraint on land modernization decisions (Equation 5.41) is practically inactive during most of the simulated time and only becomes effective toward the end of the simulation period when consumption expenditures are greatly increased. It is more likely that the capital outflow effect discussed above coupled to the demand for capital to buy cattle on an individual farm basis, which is not in the model, would put an earlier constraint on land modernization decisions.

Other constraints, which are not in the model at all, are the allocation of commercial credit through the banking system, the availability of labor (including management) and the availability of other inputs (fertilizers,

herbicides, seeds, and drugs, primarily). Thus, it may be desirable, if the model is to be implemented, to give high priority to modifying the model to realistically reflect actual input constraints on land allocation and production decisions.

Related to these possible shortcomings of the model are the problems of investing and disinvesting and the generation and use of farm-produced capital. The former is approximated in the model by the land modernization and reversion mechanisms of Equations 6.36 and 6.47, and the retention or sale of cattle accompanying the increased or reduced carrying capacity brought about by these land transitions. Yet, as pointed out by Johnson [47], a solution to these problems needs more development in economic theory concerning user costs which partially determine how many units of productive services are generated from fixed durable inputs in the intricate process of agricultural growth, change, and/or deterioration.

Two examples of other structures of the Costa model which may require further verification are the on-farm resource use response and the living expenditures adjustment mechanism. First, it may be questioned whether Equation 6.36, in assuming the functional relationship shown in Figure II.7 between the perceived relative profitability differential of traditional and modern cattle on the one hand and, on the other, the extent to which farmers make

use of their on-farm resources, realistically or even adequately determines their preference function.

Secondly, further information may indicate weaknesses in the formulation of living expenditures, particularly if disaggregation by income groups is accomplished. Likewise, this formulation does not model income effects on consumption brought about by changes in the real income of farmers.

Finally, this model may always be improved by refining the data that go into it and by a closer interplay among specialists from related disciplines and policy makers.

Extensions

Seven additional ways in which the Costa cattle simulation model can be extended for policy analysis will be listed here. First, it should provide a more comprehensive basis than it currently does for analyzing government revenue and budget expenditures for agricultural modernization programs. The present model was not able, nor built, to generate the effect of a graduated income and wealth tax for cattle producers whose efficiency could be compared with alternative consumption, land and special taxes. Likewise, the present model did not provide comprehensive grounds for balancing and allocating the government budget for different modernization programs whether on a regional or national basis.

Secondly, to discuss meaningfully the distributional impact of government policies on investment in production campaigns, exports and public revenues, and the response of farmers to these policies, the cattle subsector may have to be disaggregated by farm size. Since farmers in each size category have a different command over resources and their own beliefs and values, such disaggregation may be helpful in analyzing problems of income distribution, and in simulating more realistically their decision making. It may be useful to further disaggregate the region by ecological zones and to subcategorize the cattle industry by type of activity, i.e., breeding, growing, fattening, and their combinations.

A third possible problem area which could call for an extension of the model is the question of growth and age distribution of the rural population. This is closely related to the problems of employment, labor supply, and pressure over natural resources, which in turn involve aspects of income distribution, rural-urban migration and land ownership distribution. The dimension of income distribution, a pervasive one in all development plans, would be an important output criterion for evaluating alternative policies.

Fourth, as part of the process of improving the land use decision mechanism of Chapter 5, the crop subsector may have to be disaggregated by competing commodities in order to determine a more realistic crop mix. This will

allow the more accurate simulation of the competition between crops and cattle and, in addition, may suggest policies toward improvement of individual crops and regional specialization. Likewise, the model may be extended to relax the constraint of testing each modern alternative one at a time and include mechanisms for the adoption of various alternatives simultaneously. This may reflect more realistically the various responses of farmers with respect to profitability perceptions. The two extensions suggested here may have substantial impact on the performance variables that could be of interest to policy makers.

Fifth, the sensitivity of the model to cattle price changes suggests the need for including a semi-automatic decision-making mechanism whereby the government export policies in any one year depend on the interaction between the prevailing world and domestic price of beef. Export targets, subsidies and exchange rates could be set with the aim at maintaining both a price incentive to producers as well as a competitive position in international markets. The major benefit of such a model extension would be to help determine a more flexible governmental export policy which would stabilize farmers' income and net government revenues from exports, given the fluctuations of beef prices.

Sixth, one extension of a technical nature mentioned in Chapter 10 is running the model in a Monte Carlo stochastic mode rather than deterministically. Although there are various theoretical problems involved in the

use of Monte Carlo techniques [1, Chapter 11] such stochastic runs could be useful in dealing with data problems and in evaluating the relative stability and sensitivity of policy alternatives in the face of uncertainty. Giving a probability distribution to some of the data instead of a mean value, it is possible to incorporate methods of statistical sampling and inference into the outcome of the model. Such statistics would permit the evaluation of ranges and distributions of possible outcomes for different policy options rather than point predictions of absolute output levels.

Finally, there are extensions on the scope of the Costa model that would be relevant to policy makers in their task of solving the problems of development. First, the present version of the model can be easily adapted to the other four Colombian cattle producing regions and further integrated into a national subsectorial model. Secondly, based on other experiences, it could be expanded into an agricultural sector regional model or even a complete regional model including both the agricultural and nonagricultural sectors. The experience gained from these extensions and the information they contribute are of unquestionable relevancy for development planning in Colombia.

Concluding Remarks

We have discussed some of the shortcomings of this study and have suggested means by which they can be dealt with in order to improve the model's predictive and prescriptive capabilities. As we have seen most of these shortcomings

arise from data problems and from deficiencies in the economic theory required as a basis for modeling many of the activities found in developing economies [47]. The shortcomings we have encountered, however, also affect the accuracy of models built using simple, paper-and-pencil techniques, or the more complex and specialized techniques discussed in Chapter 1. Nonetheless, we have reasoned that the systems simulation analysis as used here, with its flexible approach to many of the methodological problems found in studying economic development, provided an improved framework for policy, program and project problem analysis.

It must be stressed that the Costa model yields usable estimates of the consequences of following several policy strategy alternatives over a period of several years. Furthermore, the present work constitutes a major improvement over other cattle production studies made in Colombia as well as a useful contribution to the study of likely consequences upon regional growth of developing a leading agricultural industry. In the future, when more and better regional statistics and research and more advances in our knowledge of regional development are available, still more information could be introduced into the model to correct current inadequacies. The experience and lessons learned in the present work and others like it will be valuable in future modeling efforts.

APPENDIX

COMPUTER PROGRAM

```
      PROGRAM SIMCOL(INPUT,OUTPUT,TAPE1=INPUT,TAPE2=OUTPUT)                SIMCOL     2
      COMMON /CONTRL/ T,DT,DUM,IRUN,BEGPRT,PRTCHG,PRTVL1,PRTVL2,IPRINT,    CM5        1
     1                NAL,TMOU,TDO                                         CM5        2
      READ900,NRUN                                                         SIMCOL     4
      DO 200 IRUN=1,NRUN                                                   SIMCOL     5
      CALL RUNDAT                                                          SIMCOL     6
      CALL PRISET                                                          SIMCOL     7
      CALL LANSET                                                          SIMCOL     8
      CALL CATSET                                                          SIMCOL     9
      CALL CRDSET                                                          SIMCOL    10
      CALL PRDSET                                                          SIMCOL    11
      CALL ACCSET                                                          SIMCOL    12
      CALL MODSET                                                          SIMCOL    13
      CALL CRTSET                                                          SIMCOL    14
      PRT = BEGPRT                                                         SIMCOL    15
      PRTVL = PRTVL1                                                       CM5        3
      T = 0.                                                               SIMCOL    16
   20 IPRINT = 0                                                           SIMCOL    17
      T = T+DT                                                             SIMCOL    18
      IF(T.LT.PRT)GO TO 40                                                 SIMCOL    19
      IPRINT = 1                                                           SIMCOL    20
      IF(T.EQ.PRTCHG)PRTVL=PRTVL2                                          CM2        3
      PRT = T+PRTVL                                                        SIMCOL    21
   40 CALL PRIGEN                                                          SIMCOL    22
      CALL LANDAL                                                          SIMCOL    23
      CALL AGPROD                                                          SIMCOL    24
      CALL DEMOG                                                           SIMCOL    25
      IF(T.GE.TMOD)CALL MODCHU                                             SIMCOL    26
      CALL AGACC                                                           SIMCOL    27
      CALL MODRAT                                                          SIMCOL    28
      CALL CNTACC                                                          SIMCOL    29
      IF(T.LT.DUM)GO TO 20                                                 SIMCOL    30
  200 CONTINUE                                                             SIMCOL    31
      STOP                                                                 SIMCOL    32
  900 FORMAT(I1)                                                           SIMCOL    33
      END                                                                  SIMCOL    34
```

```
      SUBROUTINE RUNDAT                                                 RUNDA↑     2
      COMMON /CONTRL/ T,DT,DUR,IRUN,BEGPRT,PRTCHG,PRTVL1,PRTVL2,IPRINT,  CM5       1
     1               MAL,TMOD,TDO                                       CM5       2
      NAMELIST /NAMRUN/ DT,DUR,BEGPRT,PRTCHG,PRTVL1,PRTVL2,MAL,TMOD,TDO  CM5       4
      IF(IRUN.GT.1)GO TO 30                                             RUNDA↑     5
      DUR = 10.                                                         RUNDA↑     6
      PRTCHG = 100.                                                     CM2        5
      PRTVL2 = 5.                                                       CM2        6
      PRTVL1 = 1.                                                       CM5        5
      TDO = 100.                                                        CM5        6
      BEGPRT = 1.                                                       RUNDA↑     8
      TMOD = 100.                                                       RUNDA↑     9
      MAL = 3                                                           RUNDA↑    10
      DT = .25                                                          RUNDA↑    11
   30 READ(1,NAMRUN)                                                    RUNDA↑    12
      WRITE(2,NAMRUN)                                                   RUNDA↑    13
      RETURN                                                            RUNDA↑    14
      END                                                               RUNDA↑    15
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      SUBROUTINE PRIGEN                                                 PRIGEN     2
      COMMON /ACCOUN/ DELAT,AMLAT,ACLAT,VLANDT,VLDTXT,TAXCT,AGSUT,     ACCOUN     2
     1                DELAM,AMLAM,ACLAM,VLANDM,VLDTXM,TAXCM,AGSUM,     ACCOUN     3
     2                DELAV,DCRU,FARMIC,DITOUS,DCRDT,RCSTDT,EXPLIV,NCFR, ACCOUN     4
     3                ALPM1,TEC,TCEC,TRNSLS,TLF,TLFP,CPLF,RINT,RINTL,  ACCOUN     5
     4                CREDT,DIV,C250,C253,C254,LT1,LT2,LT3,CBSTG,CSTGM, C=7       1
     5                EPCRPJ,PCROPU,PCROPL,PFCROP,                     ACCOUN     7
     6                EYLDCJ,YLDCU,YLDCL,YLDFC,DYLDCU,DYLDCL,DYLDFC    ACCOUN     8
      REAL NCFR                                                         ACCOUN     9
      COMMON /CATTLE/ PFGT,FEMT,PFPT,PMJT,PWPT,TOPOPT,TOPOPR,          CATTLE     2
     1                PFGM,     PFPM,PMJM,PWPM,TOPOPM,VACAPL,AUXL12,   CATTLE     3
     2                SLFERT,SLSCCT,SOLDFT,SLSMLT,SLSPT,SLSPTP,FEMSCT, CATTLE     4
     3                SLFERM,SLSCCM,SOLDFM,SLSMLM,SLSPM,SUPR,FEMSCM,   CATTLE     5
     4                PPFGTT,PPFPTT,PPMJTT,PPWPTT,PPFGTM,              CATTLE     6
     5                PPFPTM,PPMGTM,PPMPTM,RFGTT,RFPTT,                CATTLE     7
     6                RMGTT,RMPTT,RFGTM,RFPTM,RMGTM,RMPTM,             CATTLE     8
     7                TDNT,TDMAT,TDNM,TDMIP,TDMAM,PATADT,GMM,GMT,PFLACT, CATTLE     9
     8                YMAT,PA,PAP,PAPP,PRAT,EXPL,UNEXPL,CT202,C214,C244 CATTLE    10
      COMMON /CONTRL/ T,DT,DUM,IRUN,BEGPRT,PRTCHG,PRTVL1,PRTVL2,IPRINT, C=5       1
     1                MAL,TMOU,TDO                                     C=5       2
      REAL MKM                                                          PRIGEN     5
      DIMENSION VAL90(11)                                               PRIGEN     6
      DATA C219,C237,C238 / 1.. ,1.  .032 /                             PRIGEN     7
      DATA ELASD,ELASI,ELASP / .7, .6, 1. /                             PRIGEN     8
      DATA MKM,UNEXPL / .15, 300000. /                                  PRIGEN     9
      DATA DEL7 / 5. /                                                  C=5        7
      DATA SMALL90,DIFF90,K90 / 4., 1., 10 /                            PRIGEN    11
      DATA VAL90 / 3100., 78023., 98379., 19848., 19148., 98278.,       PRIGEN    12
     1            129799., 191700., 249000., 282000., 329000. /        PRIGEN    13
      DATA PAP0 / 907./                                                 PRIGEN    14
      EPCRPU = EPCRPU+(PCROPU-EPCRPU)*DT/DEL7                           PRIGEN    15
      PCROPU = PCROPU*RCSTDT                                            C=4        1
      PCROPL = PCROPL*RCSTDT                                            C=4        2
      PFCROP = PFCROP*RCSTDT                                            C=4        3
      PPA = PA                                                          PRIGEN    19
      PA = PA*(1.+C219*(TDEM-SUPB)*DT/(TDEM*ELASD))                     PRIGEN    20
      PAPP = PAP                                                        PRIGEN    21
      PAP = PA*(1.-MKM)                                                 PRIGEN    22
      PRAT = PAP/PAP0                                                   PRIGEN    23
      RDEM = ELASI*C237*ELASP*C238*ELASD*(PA-PPA)/(PPA*DT)              PRIGEN    24
      DEM = DEM+DT*(DEM*RDEM)                                           PRIGEN    25
      EXPL = 0.                                                         PRIGEN    26
      IF(T.GE.4.)EXPL=TABLIE(VAL90,SMALL90,DIFF90,K90,T)                PRIGEN    27
      TDEM = DEM*EXPL*UNEXPL                                            PRIGEN    28
      IF(IPRINT.LT.1)RETURN                                             PRIGEN    29
      PRINT890,T                                                        PRIGEN    30
      PRINT910,PA,PAP,EXPL,DEM,TDEM,EPCRPU,PCROPU,PCROPL,PFCROP         PRIGEN    31
      RETURN                                                            PRIGEN    32
  890 FORMAT(36H1OUTPUT OF SUBROUTINE PRIGEN AT TIME,F8.2)              PRIGEN    33
  910 FORMAT(1H0,9X,2HPA,18X,3HPAP,9X,4HEXPL,8X,3HDEM,9X,4HTDEM,8X,     PRIGEN    34
     1       6HEPCRPU,6X,6HPCROPU,6X,6HPCROPL,6X,6HPFCROP/1H0,8X,9E12.4) PRIGEN    35
      ENTRY PRISET                                                      PRIGEN    36
      PCROPU = 630.                                                     PRIGEN    37
      PCROPL = 892.                                                     PRIGEN    38
      PFCROP = 269.                                                     PRIGEN    39
      EPCRPU = PCROPU                                                   PRIGEN    40
      PA = 1067.                                                        PRIGEN    41
      TDEM = 1889100.                                                   PRIGEN    42
      DEM = 1739100.                                                    PRIGEN    43
      SUPB = 1889100.                                                   PRIGEN    44
      PAP = 907.                                                        PRIGEN    45
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      RETURN                                          PRIQEN    46
      END                                             PRIQEN    47
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      SUBROUTINE LANDAL                                                 LANDAL     2
      COMMON /CONTRL/ T,DT,DUM,IRUN,BEGPRT,PRTCHG,PRTVL1,PRTVL2,IPRINT, CN3       1
     1                MAL,TMOD,TDO                                      CN3       2
      COMMON /LAND/   TGL,TTGL,TTGLL,TTGLU1,TTGLU2,TGLSF0,              LAND      2
     1                TRSL,TLMOD,TLMOD1,TLMOD2,TLMOD3,TTGLR,TGLR,       LAND      3
     2                TLCRL,TLCRU,TLCRUP,TGLSF,TGLU1P,TLFC,TLC,         LAND      4
     3                XR1,R1,R2,PR2,PDR,CRM,RLM,RLMI,RLCRU,AUX1,AUX3,   LAND      5
     4                ARM1,ARM2,ARM3,A9,C9,GRT,CPLPT,XDEL,RPTM,GRE      LAND      6
      DIMENSION COUT4(3),COUT11(6),VAL49(9)                             LANDAL     5
      DATA AL2,C249,CFD1,CL2 / .03, .8, .9, .5 /                        LANDAL     6
      DATA VAL49 / 20000., 18920., 8950., 7860., 5000. /                LANDAL     7
      DATA DEL4,DEL11 /1.9, 10./                                        CN4        6
      DATA DEL15,DEL16,DEL17,DEL18 / 4*5. /                             LANDAL     9
      DATA K4,K11,K49,DIFF49,SMALL49/ 3, 6, 4, 1., 0. /                 LANDAL    10
      DATA TLFC0,TGLSF0,TLDRNL0 / 161730., 31379500., 3137950., /       LANDAL    11
      DATA TLAVL0,TLAVU01,TLAVU02 / 93330., 2169000., 1070000. /        LANDAL    12
      DATA XDEL,RLDRN,RLCRL / 1., 13900., 4900. /                       CN4        9
      IF(T.LT.TMOD)GO TO 20                                             LANDAL    14
      TRSL = (XR1+R2+RLM)+XDEL                                          LANDAL    15
      E6 = 1.                                                           LANDAL    16
      IF(RTGLL.LT.0..AND.TTGLL.GT.DT+(+RTGLL))E6=0.                     LANDAL    17
      E10 = 1.                                                          LANDAL    18
      IF(RTGLU1.LT.0..AND.TTGLU1.GT.DT+(+RTGLU1))E10=0.                 LANDAL    19
      E14 = 1.                                                          LANDAL    20
      IF(RTGLU2.LT.0..AND.TTGLU2.GT.DT+(+RTGLU2))E14=0.                 LANDAL    21
      TLMOD1 = AMAX1(AMIN1(TLMOD1+DT+(RLM+TGLL/TGL+TLMOD1+PR2+E6+RTGLL+ LANDAL    22
     1         TLMOD1/TGLL), TGLL), 0.)                                 LANDAL    23
      TLMOD2 = AMAX1(AMIN1(TLMOD2+DT+(RLM+TGLU1/TGL+TLMOD2+PR2+RTGLU1+  LANDAL    24
     1         E10+TLMOD2/TGLU1), TGLU1), 0.)                           LANDAL    25
      TLMOD3 = AMAX1(AMIN1(TLMOD3+DT+(RLM+TGLU2/TGL+TLMOD3+PR2+RTGLU2+  LANDAL    26
     1         E14+TLMOD3/TGLU2), TGLU2), 0.)                           LANDAL    27
      TLMOD = TLMOD1+TLMOD2+TLMOD3                                      LANDAL    28
   20 CONTINUE                                                          LANDAL    29
      TLAVL = TLAVL+(TLAVL0-TLAVL)+DT/DEL15                             LANDAL    30
      TLAVU1 = TLAVU1+(TLAVU01-TLAVU1)+DT/DEL16                         LANDAL    31
      TLAVU2 = TLAVU2+(TLAVU02-TLAVU2)+DT/DEL17                         LANDAL    32
      RLFC = AL2+TLFC0+EXP(AL2+T)                                       LANDAL    33
      TLFC = TLFC+DT+RLFC                                               LANDAL    34
      TLFCU = C249+TLFC                                                 LANDAL    35
      CALL DELAY(RLDRN,AUX10,COUT11,DEL11,DT,K11)                       LANDAL    36
      TLDRN = AMIN1(TLDRN+DT+AUX10, TLDRNL0)                            LANDAL    37
      TLFCL = AMIN1(TLFC-TLFCU, TLAVL0+TLDRN)                           LANDAL    38
      TLBAN = 20000.                                                    LANDAL    39
      IF(T.GE.0.)TLBAN = TABLIE(VAL49,SMALL49,DIFF49,K49,T)             LANDAL    40
      ALNDL = TLAVL+TLDRN-TLFCL-TLBAN                                   LANDAL    41
      TLCRL = AMIN1(TLCRL+DT+RLCRL, ALNDL)                              LANDAL    42
      TLCRLR = TLCRL+TLPAN                                              LANDAL    43
      TGLLP = TGLL                                                      LANDAL    44
      TGLL = AMAX1(TLAVL-TLFCL-TLCRLR, 0.)                              LANDAL    45
      RTGLL = (TGLL-TGLLP)/DT                                           LANDAL    46
      TGLSF1 = TGLSF1+(TGLSF0-TGLSF1)+DT/DEL18                          LANDAL    47
      TGLSF = TGLSF1-TLDRN                                              LANDAL    48
      TLFCU1P = TLFCU1                                                  LANDAL    49
      TLFCU1 = AMIN1(CFD1+TLFCU, TLAVU1)                                LANDAL    50
      DLFCU1 = TLFCU1+TLFCU1P                                           LANDAL    51
      ALNDU1 = TLAVU1+TLFCU1                                            LANDAL    52
      AUX4 = 0.                                                         LANDAL    53
      IF(RLCRU.LE.0.)AUX4=CL2+DLFCU1                                    LANDAL    54
      TLCRUP = TLCRU                                                    LANDAL    55
      TLCRU = AMAX1(AMIN1(TLCRU+AUX4+DT+(AUX2+AUX3), ALNDU1), 0.)       LANDAL    56
      TGLU1P = TGLU1                                                    LANDAL    57
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      TGLU1 = ALNDU1-TLCRU                                                  LANDAL     90
      RTGLU1 = (TGLU1-TGLU1P)/DT                                            LANDAL     91
      CALL DELAY(AUX1,AUX2,CROUT4,DEL4,DT,R4)                               LANDAL     92
      TLFCU2 = AMIN1((1.-CFC1)*TLFCU, TLAVU2)                               LANDAL     93
      TGLU2P = TGLU2                                                        LANDAL     94
      TGLU2 = TLAVU2-TLFCU2                                                 LANDAL     95
      RTGLU2 = (TGLU2-TGLU2P)/DT                                            LANDAL     96
      TLCC = TLCRLR+TLCRU                                                   LANDAL     97
      TLC = TLFC+TLCC                                                       LANDAL     98
      TGLU = TGLU1+TGLU2                                                    LANDAL     99
      TGL = TGLL+TGLU                                                       LANDAL    100
      TTGLL = TGLL+TLMOD1                                                   LANDAL    101
      TTGLU1 = TGLU1-TLMOD2                                                 LANDAL    102
      TTGLU2 = TGLU2-TLMOD3                                                 LANDAL    103
      TTGL = TGL-TLMOD-TRSL                                                 LANDAL    104
      TTGLR = TTGL+TGLSF*C9                                                 LANDAL    105
      TGLR = TGL+TGLSF*C9                                                   LANDAL    106
      IF(IPRINT.LT.1)RETURN                                                 LANDAL    107
      PRINT890,T                                                            LANDAL    108
      PRINT900,ALNDL,TLAVL,ALNDU1,TLAVU1,TLAVU2,TLDRN,TLBAN                 LANDAL    109
      PRINT908,TLFCL,TLFCU1,TLFCU2,TLFCJ,TLFC,TLCRL,TLCRLR,TLCRU,TLCC,      LANDAL    110
     1         TLC                                                          LANDAL    111
      PRINT916,TTGLL,TTGLU1,TTGLU2,TGLU,TGL,TTGL,TGLSF,TTGLR                LANDAL    112
      PRINT924,RTGLL,RTGLU1,RTGLU2,RLFC,AUX3,AUX4,AUX10                     LANDAL    113
      PRINT930,CROUT4,CROUT11                                               LANDAL    114
      IF(T.LT.TMOD)RETURN                                                   LANDAL    115
      PRINT950,TLMOD,TLMOD1,TLMOD2,TLMOD3,TRSL,TGLL,TGLU1,TGLU2,TGLR        LANDAL    116
      RETURN                                                                LANDAL    117
  890 FORMAT(36H0OUTPUT OF SUBROUTINE LANDAL AT TIME,F8.2)                  LANDAL    118
  900 FORMAT(1H0,9X,5HALNDL,7X,5HTLAVL,7X,6HALNDU1,6X,6HTLAVU1,6X,          LANDAL    119
     1       6HTLAVU2,6X,5HTLDRN,7X,5HTLBAN/1H0,9X,7(E11.4,1X))             LANDAL    120
  908 FORMAT(1H0,9X,5HTLFCL,7X,6HTLFCU1,6X,6HTLFCU2,6X,5HTLFCU,7X,          LANDAL    121
     1       4HTLFC,8X,4HTLCRL,7X,6HTLCRLR,6X,5HTLCRU,7X,4HTLCC,8X,         LANDAL    122
     2       3HTLC/1H0,9X,10(E11.4,1X))                                     LANDAL    123
  916 FORMAT(1H0,9X,5HTTGLL,7X,6HTTGLU1,6X,6HTTGLU2,6X,4HTGLU,8X,3HTGL,     LANDAL    124
     1       9X,4HTTGL,8X,5HTGLSF,7X,5HTTGLR/1H0,8X,8E12.4)                 LANDAL    125
  924 FORMAT(1H0,9X,5HRTGLL,7X,6HRTGLU1,6X,6HRTGLU2,6X,4HRLFC,8X,4HAUX3,    LANDAL    126
     1       8X,4HAUX4,8X,5HAUX10/1H0,9X,7(E11.4,1X))                       LANDAL    127
  930 FORMAT(1H0,9X,6HCROUT4,38X,7HCROUT11/1H0,9X,9(E11.4,1X))              LANDAL    128
  950 FORMAT(1H0,9X,5HTLMOD,7X,6HTLMOD1,6X,6HTLMOD2,6X,6HTLMOD3,8X,         LANDAL    129
     1       4HTRSL,8X,4HTGLL,8X,5HTGLU1,7X,5HTGLU2,7X,4HTGLR/1H0,8X,       LANDAL    130
     2       9E12.4)                                                        LANDAL    131
      ENTRY LANSET                                                          LANDAL    132
C                                                                           LANDAL    133
C                     VALUES FOR LAND ALLOCATION                            LANDAL    134
C                                                                           LANDAL    135
      TLAVL = 4316[0.                                                       LANDAL    136
      TLAVU1 = 1726729.                                                     LANDAL    137
      TLAVU2 = 1293617.                                                     LANDAL    138
      TGLSF1 = .8*TGLSF0                                                    LANDAL    139
      TLDRN = 0.                                                            LANDAL    140
      TLBAN = 20000.                                                        LANDAL    141
      TLCRL = 140900.                                                       CM4         6
      TLCRU = 201300.                                                       CM4         7
      RLCRU = 3500.                                                         CM4         8
      TLFC = 101730.                                                        LANDAL    145
      TLFCU1 = 40915.                                                       LANDAL    146
      TLC = TLBAN+TLCRL+TLCRU+TLFC                                          LANDAL    147
      TLMOD = 0.                                                            LANDAL    148
      TLMOD1 = 0.                                                           LANDAL    149
      TLMOD2 = 0.                                                           LANDAL    150
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      TLMOD3 = 0.                                                       LANDAL  119
      TRSL = 0.                                                         LANDAL  120
      TGLU1 = 1471730.                                                  LANDAL  121
      TGLU2 = 1252325.                                                  LANDAL  122
      TGLL = 319864.                                                    LANDAL  123
      TTGLU1 = TGLU1                                                    LANDAL  124
      TTGLU2 = TGLU2                                                    LANDAL  125
      TTGLL = TGLL                                                      LANDAL  126
      RTGLU1 = -8837.                                                   LANDAL  127
      RTGLU2 = -1[illegible]37.                                         LANDAL  128
      RTGLL = -10[illegible]76.                                         LANDAL  129
      TGL = TGLL+TGLU1+TGLU2                                            LANDAL  130
      TGLR = TGL+TGLSEC*C9                                              LANDAL  131
      TTGLR = TGLR                                                      LANDAL  132
      AUX1 = 0.                                                         LANDAL  133
      AUX2 = 0.                                                         LANDAL  134
      AUX3 = 7000.                                                      LANDAL  135
      PR2 = 0.                                                          LANDAL  136
      H2 = 0.                                                           LANDAL  137
      RLM = 0.                                                          LANDAL  138
      XM1 = 0.                                                          LANDAL  139
      CROUT4(1) = 0.                                                    LANDAL  140
      CROUT4(2) = 0.                                                    LANDAL  141
      CROUT4(3) = 0.                                                    LANDAL  142
      DO 990 I=1,6                                                      LANDAL  143
      CROUT11(I) = 2700.                                                LANDAL  144
  990 CONTINUE                                                          LANDAL  145
      RETURN                                                            LANDAL  146
      END                                                               LANDAL  147
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      SUBROUTINE AGPROD                                                 AGPROD     2
      COMMON /ACCOUN/ DELAT,AMLAT,ACLAT,VLANDT,VLDTXT,TAXCT,AGSUT,     ACCOUN     2
     1                DELAM,AMLAM,ACLAM,VLANDM,VLDTXM,TAXCM,AGSUM,     ACCOUN     3
     2                DELAV,DCRU,FARMIC,DHTOUS,DCRDT,PCSTDT,EXPLIV,NCFM,ACCOUN     4
     3                ALPM1,TEC,TCEC,TRISL3,TLF,TLFP,CPLF,RINT,RINTL,  ACCOUN     5
     4                CRELT,DIR,C250,C253,C254,LT1,LT2,LT3,CDSTG,CSTGM,C=7        1
     9                EPCRPJ,PCROPU,PCRIPL,PFCROP,                     ACCOUN     7
     A                EVLDCJ,VLDCU,VLDCL,VLDFC,DVLDCU,DVLDCL,DVLDFC    ACCOUN     8
      REAL NCFM                                                         ACCOUN     9
      COMMON /CATTLE/ PFGT,FEMT,PFPT,PMGT,PMPT,TOPCPT,TOPCPR,          CATTLE     2
     1                PFGM,     PFPM,PMGM,PMPM,TOPCPM,VACAPL,AUXL12,   CATTLE     3
     2                SLFFNT,SLSCCT,SDLDFT,SLSMLT,SLSPT,SLSPTP,FEMSCT, CATTLE     4
     3                SLFFNM,SLSCCM,SDLDFM,SLSMLM,SLSPM,SUPR,FEMSCM,   CATTLE     5
     4                PPGTT,PPFPTT,PPMGTT,PPMPTT,PPFGTM,               CATTLE     6
     9                PPFPTM,PPMGTM,PPMPTM,RFGTT,RFPTT,                CATTLE     7
     6                RMGTT,RMPTT,RFGTM,RFPTM,RMGTM,RMPTM,             CATTLE     8
     7                TDNT,TDMAT,TDNM,TDNMP,TDMAM,PATADT,DMM,GMT,PFLACT,CATTLE     9
     8                YMAT,PA,PAP,PAPP,PRAT,EXPL,UNEXPL,CT202,C214,C244 CATTLE    10
      COMMON /CONTRL/ T,DT,DLM,IRUN,BEGPRT,PRTCHG,PRTVL1,PRTVL2,IPRINT, C=5        1
     1                MAL,TMOD,TDD                                     C=5        2
      COMMON /LAND/   TGL,TTGL,TTGLL,TTGLU1,TTGLU2,TGLSFO,             LAND       2
     1                TRSL,TLMOD,TLMOD1,TLMOD2,TLMOD3,TTGLR,TGLR,      LAND       3
     2                TLCRL,TLCRU,TLCROP,TGLSF,TGLUIP,TLFC,TLC,        LAND       4
     3                XR1,R1,R2,PR2,PDR,CHM,RLM,PLMI,RLCRU,AUX1,AUX3,  LAND       5
     4                ARM1,ARM2,ARM3,A5,CO,GRT,CPLPT,XDEL,RPTM,GRE     LAND       6
      DATA CGOU,CGCU1,CGU1,CGU2 / 3.48, 1.16, 5., 1.7 /                 AGPROD     7
      DATA CGOL,CGCL1,CGL1,CGL2 / 3.8, 1.26, 5., 1.7 /                  AGPROD     8
      DATA C5,C7,C9,C10,C220 / .003, 1.16, .55,2.8, .21 /               AGPROD     9
      DATA CPLPT,GRE,TDND,TDN30 / .45, .74,7.4, .2343 /                 AGPROD    10
      DATA CG3,CG4 / 3.3, 1.16 /                                        AGPROD    11
      DATA TMODC,DEL8,DEL9,DEL10 / 100., 3e9, /                         AGPROD    12
      CG0 = (CGOU*(TTGLU1+TTGLU2)+CGOL*TTGLL)/TTGL                      AGPROD    13
      CG01 = (CGOU1*(TTGLU1+TTGLU2)+CGOL1*TTGLL)/TTGL                   AGPROD    14
      RCON = AMAX1(RCON*DT*C5*(GRT-GRE), .1)                            AGPROD    15
      TDNTG = RCON*(CG0+CPLPT*TTGL*CG01*(1.-CPLPT)*TTGL)                AGPROD    16
      TDNRE = C7*C220*(TLCRU +TLCRL)                                    AGPROD    17
      TDNSF = TGLSF*C9*C10                                              AGPROD    18
      TDNT = TDNTG+TDNRE+TDNSF                                          AGPROD    19
      EVLDCU = EVLDCU+(VLDCU-EVLDCU)*DT/DEL8                            AGPROD    20
      IF(T.LT.TMODC)GO TO 30                                            AGPROD    21
      VLDCU = VLDCU+(DVLDCU-VLDCU)*DT/DEL9                              AGPROD    22
      VLDCL = VLDCL+(DVLDCL-VLDCL)*DT/DEL9                              AGPROD    23
      VLDFC = VLDFC+(DVLDFC-VLDFC)*DT/DEL10                             AGPROD    24
   30 CONTINUE                                                          AGPROD    25
      IF(T.LT.TMOD)GO TO 200                                            AGPROD    26
      TDNMP = TDNM                                                      AGPROD    27
      IF(TLMOD.LE.0.)GO TO 40                                           AGPROD    28
      CG1 = (CGU1*(TLMOD2+TLMOD3)+CGL1*TLMOD1)/TLMOD                    AGPROD    29
      CG2 = (CGU2*(TLMOD2+TLMOD3)+CGL2*TLMOD1)/TLMOD                    AGPROD    30
      GO TO 50                                                          AGPROD    31
   40 CG1 = CG2 = 0.                                                    AGPROD    32
   50 IF(MAL.EQ.2.OR.MAL.EQ.4)GO TO 80                                  AGPROD    33
      CGA = CG1+CPLPT*CG2*(1.-CPLPT)                                    AGPROD    34
      CTR = CG3+CPLPT*CG4*(1.-CPLPT)                                    AGPROD    35
      GO TO 100                                                         AGPROD    36
   80 CGA = CG1                                                         AGPROD    37
      CTR = CG3                                                         AGPROD    38
  100 IF(MAL.GT.2)GO TO 140                                             AGPROD    39
      TDNM = CGA*TLMOD+CTR*TRSL                                         AGPROD    40
      GO TO 200                                                         AGPROD    41
  140 IF(TLMOD*TRSL.LE.0.)GO TO 145                                     AGPROD    42
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      TDNG = (CGA*TLMOD*CTR*TRSL)/(TLMOD*TRSL)                          AGPROD     43
      GO TO 150                                                         AGPROD     44
  145 TDNG = 0.                                                         AGPROD     45
  150 TDNF = C253*C254*TDNS3/C250                                       AGPROD     46
      CPLF = (TDNG*TDNG)/(TDLF-TDNG)                                    AGPROD     47
      TLFP = TLF                                                        AGPROD     48
      TLF = CPLF*(TLMOD*TRSL)                                           AGPROD     49
      TMPL = TLMOD*TRSL-TLF                                             AGPROD     50
      TDNM = TDNF*TLF+TDNG*TMPL                                         AGPROD     51
  200 IF(IPRINT.LT.1)RETURN                                             AGPROD     52
      PRINT890,T                                                        AGPROD     53
      PRINT900,HCON,CGA,CG01,TDNTG,TDNRE,TDNSF,TDNT                     AGPROD     54
      PRINT910,BYLDCU,YLDFC,YLDCL,YLDFC                                 AGPROD     55
      IF(T.LT.TMOD)RETURN                                               AGPROD     56
      PRINT950,CGA,CTR,CPLF,TLF,TMPL,TDNM                               AGPROD     57
      RETURN                                                            AGPROD     58
  890 FORMAT(36H4OUTPUT OF SUBROUTINE AGPROD AT TIME,F8.2)              AGPROD     59
  900 FORMAT(1H0,9X,4HHCON,9X,3HCGA,9X,4HCG01,8X,5HTDNTG,7X,5HTDNRE,7X, AGPROD     60
     1       5HTDNSF,7X,4HTDNT/1H0,9X,7(E11.4,1X))                      AGPROD     61
  910 FORMAT(1H0,9X,6HYLDCU,8X,5HYLDCU,7X,5HYLDCL,7X,5HYLDFC/1H0,8X,    AGPROD     62
     1       4E12.4)                                                    AGPROD     63
  950 FORMAT(1H0,9X,3HCGA,9X,3HCTR,9X,4HCPLF,8X,3HTLF,9X,4HTMPL,8X,     AGPROD     64
     1       4HTDNM/1H0,8X,5E12.4)                                      AGPROD     65
      ENTRY PRDSET                                                      AGPROD     66
                                                                        AGPROD     67
C                                                                       AGPROD     68
C                     VALUES FOR PRODUCTION                             AGPROD     69
C                                                                       AGPROD     70
      GRT = (TGL*TGLSFC*C9)/TOPOPT                                      AGPROD     71
      HCON = 1.                                                         AGPROD     72
      TDNM = 6.                                                         AGPROD     73
      TLF  = 3.                                                         AGPROD     74
      TLFP = 3.                                                         AGPROD     75
      RETURN                                                            AGPROD     76
      END
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      SUBROUTINE DEMOG                                                  DEMOG     2
      COMMON /CATTLE/ PFGT,FERT,PFPT,PMGT,PMPT,TOPOPT,TOPOPR,           CATTLE    2
     1                PFGM,     PFPM,PMGM,PMPM,TOPOPM,VACAPL,AUXL12,    CATTLE    3
     2                SLFERT,SLSGGT,SOLDFT,SLSMLT,SLSPT,SLSPTP,FEMSGT, CATTLE    4
     3                SLFERM,SLSGGM,SOLDFM,SLSMLM,SLSPM,SUPB,FEMSGM,   CATTLE    5
     4                PPFGTT,PPFPTT,PPMGTT,PPMPTT,PPFGTM,              CATTLE    6
     5                PPFPTM,PPMGTM,PPMPTM,PFGTT,PFPTT,                CATTLE    7
     6                PMGTT,PMPTT,PFGTM,PFPTM,PMGTM,PMPTM,             CATTLE    8
     7                TDNT,TDNAT,TDNM,TDNMP,TDNAM,PATAOT,DM4,QMT,PFLACT, CATTLE  9
     8                YMAT,PA,PAP,PAPP,PPAT,EXPL,UNEXPL,CT202,C214,C244 CATTLE   10
      COMMON /CONTRL/ T,DT,DUR,IRUN,BEGPRT,PRTCHG,PRTVL1,PRTVL2,IPRINT, CH5     1
     1                WAL,TMOD,TDO                                     CH5     2
      COMMON /LAND/   TGL,TTGL,TTGLL,TTGLU1,TTGLU2,TGLSFD,             LAND    2
     1                TRSL,TLMOD,TLMOD1,TLMOD2,TLMOD3,TTGLR,TGLR,      LAND    3
     2                TLPRL,TLCPU,TLCRUP,TGLSF,TGLU1P,TLFC,TLC,        LAND    4
     3                XR1,R1,R2,PR2,PDR,CRM,RLM,RLMI,RLCRU,AUX1,AUX3,  LAND    5
     4                ARM1,ARM2,ARM3,A5,C9,GRT,CPLPT,XDEL,RPTN,GRE     LAND    6
      DIMENSION VAL1(6),VAL2(6),VAL3(6),VAL4(2),VAL5(2),VAL6(5),VAL9(4) DEMOG   6
      DIMENSION VALM1(6),VALM2(6),VALM3(6)                              DEMOG     7
      DIMENSION VAL7(8)                                                 DEMOG     8
      DIMENSION VAL9(8)                                                 DEMOG     9
      DIMENSION RINTFT1(15),RINTFM1(15),RINTFT2(15),RINTFM2(15)         DEMOG    10
      DIMENSION RINTMT1(15),RINTMM1(15),RINTMT2(15),RINTMM2(15)         DEMOG    11
      REAL NREQT,NREQM                                                  DEMOG    12
      DATA C12 / 1. /                                                   DEMOG    13
      DATA C198,C199,C200,CPU1,CT202,CM202/.95, 2., .7, .4, .4, .4/     DEMOG    14
      DATA C206,C207,C208,C209,C210,C211/ 1., 1., 1., 1., 1., 1./       DEMOG    15
      DATA C212,C213,C214,C215,C216,C217 / 1.4, 1., .6, .2,0.,.0285/    CH4      9
      DATA C224,C225,C226,C227,C228 / .98, .92, .88, .42, .535 /        DEMOG    17
      DATA C230,C231,CT232,CM232,C233/.01,.05, 1.,1.5, 1.09/            DEMOG    18
      DATA CT241,CM241,C242,C243,C244,C245/ .9,.95, .05,0.,.3,0./       DEMOG    19
      DATA C246,C280,C283 / 1., 1., 3. /                                DEMOG    20
      DATA PRSIT1,ELAST1,AMXT1,AMNT1,BMNT1,BMXT1/.5,1.,.75,2*.5,.75/    DEMOG    21
      DATA PRSIT2,ELAST2,AMXT2,AMNT2,BMNT2,BMXT2/.1,.7,.25,.15,.15,.18/ DEMOG    22
      DATA PRSIT3,ELAST3,AMXT3,AMNT3,BMNT3,BMXT3/.8,1.,1.,.7,.7,1./     DEMOG    23
      DATA PRSIT4,ELAST4,AMXT4,AMNT4,BMNT4,BMXT4/.1,.8,.23,2*.11,.14 /  DEMOG    24
      DATA PRSIT5,ELAST5,AMXT5,AMNT5,BMNT5,BMXT5/.13,.85,.21,2*.13,.17 / DEMOG   25
      DATA PRSIT6,ELAST6,AMXT6,AMNT6,BMNT6,BMXT6/.002,.7,.06,2*.02,.05/ DEMOG    26
      DATA PRSIT7,ELAST7,AMXT7,AMNT7,BMNT7,BMXT7/.13,.6,.2,2*.1,.15/    DEMOG    27
      DATA PRSIM1,ELASM1,AMNM1,AMXM1,BMNM1,BMXM1/.5,1.,.9,1.,.9,1. /    DEMOG    28
      DATA PRSIM2,ELASM2,AMNM2,AMXM2,BMNM2,BMXM2/.5,.7,.8,1.,.8,.95/    DEMOG    29
      DATA PRSIM3,ELASM3,AMNM3,AMXM3,BMNM3,BMXM3/.8,1.,.8,1.,.8,1. /    DEMOG    30
      DATA PRSIM4,ELASM4,AMNM4,AMXM4,BMNM4,BMXM4/.1,.8,.11,.3 ,.11,.2/  DEMOG    31
      DATA PRSIM5,ELASM5,AMNM5,AMXM5,BMNM5,BMXM5/.13,.85,.13,.25,.13,
     1                                                    ,19 /         DEMOG    33
      DATA PRSIM6,ELASM6,AMNM6,AMXM6,BMNM6,BMXM6/.002, .7, .02, .06,    DEMOG    34
     1                                            .02,.05 /           DEMOG    35
      DATA PRSIM7,ELASM7,AMNM7,AMXM7,BMNM7,BMXM7/.13,.6,.1,.2,.1,.15 /  DEMOG    36
      DATA IDTF1,IDTF2,IDTM1,IDTM2 / 2, 2, 2, 2/                        DEMOG    37
      DATA KGROF,KPROOF,KGROM,KPROOM / 10, 6, 10, 6/                    DEMOG    38
      DATA QGROF,QPROOF,QGROM,QPROOM / 2.5, 10., 2.5, 3.0/              DEMOG    39
      DATA SMALL1,DIFF1,K1/ .36, .36, 5/                                DEMOG    40
      DATA SMALLM1,DIFFM1,KM1/ .36, .36, 5 /                            DEMOG    41
      DATA SMALL2,DIFF2,K2/ .36, .36, 5/                                DEMOG    42
      DATA SMALLM2,DIFFM2,KM2/ .36, .36, 5 /                            DEMOG    43
      DATA SMALL3,DIFF3,K3/ .36, .36, 5/                                DEMOG    44
      DATA SMALLM3,DIFFM3,KM3/ .36, .36, 5 /                            DEMOG    45
      DATA SMALL4,DIFF4,K4/ 0., 1., 1/                                  DEMOG    46
      DATA SMALL5,DIFF5,K5/ 0., 1., 1/                                  DEMOG    47
      DATA SMALL7,DIFF7,K7/ 0., 1., 7/                                  DEMOG    48
      DATA SMALL8,DIFF8,K8/ 0., 1., 3/                                  DEMOG    49
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      DATA SMALL9,DIFF9,<9/ ...,1.,7/
      DATA VAL1/ ^., .25, .55, .63, .7, .75/
      DATA VALM1/ ..., .3, .6, .7, .8, .85 /
      DATA VAL2/ .76, .17, .13, .056, .041, .029/
      DATA VALM2/ .7, .15, . 9, .057, .032, .022 /
      DATA VAL3/ .45, .15, . 5, .04, .025, .018/
      DATA VALM3/ .45, .09, .047, .027, .012, .01/
      DATA VAL4(1),VAL4(2)/ .04, ../,VAL5(1),VAL5(2)/ 1.33, 1.0/
      DATA VAL6/  ., ..., .5, 1., 1.2/
      DATA VAL7/ 1367., 1058., 1054., 1117., 1346., 1629., 2089., 2345./
      DATA VAL8/ .9E+7, 1.E+7, 1.3E+7, 1.6E+7/
      DATA VAL9 / .119,.135,.153,.168,.17,.162,.137,.115 /
      DATA ERK,ELAS8,TOPOK. / .13, .5, 8843000./
      DATA COSTFT,COSTFM / 4.5, 3./
      DATA NPEDT,NPEDM/ .55, .54 /
      DATA TONPED / 1.85 /
      DATA DEL1,DEL2,DEL3,DEL23 /3*1., 5. /
      DATA YMAT,YMAM / 525., 1250. /
C                   INFERTILITY AND MASTITIS - NUMBERS
C
      FINFT  = (PFINFT*(PFPT-DT*(DFPT+RFOUT2+SLMAST))-SLINFT*DT+
     1         DT*(CBT*0.10+FIFNUT)*((PFPT-DT*(DFPT+RFOUT2+SLMAST))*
     2         (1.0-PFINFT))+DT*(PFOUT1-RFPTT-SLFERT)))
      TFMAST =PFMAST*(PFPT-DT*(DFPT+PFOUT2+SLINFT))-SLMAST*DT+(1.0-
     1         PATAFT)*DT*0.18*0.05*((PFPT-DT*(DFPT+RFOUT2+SLINFT)*
     2         (1.0-PFMAST))+DT*(RFOUT1-RFPTT-SLFERT))
      IF(T.LT.TMOD)GO TO 20
      FINFM  = (PFINFM*(PFPM-DT*(DFPM+RFOUM2+SLMASM))-SLINFM*DT+
     1         DT*(CBM*0.10+FIFNUM)*((PFPM-DT*(DFPM+RFOUM2+SLMASM)*
     2         (1.0-PFINFM))+DT*(RFOUM1-PFPTM-SLFERM)))
      TFMASM =  PFMASM*(PFPM-DT*(DFPM+RFOUM2+SLINFM))-SLMASM*DT+(1.0-
     1         PATAFM)*DT*0.18*0.05*((PFPM-DT*(DFPM+RFOUM2+SLINFM)*
     2         (1.0-PFMASM))+DT*(RFOUM1-PFPTM-SLFERM))
   20 CONTINUE
C
C                   DEMOGRAPHY - TRADITIONAL
C
      RFOUPT1 = PFOUT1-RFOUT1*(DRLT1+PSFGT+PPFGTT)*DT
      PFGT = PFGT+DT*(PFT-DRLT1*PFGT-SLSFGT-RFGTT-PFOUPT1)
      RFOUPT2 = RFOUT2-RFOUT2*(DRLT2+PSFPT+PPFPTT)*DT
      PFPT = PFPT+DT*(RFOUPT1-DRLT2*PFPT-SLSFPT-RFPTT-PFOUPT2)
      OLDFT = (RFOUPT2-SOLDFT-DRLT2*OLDFT)*DT+OLDFT
      RMOUPT1 = RMOUT1-RMOUT1*(DRLT1+PSMGT+PPMGTT)*DT
      PMGT = PMGT+DT*(PMT-DRLT1*PMGT-SLSMGT-RMGTT-RMOUPT1)
      RMOUPT2 = RMOUT2-RMOUT2*(DRLT2+PSMPT+PPMPTT)*DT
      PMPT = PMPT+DT*(RMOUPT1-DRLT2*PMPT-SLSMPT-RMPTT-RMOUPT2)
C
C                   DEMOGRAPHY - MODERN
C
      IF(T.LT.TMOD)GO TO 40
      RFOUPM1 = RFOUM1-RFOUM1*(DRLM1+PSFGM+PPFGTM)*DT
      PFGM = PFGM+DT*(PFM-DRLM1*PFGM-SLSFGM-RFGTM-RFOUPM1)
      RFOUPM2 = RFOUM2-RFOUM2*(DRLM2+PSFPM+PPFPTM)*DT
      PFPM = PFPM+DT*(RFOUPM1-DRLM2*PFPM-SLSFPM-RFPTM-RFOUPM2)
      OLDFM = (RFOUPM2-SOLDFM-DRLM2*OLDFM)*DT+OLDFM
      RMOUPM1 = RMOUM1-RMOUM1*(DRLM1+PSMGM+PPMGTM)*DT
      PMGM = PMGM+DT*(PMM-DRLM1*PMGM-SLSMGM-RMGTM-RMOUPM1)
      RMOUPM2 = RMOUM2-RMOUM2*(DRLM2+PSMPM+PPMPTM)*DT
      PMPM = PMPM+DT*(RMOUPM1-DRLM2*PMPM-SLSMPM-RMPTM-RMOUPM2)
   40 CONTINUE
C
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C                    TOTALS - TRADITIONAL AND MODERN                    DEMOG  112
C                                                                       DEMOG  113
      PFGT = PFPT+OLDFT                                                 DEMOG  114
      PFT = PFGT+PFPT+OLDFT                                             DEMOG  115
      PMT = PMGT+PMPT                                                   DEMOG  116
      TOPOPT = PFT+PMT                                                  DEMOG  117
      PPFGT = PFGT/TOPOPT                                               DEMOG  118
      PPFGT = PFGT/TOPOPT                                               DEMOG  119
      PPMGT = PMGT/TOPOPT                                               DEMOG  120
      PPMPT = PMPT/TOPOPT                                               DEMOG  121
      PFGM = PFPM+OLDFM                                                 DEMOG  122
      PFM = PFGM+PFPM+OLDFM                                             DEMOG  123
      PMM = PMGM+PMPM                                                   DEMOG  124
      TOPOPM = PFM+PMM                                                  DEMOG  125
      PPFGM = PFGM/TOPOPM                                               DEMOG  126
      PPFGM = PFGM/TOPOPM                                               DEMOG  127
      PPMGM = PMGM/TOPOPM                                               DEMOG  128
      PPMPM = PMPM/TOPOPM                                               DEMOG  129
      TOPOPP = TOPOPT+TOPOPM                                            DEMOG  130
      VACAPL = PAP*(C227*(PFGT+C212*PFGM)+C225*(PFPT+C212*PFPM)+C224*   DEMOG  131
     1          (OLDFT+C212*OLDFM)+C229*(PMGT+C212*PMGM)+C228*(PMPT+C212*DEMOG  132
     2          PMPM))                                                  DEMOG  133
      IF(T.GT.TMOD) AUXL12 = AUXL12+(AUX12-AUXL12)*DT/DEL23             DEMOG  134
      AUX12 = (C227*PFGT+C224*PFPT+C224*OLDFT+C228*PMGT+C225*PMPT)*C299/DEMOG  135
     1        TTGLP                                                     DEMOG  136
      IF(T.EQ.TMOD) AUXL12 = AUX12                                      DEMOG  137
C                                                                       DEMOG  138
C                    TOTAL DIGESTIBLE NUTRIENTS                         DEMOG  139
C                                                                       DEMOG  140
      TONAT = TDNT/TOPOPT                                               DEMOG  141
      TOPEQT = TDNT*XPEQT                                               DEMOG  142
      PANT = TOPOPT-TOPEQT                                              DEMOG  143
      PAIT = PANT                                                       DEMOG  144
      IF(T.LT.TMOD)GO TO 65                                             DEMOG  145
      IF(TOPOPM.EQ.0.)GO TO 62                                          DEMOG  146
      TONAM = TDNM/TOPOPM                                               DEMOG  147
      GO TO 63                                                          DEMOG  148
   62 TONAM = 0.                                                        DEMOG  149
   63 TOPEQM = TDNM*XPEQM                                               DEMOG  150
      PANM = TOPOPM-TOPEQM                                              DEMOG  151
      PAIM = PANM                                                       DEMOG  152
   65 CONTINUE                                                          DEMOG  153
C                                                                       DEMOG  154
C                    INFERTILITY AND MASTITIS - PROPORTIONS             DEMOG  155
C                                                                       DEMOG  156
      PFINFT = FINFT/PFPT                                               DEMOG  157
      PFMAST = TFMAST/PFPT                                              DEMOG  158
      FMAST = PFPT*PFMAST*(1.-PFINFT)                                   DEMOG  159
      FFPT = PFPT-FMAST-FINFT                                           DEMOG  160
      PIFNUT = C230+AMIN1(C231-C230, (C231-C230)*EXP(-CT232*(TONAT-     DEMOG  161
     1          C233)))                                                 DEMOG  162
      IF(T.LT.TMOD)GO TO 50                                             DEMOG  163
      IF(PFPM.LE.0.)GO TO 67                                            DEMOG  164
      PFINFM = FINFM/PFPM                                               DEMOG  165
      PFMASM = TFMASM/PFPM                                              DEMOG  166
      GO TO 69                                                          DEMOG  167
   67 PFINFM = PFMASM = 0.                                              DEMOG  168
   69 FMASM = PFPM*PFMASM*(1.-PFINFM)                                   DEMOG  169
      FFPM = PFPM-FMASM-FINFM                                           DEMOG  170
      IF(TOPOPM.GT.0.)PIFNUM = C230+AMIN1(C231-C230, (C231-C230)*       DEMOG  171
     1                         EXP(-CM232*(TONAM-C233)))                DEMOG  172
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   53 CONTINUE
C
C                    BRUCELLOSIS TREATMENT
C
      TACAD = T-TOO
      ATABTT = BFT*AMAX1(1.-C198*EXP(-C199*TACAD), C262)
      ATABMT = BFM
      ATAB = ATABTT+ATABMT
      CTABT = RFOUT1*PGFTBT*DT+PCTABT*(PFPT-RFOUT1*DT)
      CTABM = (RFOUM1*PGFTBM-RFPTM*PCTABT)*DT+PCTABM*(PFPM-(RFOUM1-
     1         RFPTM)*DT)
      CTAB = AMIN1(CTABT+CTABM, PFPT+PFPM)
      IF(PFPM.LE.0.)GO TO 62
      PCTABM = CTABM/PFPM
      GO TO 63
   62 PCTABM = 0.
   63 PCTABT = CTABT/PFPT
      IF(PFGM.LE.0.)GO TO 65
      PGFTBM = ((ATABMT-RFGTM*PGFTBT)*DT+PGFTBM*(PFGM-(BFM-RFGTM)*DT))/
     1         PFGM
      GO TO 66
   65 PGFTBM = 0.
   66 PGFTBT = (ATABTT*DT+PGFTBT*(PFGT-BFT*DT))/PFGT
C
C                    FOOT AND MOUTH TREATMENT
C
      EXPOS = EXPOS+DT*EXPAFT
      EXPAFT = 0.
      IF(T.GE.TOO)EXPAFT=TABLIE(VAL8,SMALL8,DIFF8,K8,T)
      ATAFT = AMIN1(EXPAFT/COSTFT,TOPOPT)
      ATAFPT = (TOPOPT-ATAFT)*AMAX1(1.-C200*EXP(-C201*TACAD), C266)
      ATAFTT = ATAFT+ATAFPT
      ATAF = (ATAFTT+TOPOPM)*C293
      PATAFT = ATAFTT/TOPOPT
      IF(T.GE.TOO)PATADT=(ATAFTT+ATABTT*(1.-PATAFT))/TOPOPT
C
C                    ADJUSTMENT OF INTERMEDIATE RATES
C
      RCHNGT = 1.-(ORLT1+PSFGT+PPFGTT)*DT
      RCHNGM = 1.-(ORLM1+PSFGM+PPFGTM)*DT
      DO 100 I=1,KGROF
      RINTFT1(I) = RINTFT1(I)*RCHNGT
      RINTFM1(I) = RINTFM1(I)*RCHNGM
  100 CONTINUE
      RCHNGT = 1.-(ORLT2+PSFPT+PPFPTT)*DT
      RCHNGM = 1.-(ORLM2+PSFPM+PPFPTM)*DT
      DO 120 I=1,KPROF
      RINTFT2(I) = RINTFT2(I)*RCHNGT
      RINTFM2(I) = RINTFM2(I)*RCHNGM
  120 CONTINUE
      RCHNGT = 1.-(ORLT1+PSMGT+PPMGTT)*DT
      RCHNGM = 1.-(ORLM1+PSMGM+PPMGTM)*DT
      DO 140 I=1,KGROM
      RINTMT1(I) = RINTMT1(I)*RCHNGT
      RINTMM1(I) = RINTMM1(I)*RCHNGM
  140 CONTINUE
      RCHNGT = 1.-(ORLT2+PSMPT+PPMPTT)*DT
      RCHNGM = 1.-(ORLM2+PSMPM+PPMPTM)*DT
      DO 160 I=1,KPROM
      RINTMT2(I) = RINTMT2(I)*RCHNGT
      RINTMM2(I) = RINTMM2(I)*RCHNGM
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 180 CONTINUE                                                              DEMOG   234
     CALL DELAY(RFT, RFOUT1, RINTFT1, DGROF, IOTF1, DT, KGROF)             DEMOG   235
     CALL DELAY(RFOUT1, RFOUT2, RINTFT2, DPROOF, IOTF2, DT, KPROOF)        DEMOG   236
     CALL DELAY(RMT, RMOUT1, RINTMT1, DGROM, IOTM1, DT, KGROM)             DEMOG   237
     CALL DELAY(RMOUT1, RMOUT2, RINTMT2, DPROOM, IOTM2, DT, KPROOM)        DEMOG   238
     IF(T.LT.TMO)GO TO 180                                                 DEMOG   239
     RTOM =(TONM-TONMP)/DT                                                 DEMOG   240
     RAA = (RT)+D1)*TOPOPM*(TONMM-TONREQ))/TONPEO                          DEMOG   241
     TOPOPT1 = PFGT+FERT+PMT                                               CM7       2
     RFGTT = SAA*PFGT/TOPOPT1                                              CM7       3
     RFPTT = RAA*FEPT/TOPOPT1                                              CM7       4
     RMGTT = RAA*PMGT/TOPOPT1                                              CM7       5
     RMPTT = RAA*PMPT/TOPOPT1                                              CM7       6
     RFGTM = -RFGTT                                                        DEMOG   246
     RFPTM = -RFPTT                                                        DEMOG   247
     RMGTM = -RMGTT                                                        DEMOG   248
     RMPTM = -RMPTT                                                        DEMOG   249
     PPFGTT = RFGTT/PFGT                                                   CMA       1
     PPFPTT = RFPTT/PFPT                                                   CMA       2
     PPMGTT = RMGTT/PMGT                                                   CM8       3
     PPMPTT = RMPTT/PMPT                                                   CM8       4
     PPFGTM = RFGTM/PFGM                                                   CM8       5
     IF(PFGM.LE.0.)PPFGTM = 0.                                             DEMOG   255
     PPFPTM = RFPTM/PFPM                                                   CM8       6
     IF(PFPM.LE.0.)PPFPTM = 0.                                             DEMOG   257
     PPMGTM = RMGTM/PMGM                                                   CMA       7
     IF(PMGM.LE.0.)PPMGTM = 0.                                             DEMOS   259
     PPMPTM = RMPTM/PMPM                                                   CM8       8
     IF(PMPM.LE.0.)PPMPTM = 0.                                             DEMOS   261
     IF(PFGM .GT.0..AND.RINTFM1(1).EQ.0.)GO TO 170                         DEMOS   262
     CALL DELAY(RFM, RFOUM1, RINTFM1, DGROF, IOTF1, DT, KGROF)             DEMOS   263
     CALL DELAY(RFOUM1, RFOUM2, RINTFM2, DPROOF, IOTF2, DT, KPROOF)        DEMOG   264
     CALL DELAY(RMM, RMOUM1, RINTMM1, DGROM, IOTM1, DT, KGROM)             DEMOG   265
     CALL DELAY(RMOUM1, RMOUM2, RINTMM2, DPROOM, IOTM2, DT, KPROOM)        DEMOG   266
     GO TO 190                                                             DEMOG   267
 170 DO 172 I=1,KGROF                                                      DEMOG   268
     RINTFM1(I) = PFGM/(DGROF*IOTF1)                                       DEMOG   269
 172 CONTINUE                                                              DEMOS   270
     RFOUM1 = PFGM/DGROF                                                   DEMOG   271
     DO 174 I=1,KPROOF                                                     DEMOS   272
     RINTFM2(I) = PFPM/(DPROOF*IOTF2)                                      DEMOS   273
 174 CONTINUE                                                              DEMOG   274
     RFOUM2 = PFPM/DPROOF                                                  DEMOG   275
     DO 175 I=1,KGROM                                                      DEMOG   276
     RINTMM1(I) = PMGM/(DGROM*IOTM1)                                       DEMOG   277
 175 CONTINUE                                                              DEMOS   278
     RMOUM1 = PMGM/DGROM                                                   DEMOS   279
     DO 179 I=1,KPROOM                                                     DEMOG   280
     RINTMM2(I) = PMPM/(DPROOM*IOTM2)                                      DEMOG   281
 179 CONTINUE                                                              DEMOS   282
     RMOUM2 = PMPM/DPROOM                                                  DEMOG   283
 190 CONTINUE                                                              DEMOG   284
C                                                                          DEMOG   285
C                     BIRTH RATES AND BIRTHS - TRADITIONAL                 DEMOG   286
C                                                                          DEMOG   287
     CHANGT = TABLIE(VAL6, SMALL6, DIFF6, K6, PCTABT)                      DEMOG   288
     BRT2 = BRT2+DT/DEL1*(BRT-BRT2)                                        DEMOG   289
     BRT = TABLIE(VAL1, SMALL1, DIFF1, K1, TONAT)                          DEMOG   290
     DELT2 = BRT2*(1.-CHANGT)                                              DEMOS   291
     BAT = BDLT2*FEPT                                                      DEMOG   292
     BFT = .5*BAT                                                          DEMOS   293
```

```
      RMT = RAT-RET                                                     DEMOG  294
      CBT = RPT2*CHANGT                                                 DEMOG  295
C                                                                       DEMOG  296
C                     BIRTH RATES AND BIRTHS - MODERN                   DEMOG  297
C                                                                       DEMOG  298
      IF(T.LT.TMOD)GO TO 210                                            DEMOG  299
      CHANGM = TABLIE(VAL4, SMALL4, DIFF4, K4, PCTABM)                  DEMOG  300
      BRM2 = BRM2+DT/DEL1*(BRM-BRM2)                                    DEMOG  301
      IF(TOPOPM.GT.0.)DR1=TABLIE(VALM1,SMALLM1,DIFFM1,KM1,TONAM)        DEMOG  302
      BPLM2 = BRM2*(1.+CHANGM)                                          DEMOG  303
      BAM = BPLM2*FFRM                                                  DEMOG  304
      BFM = .5*BAM                                                      DEMOG  305
      BMM = BAM-BFM                                                     DEMOG  306
      CBM = BRM2*CHANGM                                                 DEMOG  307
  210 CONTINUE                                                          DEMOG  308
C                                                                       DEMOG  309
C                     DEATH RATES AND DEATHS - TRADITIONAL              DEMOG  310
C                                                                       DEMOG  311
      DRAT = TABLIE(VAL5, SMALL5, DIFF5, K5, RATAFT)                    DEMOG  312
      DPT1 = DPT1+DT/DEL2*(DPGT-DPT1)                                   DEMOG  313
      DMT2 = DPT2+DT/DEL1*(DPPT-DPT2)                                   DEMOG  314
      DPGT = TABLIE(VAL2, SMALL2, DIFF2, K2, TONAT)                     DEMOG  315
      DRPT = TABLIE(VAL3, SMALL3, DIFF3, K3, TONAT)                     DEMOG  316
      DRLT1 = DRT1*DRAT                                                 DEMOG  317
      DRLT2 = DRT2*DRAT                                                 DEMOG  318
      DFGT = PFGT*DRLT1                                                 DEMOG  319
      DFPT = PFPT*DRLT2                                                 DEMOG  320
      DOLDFT = OLDFT*DRLT2                                              DEMOG  321
      DMGT = PMGT*DRLT1                                                 DEMOG  322
      DMPT = PMPT*DRLT2                                                 DEMOG  323
      TOTMST = DFGT+DFPT+DMGT+DMPT+DOLDFT                               DEMOG  324
      DRT = TOTMST/TOPOPT                                               DEMOG  325
C                                                                       DEMOG  326
C                     DEATH RATES AND DEATHS - MODERN                   DEMOG  327
C                                                                       DEMOG  328
      IF(T.LT.TMOD)GO TO 260                                            DEMOG  329
      DRAM = TABLIE(VAL5, SMALL5, DIFF5, K5, RATAFM)                    DEMOG  330
      DPM1 = DRM1 +DT/DEL2*(DRGM-DRM1)                                  DEMOG  331
      DRM2 = DRM2 +DT/DEL1*(DRPM-DRM2)                                  DEMOG  332
      IF(TOPOPM.GT.0.)DRGM=TABLIE(VALM2,SMALLM2,DIFFM2,KM2,TONAM)       DEMOG  333
      IF(TOPOPM.GT.0.)DRPM=TABLIE(VALM3,SMALLM3,DIFFM3,KM3,TONAM)       DEMOG  334
      DRLM1 = DRM1*DRAM                                                 DEMOG  335
      DPLM2 = DRM2*DRAM                                                 DEMOG  336
      DFGM = PFGM*DRLM1                                                 DEMOG  337
      DFPM = PFPM*DRLM2                                                 DEMOG  338
      DOLDFM = OLDFM*DRLM2                                              DEMOG  339
      DMGM = PMGM*DRLM1                                                 DEMOG  340
      DMPM = PMPM*DRLM2                                                 DEMOG  341
      TOTMSM = DFGM+DFPM+DMGM+DMPM+DOLDFM                               DEMOG  342
      IF(TOPOPM.LE.0.)GO TO 250                                         DEMOG  343
      DRM = TOTMSM/TOPOPM                                               DEMOG  344
      GO TO 261                                                         DEMOG  345
  250 DRM = 0.                                                          DEMOG  346
  261 CONTINUE                                                          DEMOG  347
C                                                                       DEMOG  348
C                     SALES - TRADITIONAL                               DEMOG  349
C                                                                       DEMOG  350
C                       OLD FEMALES                                     DEMOG  351
C                                                                       DEMOG  352
      RP1 = PRAT**CLAST1*PRSIT1                                         DEMOG  353
      PREST1 = AMIN1(RMXT1, AMAX1(BMNT1, BP1))                          DEMOG  354
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```
      AP1 = PRSST1*C206*PANT/OLDFT                                      DEMOG  354
      PSFOT  = AMIN1(AMXT1, AMAX1(AMNT1, AP1))                          DEMOG  355
      SOLDFT = OLDFT*PSFOT                                              DEMOG  356
      PANT = PANT-SOLDFT                                                DEMOG  357
C                                                                       DEMOG  358
C                     INFERTILE AND MASTITIS                            DEMOG  359
C                                                                       DEMOG  360
      RP2 = PRAT**ELAST2*PRSIT2                                         DEMOG  361
      PREST2 = AMIN1(BMXT2, AMAX1(BMNT2, RP2))                          DEMOG  362
      AP2 = PREST2*C227*PANT/FINFT                                      DEMOG  363
      PSINFT = AMIN1(AMXT2, AMAX1(AMNT2, AP2))                          DEMOG  364
      SLINFT = FINFT*PSINFT                                             DEMOG  365
      PANT = PANT-SLINFT                                                DEMOG  366
      RP3 = PRAT**ELAST3*PRSIT3                                         DEMOG  367
      PREST3 = AMIN1(BMXT3, AMAX1(BMNT3, RP3))                          DEMOG  368
      AP3 = PREST3*C246*PANT/FMAST                                      DEMOG  369
      PSMAST = AMIN1(AMXT3, AMAX1(AMNT3, AP3))                          DEMOG  370
      SLMAST = FMAST*PSMAST                                             DEMOG  371
      PANT = PANT-SLMAST                                                DEMOG  372
C                                                                       DEMOG  373
C                     GROWING MALES                                     DEMOG  374
C                                                                       DEMOG  375
      RP4 = PRAT**ELAST4*PRSIT4                                         DEMOG  376
      PREST4 = AMIN1(BMXT4, AMAX1(BMNT4, RP4))                          DEMOG  377
      AP4 = PREST4*C2C9*PANT/PMGT                                       DEMOG  378
      PSMGT  = AMIN1(AMXT4, AMAX1(AMNT4, AP4))                          DEMOG  379
      SLSMGT = PMGT*PSMGT                                               DEMOG  380
      PANT = PANT-SLSMGT                                                DEMOG  381
C                                                                       DEMOG  382
C                     GROWING FEMALES                                   DEMOG  383
C                                                                       DEMOG  384
      RP5 = PRAT**ELAST5*PRSIT5                                         DEMOG  385
      PREST5 = AMIN1(BMXT5, AMAX1(BMNT5, RP5))                          DEMOG  386
      AP5 = PREST5*C2C9*PANT/PFGT                                       DEMOG  387
      PSFGT  = AMIN1(AMXT5, AMAX1(AMNT5, AP5))                          DEMOG  388
      SLSFGT = PFGT*PSFGT                                               DEMOG  389
      PANT = PANT-SLSFGT                                                DEMOG  390
C                                                                       DEMOG  391
C                     FERTILE FEMALES                                   DEMOG  392
C                                                                       DEMOG  393
      RP6 = PRAT**ELAST6*PRSIT6                                         DEMOG  394
      PREST6 = AMIN1(BMXT6, AMAX1(BMNT6, RP6))                          DEMOG  395
      AP6 = PREST6*C21.*PANT/FERT                                       DEMOG  396
      PSFERT = AMIN1(AMXT6, AMAX1(AMNT6, AP6))                          DEMOG  397
      SLFERT = FERT*PSFERT                                              DEMOG  398
      PANT = PANT-SLFERT                                                DEMOG  399
C                                                                       DEMOG  400
C                     PRODUCING MALES                                   DEMOG  401
C                                                                       DEMOG  402
      RP7 = PRAT**ELAST7*PRSIT7                                         DEMOG  403
      PREST7 = AMIN1(BMXT7, AMAX1(BMNT7, RP7))                          DEMOG  404
      AP7 = PREST7*C211*PANT/PMPT                                       DEMOG  405
      PSMPT  = AMIN1(AMXT7, AMAX1(AMNT7, AP7))                          DEMOG  406
      SLSMPT = PMPT*PSMPT                                               DEMOG  407
C                                                                       DEMOG  408
C                     MISCELLANEOUS                                     DEMOG  409
C                                                                       DEMOG  410
      SLSMFT = RMOUT2*(1.-(DRLT2*PSMPT*PPMPTT)*DT)                      DEMOG  411
      SLSMLT = SLSMPT*SLSMFT                                            DEMOG  412
      SLSMT = SLSMLT*SLSMGT                                             DEMOG  413
      SLSOOT = SLINFT*SLMAST -                                          DEMOG  414
                                                                        DEMOG  415
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      SLSFPT = SLSOPT*SLFEP*
      PSFPT = SLSFPT/PFPT                                                DEMOG    614
      FEMSOT = SLSOOT*SOLOFT*C216*SLFERT*C215*SLSFGT                     DEMOG    615
      SLSFT = SLSFPT*SOLOFT*SLSFGT                                       DEMOG    616
      SLST = SLSFT*SLSMT                                                 DEMOG    617
      SLSPTP = SLSPT/TTSLP                                               DEMOG    618
      SLSPT = (SLSOOT*SOLOFT)*C224*SLSMPT*C225*SLSMFT*SLFEPT*C224*       DEMOG    619
     1        SLSFGT*C227*SLSMGT*C224                                     DEMOG    620
C                                                                        DEMOG    621
C                    SALES - MONFOM                                      DEMOG    622
      IF(IT.LT.TMONTO) GO TO 50                                          DEMOG    623
C                                                                        DEMOG    624
C                      OLD FEMALES                                       DEMOG    625
C                                                                        DEMOG    626
      BM1 = PRAT**ELASM1*PRSTM1                                          DEMOG    627
      PRESM1 = AMIN1(BMXM1, AMAX1(BMNM1, BM1))                           DEMOG    628
      AM1 = PRESM1*C216*PANM/OLDFM                                       DEMOG    629
      PSFOM = AMIN1(AMXM1, AMAX1(AMNM1, AM1))                            DEMOG    630
      SOLDFM = OLDFM*PSFOM                                               DEMOG    631
      PANM = PANM-SOLDFM                                                 DEMOG    632
C                                                                        DEMOG    633
C                      INFERTILE AND MASTITIS                            DEMOG    634
C                                                                        DEMOG    635
      BM2 = PRAT**ELASM2*PRSTM2                                          DEMOG    636
      PRESM2 = AMIN1(BMXM2, AMAX1(BMNM2, BM2))                           DEMOG    637
      AM2 = PRESM2*C217*PANM/FINFM                                       DEMOG    638
      PSINFM = AMIN1(AMXM2, AMAX1(AMNM2, AM2))                           DEMOG    639
      SLINFM = FINFM*PSINFM                                              DEMOG    640
      PANM = PANM-SLINFM                                                 DEMOG    641
      BM3 = PRAT**ELASM3*PRSTM3                                          DEMOG    642
      PRESM3 = AMIN1(BMXM3, AMAX1(BMNM3, BM3))                           DEMOG    643
      AM3 = PRESM3*C246*PANM/FMASM                                       DEMOG    644
      PSMASM = AMIN1(AMXM3, AMAX1(AMNM3, AM3))                           DEMOG    645
      SLMASM = FMASM*PSMASM                                              DEMOG    646
      PANM = PANM-SLMASM                                                 DEMOG    647
C                                                                        DEMOG    648
C                      GROWING MALES                                     DEMOG    649
C                                                                        DEMOG    650
      BM4 = PRAT**ELASM4*PRSTM4                                          DEMOG    651
      PRESM4 = AMIN1(BMXM4, AMAX1(BMNM4, BM4))                           DEMOG    652
      AM4 = PRESM4*C218*PANM/PMGM                                        DEMOG    653
      PSMGM = AMIN1(AMXM4, AMAX1(AMNM4, AM4))                            DEMOG    654
      SLSMGM = PMGM*PSMGM                                                DEMOG    655
      PANM = PANM-SLSMGM                                                 DEMOG    656
C                                                                        DEMOG    657
C                      GROWING FEMALES                                   DEMOG    658
C                                                                        DEMOG    659
      BM5 = PRAT**ELASM5*PRSTM5                                          DEMOG    660
      PRESM5 = AMIN1(BMXM5, AMAX1(BMNM5, BM5))                           DEMOG    661
      AM5 = PRESM5*C220*PANM/PFGM                                        DEMOG    662
      PSFGM = AMIN1(AMXM5, AMAX1(AMNM5, AM5))                            DEMOG    663
      SLSFGM = PFGM*PSFGM                                                DEMOG    664
      PANM = PANM-SLSFGM                                                 DEMOG    665
C                                                                        DEMOG    666
C                      FERTILE FEMALES                                   DEMOG    667
C                                                                        DEMOG    668
      BM6 = PRAT**ELASM6*PRSTM6                                          DEMOG    669
      PRESM6 = AMIN1(BMXM6, AMAX1(BMNM6, BM6))                           DEMOG    670
      AM6 = PRESM6*C219*PANM/PFRM                                        DEMOG    671
      PSFERM = AMIN1(AMXM6, AMAX1(AMNM6, AM6))                           DEMOG    672
      SLFERM = FERM*PSFERM                                               DEMOG    673
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      PAMM = PAMM-SLFEPM
C
C                         PRODUCING MALES
C
      AM7 = PRAT**SLASM7*PKSTM7
      PRESM7 = AMIN1(AMXM7, AMAX1(AMNM7, BM7))
      AM7 = PRESM7+C211**ANM/PMPM
      PSMPM = AMIN1(AMXM7, AMAX1(AMNM7, AM7))
      SLSMPM = PMPM*PSMPM
C
C                         MISCELLANEOUS
C
      SLSMFM = RMOUM2*(1.-(DELM2+PSMPM+PPMPTM)*DT)
      SLSMLM = SLSMPM+SLSMFM
      SLSMM = SLSMLM+SLSMGM
      SLSCCM = SLINFM+SLMASM
      SLSFPM = SLSCCM+SLFERM
      IF(PFPM.LE.0.)GO TO 58
      PSFPM = SLSFPM/PFPM
      GO TO 59
   58 PSFPM = 0.
   59 FEMSCM = SLSCCM+SOLOFM+C214*SLFERM+C215*SLSFGM
      FEMSC = FEMSCT+FEMSCM
      SLSFM = SLSFPM+SOLOFM+SLSFGM
      SLSM = SLSFM+SLSMM
      TSLS = SLST+SLSM
      SLSPM = (SLSCCM+SOLOFM)*C224+SLSMPM*C225+SLSMFM+SLFERM*C226+
     1            SLSFGM*C227+SLSMGM*C228
   53 CONTINUE
C
C                         MILK PRODUCTION
C
      PFLACT = RRLT2*CT261
      QMT =(FERT*(PATAFT+(1.-PATAFT)*.82+(1.-PATAFT)*.18*.85))*PFLACT*
     1     CT202*YMAT*TABEXE(VAL6,.31,.31,4,TOMAT)
      QMCT = QMT/(CT2.2*210.*PFLACT*FERT)
      IF(MAL.LT.1)GO TO 330
      PFLACM = RRLM2*CM261
      QMM = (FEPM*(PATAFM+(1.-PATAFM)*.82+(1.-PATAFM)*.18*.85))*PFLACM*
     2     CM202*YMAM*TABLXE(VAL6,.31,.31,4,TOMAM)
      QMCM = QMM/(CM202*250.*PFLACM*FEPM)
  330 CONTINUE
C
C                 EXTRACTION RATIO AND TOTAL SUPPLY
C
      SUPCTA = SLSCCT+SLSMLT+SOLOFT+C212*(SLSCCM+SLSMLM+SOLOFM)+C213*
     1          (TOTHST+TOTHSM)+C214*(SLFERT+C212*SLFERM)+C215*(SLSFGT+
     2          C212*SLSFGM)+C216*(SLSMGT+C212*SLSMGM)
      SUPBM = SUPCTA/TSL
      TOPOPK = TOPOK0*EXP(C217*T)
      SUPS = SUPCTA+TOPOPK*TABLIE(VAL9,SMALL9,DIFF9,K9,AMOD(T,7.))
      TOPOP = TOPOPP+TOPOPK
      EPS = SUPR/TOPOP
      ERPT = FERT*RRLT2/TOPOPT-ORT
      ERT = (SLSFT+SLSMT)/TOPOPT
      EPPM = FEPM*RRLM2/TOPOPM-ORM
      EFM = (SLSFM+SLSMM)/TOPOPM
      ORR = (TOTHST+TOTHSM)/TOPOPP
      EPPR = (FERT*RRLT2+FERM*RRLM2)/TOPOPR-ORR
      ERR = (SLST+SLSM)/TOPOPR
      BPR = (BAT+BAM)/(PERT+FEPM)
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C                                                                       DEMOG    552
C                    CATTLE SECTOR PRINTING                             DEMOG    553
C                                                                       DEMOG    554
      IF(IPRINT.LT.1)RETURN                                             DEMOG    555
      ENTRY CATPRT                                                      DEMOG    556
      PRINT909,T,PFGT,FINFT,FMAST,FERT,PFPT,OLOFT,PFCT,PMGT,PMPT,TOPOPT DEMOG    557
      PRINT906,SLSFGT,SLINFT,SLMAST,SLFERT,SLSFPT,SOLOFT,FEMSCT,SLSMGT, DEMOG    558
     1         SLSMPT,SLST                                              DEMOG    559
      PRINT910,SLSCCT,SLSMFT,SLSMLT,SLSFT,SLS4T,SLSPT,SUPCTA,SUP8,SUP8M DEMOG    560
      PRINT912,BP1,BP2,BP3,BP4,BP5,BP6,BP7,PPFGT,PPFCT                  DEMOG    561
      PRINT914,PREST1,PREST2,PPEST3,PREST4,PREST5,PREST6,PREST7,PPMGT,  DEMOG    562
     1         PPMPT                                                    DEMOG    563
      PRINT916,AP1,AP2,AP3,AP4,AP5,AP6,AP7,TOPOPR,TOPOP                 DEMOG    564
      PRINT919,PSFOT,PSINFT,PSMAST,PSMGT,PSFGT,PSFERT,PSMPT,PSFPT       DEMOG    565
      PRINT922,ATAPTT,CTAPT,PCFTPT,PCTAPT,ATAFT,ATAFFT,ATAFTT,PATAFT,   DEMOG    566
     1         EXPOS                                                    DEMOG    567
      PRINT926,CRT,EPPT,ERS,PFINFT,PFMAST,PIFMUT,TONAT,PAIT             DEMOG    568
      PRINT933,RFT,RMT,RRT,RPLT2,BPT2,CBANGT,QMT,QMCT                   DEMOG    569
      PRINT936,DPAT,DRT1,DPLT1,DRT2,DRLT2,DRGT,DRPT,DRT                 DEMOG    570
      IF(T.LT.TM00)RETURN                                               DEMOG    583
      PRINT956,PFGM,FINFM,FMASM,FERM,PFPM,OLOFM,PFCM,PMGM,PMPM,TOPOPM   DEMOG    584
      PRINT959,SLSFGM,SLINFM,SLMASM,SLFERM,SLSFPM,SOLOFM,FEMSCM,SLSMGM, DEMOG    585
     1         SLSMPM,SLSM                                              DEMOG    586
      PRINT962,TONAM,PAIM,SLSCCM,SLSMFM,SLSMLM,SLSFM,SLSMM,SLSPM        DEMOG    587
      PRINT967,RFGTT,PFPTT,RMGTT,RMPTT,RTOM,RAA                         DEMOG    588
      PRINT965,PPFGTT,PPFPTT,PPMGTT,PPMPTT,PPFGTM,PPFPTM,PPMGTM,PPMPTM  DEMOG    589
      PRINT966,BM1,BM2,BM3,BM4,BM5,BM6,BM7,PPFGM,PPFCM                  DEMOG    590
      PRINT971,PRESM1,PRESM2,PRESM3,PRESM4,PRESM5,PRESM6,PRESM7,PPMGM,  DEMOG    591
     1         PPMPM                                                    DEMOG    592
      PRINT974,AM1,AM2,AM3,AM4,AM5,AM6,AM7                              DEMOG    593
      PRINT976,PSFOM,PSINFM,PSMASM,PSMGM,PSFGM,PSFERM,PSMPM,PSFPM       DEMOG    594
      PRINT980,ATABMT,CTABM,PCFTBM,PCTABM,PFINFM,PFMASM,PIFMUM          DEMOG    595
      PRINT984,RFM,BMM,BRM,BRLM2,BPM2,CBANGM,QMM,QMCM                   DEMOG    596
      PRINT992,DRGM,DRM1,DPLM1,DRPM,DRM2,DRLM2,DRM,ERM,ERPM             DEMOG    597
      PRINT995,APP,DRP,SRR,ERPM,ATAM,ATAF,TSLS,FEMSC,TOPOPR             DEMOG    598
      RETURN                                                            DEMOG    603
900   FORMAT(35H1OUTPUT OF SUBROUTINE DEMOG AT TIME,F8.2/1H0,9X,        DEMOG    604
     1       6HPFGT,8X,6HFINFT,7X,6HFMAST,7X,6HFERT,8X,6HPFPT,8X,       DEMOG    605
     2       5HOLOFT,7X,6HPFCT,8X,6HPMGT,8X,6HPMPT,8X,6HTOPOPT/1H0,9X,  DEMOG    606
     3       10(E11.4,1X))                                              DEMOG    607
904   FORMAT(1HC,9X,6HSLSFGT,6X,6HSLINFT,6X,6HSLMAST,6X,6HSLFERT,6X,     DEMOG    608
     1       6HSLSFPT,6X,6HSOLOFT,6X,6HFEMSCT,6X,6HSLSMGT,6X,6HSLSMPT,  DEMOG    609
     2       6X,6HSLST/14C,9X,10(E11.4,1X))                             DEMOG    610
908   FORMAT(1H0,9X,          6HSLSCCT,6X,6HSLSMFT,6X,6HSLSMLT,6X,      DEMOG    611
     1       5HSLSFT,7X,5HSLSMT,7X,          5HSLSPT,7X,6HSUPCTA,6X,   DEMOG    612
     2       6HSUP8,8X,5HSUPBM/1H0,9X,9E12.4)                           DEMOG    613
912   FORMAT(1HC,9X,3HBP1,9X,3HBP2,9X,3HBP3,9X,3HBP4,9X,3HBP5,9X,3HBP6,  DEMOG    614
     1       9X,3HBP7,21X,5HPPFGT,7X,5HPPFCT/1H0,8X,7E12.4,12X,2E12.4)  DEMOG    615
914   FORMAT(1H0,9X,6HPREST1,6X,6HPREST2,6X,6HPREST3,6X,6HPREST4,6X,     DEMOG    616
     1       6HPREST5,6X,6HPREST6,6X,6HPREST7,18X,5HPPMGT,7X,5HPPMPT/   DEMOG    617
     2       1HC,8X,7E12.4,12X,2E12.4)                                  DEMOG    618
915   FORMAT(1H0,9X,3HAP1,9X,3HAP2,9X,3HAP3,9X,3HAP4,9X,3HAP5,9X,3HAP6,  DEMOG    619
     1       9X,3HAP7,21X,6HTOPOPR,5X,5HTOPOP/1HC,8X,7E12.4,12X,2E12.4) DEMOG    620
918   FORMAT(1HC,9X,5HPSFOT,7X,6HPSINFT,6X,6HPSMAST,6X,5HPSMGT,7X,       DEMOG    621
     1       5HPSFGT,7X,5HPSFERT,6X,5HPSMPT,7X,5HPSFPT/1H0,9X,8(E11.4,   DEMOG    622
     2       1X))                                                       DEMOG    623
922   FORMAT(1H0,9X,6HATABTT,6X,5HCTABT,7X,6HPCFTBT,6X,6HPCTABT,6X,      DEMOG    624
     1       5HATAFT,7X,5HATAFFT,6X,6HATAFTT,6X,6HPATAFT,6X,5HEXPOS/    DEMOG    625
     2       1HC,8X,9E12.4)                                             DEMOG    626
926   FORMAT(1H0,9X,3HEPT,9X,4HERPT,8X,3HERS,9X,6HPFINFT,6X,6HPFMAST,    DEMOG    627
     1       6X,6HPIFMUT,6X,5HTONAT,7X,6HPANT/1HC,8X,8E12.4)            DEMOG    628
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933 FORMAT(1H0,9X,3HAFT,9X,3HBNT,9X,3HART,9X,5HAPLT2,7X,4HBRT2,9X,
   1        5HCRANGT,6X,3HQMT,9X,4HQMCT/1H0,9X,9(E11.4,1X))
936 FORMAT(1H0,9X,4HORAT,9X,4HORT1,8X,5HORLT1,7X,4HORT2,9X,5HORLT2,
   1        7X,4HORGT,9X,4HORPT,8X,4HORT /1H0,9X,8(E11.4,1X))
946 FORMAT(1H0,9X,4HPFGM,9X,5HFINFM,7X,5HFMASM,7X,4HFERM,9X,4HPFPM,8X,
   1        5HOLOFM,7X,4HPFCM,8X,4HPMGM,8X,4HPMPM,8X,6HTOPOPM/
   2        1H0,9X,10(E11.4,1X))
948 FORMAT(1H0,9X,6HSLSFGM,6X,6HSLINFM,6X,6HSLMASM,6X,6HSLFERM,6X,
   1        6HSLSFPM,6X,6HSOLOFM,6X,6HFEMSCM,6X,6HSLSMGM,6X,6HSLSMPM,
   2        6X,4HSLSM/1H0,9X,10E12.4)
952 FORMAT(1H0,9X,3HTONAP,7X,4HPANM,8X,6HSLSCCM,6X,6HSLSMFM,6X,
   1        6HSLSMLM,6X,5HSLSFM,7X,5HSLSMM,7X,6HSLSFM/1H0,8X,9E12.4)
961 FORMAT(1H0,9X,5HRFGTT,7X,5HRFPTT,7X,5HRMGTT,7X,5HRMPTT,7X,4HRTON,
   1        9X,3HRAB/1H0,9X,6(E11.4,1X))
963 FORMAT(1H0,9X,6HPPFGTT,6X,6HPPFPTT,6X,6HPPMGTT,6X,6HPPMPTT,6X,
   1        6HPPFGTM,6X,6HPPFPTM,6X,6HPPMGTM,6X,6HPPMPTM/1H0,9X,
   2        9(E11.4,1X))
965 FORMAT(1H0,9X,3HBM1,9X,3HBM2,9X,3HBM3,9X,3HBM4,9X,3HBM5,9X,3HBM6,
   1        9X,3HBM7,21X,5HPPFGM,7X,5HPPFCM/1H0,8X,7E12.4,12X,2E12.4)
970 FORMAT(1H0,9X,6HPRESM1,6X,6HPRESM2,6X,6HPRESM3,6X,6HPRESM4,6X,
   1        6HPRESM5,6X,6HPRESM6,6X,6HPRESM7,18X,5HPPMGM,7X,5HPPMPM/
   2        1H0,9X,7E12.4,12X,2E12.4)
974 FORMAT(1H0,9X,3HAM1,9X,3HAM2,9X,3HAM3,9X,3HAM4,9X,3HAM5,9X,3HAM6,
   1        9X,3HAM7/1H0,9X,7(E11.4,1X))
976 FORMAT(1H0,9X,5HPSFGM,7X,6HPSINFM,6X,6HPSMASM,6X,5HPSMGM,7X,
   1        5HPSFGM,7X,5HPSFERM,6X,5HPSMPM,7X,5HPSFFM/1H0,9X,
   2        9(E11.4,1X))
980 FORMAT(1H0,9X,6HATABMT,6X,5HCTABM,7X,6HPGFTBM,6X,6HPCTABM,6X,
   1        6HPFINFM,6X,6HPFMASM,6X,6HPIFNUM/1H0,8X,7E12.4)
990 FORMAT(1H0,9X,3HBFM,9X,3HBMM,9X,3HBRM,9X,5HBRLM2,7X,4HBRM2,8X,
   1        5HRANGM,6X,3HQMM,9X,4HQMCM/1H0,9X,8(E11.4,1X))
992 FORMAT(1H0,9X,4HORGM,9X,4HORM1,9X,5HORLM1,7X,4HORPM,8X,4HORM2,8X,
   1        5HORLM2,7X,3HORM,9X,3HERM,9X,4HERPM/1H0,8X,9E12.4)
995 FORMAT(1H0,9X,3HORP,9X,3HORR,9X,3HERR,9X,4HERPF,8X,4HATAB,9X,
   1        6HATAF,9X,4HTSLS,8X,5HFEMSC,7X,6HTOPOPR/1H0,9X,9E12.4)
    ENTRY CATSET
    PMGT = 1174000.
    PMPT = 943000.
    PFGT = 1193000.
    PFPT = 2424000.
    OLOFT = 427000.
    TOPOPT = PFGT+PFPT+OLOFT+PMGT+PMPT
    PSFGT = .13
    PSFPT = .012
    PSMGT = .1
    PSMPT = .135
    PSFGM = PSFPM = PSMGM = PSMPM = 0.
    SLSFGT = PSFGT*PFGT
    SLMAST = .005*PFPT
    SLINFT = .004*PFPT
    SLFERT = .002*PFPT
    SLSFPT = SLFERT+SLMAST+SLINFT
    SOLOFT = .3*OLOFT
    SLSFT = SLSFGT+SLSFPT+SOLOFT
    SLSMGT = PSMGT*PMGT
    SLSMPT = PSMPT*PMPT
    SLSMT = PMOUT2+SLSMGT+SLSMPT
    SLSPT =  (SLINFT+SLMAST+SOLOFT)*C224+SLSMPT*C225+SLFERT*C226+
   1        SLSFGT*C227+SLSMGT*C228
    ORGT = .041
    ORT1 = .241
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      DPLT1 = .05
      DPPT = .025
      DRT2 = .025
      DRLT2 = .03
      DFPT = DRLT2*PFPT
      RRT = .7
      RRT2 = .625
      RFT = PFPT*.6*.5
      BMT = RFT
      CRT = .025
      PGFTBT = .05
      PCTABT = .1
      EXPAFT = 0.
      EXPOS = 0.
      PATAFT = .3
      PATADT = C244
      PFMAST = .00126
      PFINFT = .13
      PIFNUT = 0.
      DO 10 I=1,KGROF
      RINTFT1(I) = PFGT/(DGROF*IOTF1)
      RINTFM1(I) = 0.
   10 CONTINUE
      RFOUT1 = PFGT/DGROF
      DO 12 I=1,KPRODF
      RINTFT2(I) = PFPT/(DPRODF*IOTF2)
      RINTFM2(I) = 0.
   12 CONTINUE
      RFOUT2 = PFPT/DPRODF
      DO 14 I=1,KGROM
      RINTMT1(I) = PMGT/(DGROM*IOTM1)
      RINTMM1(I) = 0.
   14 CONTINUE
      RMOUT1 = PMGT/DGROM
      DO 16 I=1,KPRODM
      RINTMT2(I) = PMPT/(DPRODM*IOTM2)
      RINTMM2(I) = 0.
   16 CONTINUE
      RMOUT2 = PMPT/DPRODM
      PFGM = PFPM = OLDFM = PMGM = PMPM = 0.
      SLSFGM = SLSFPM = SLSMGM = SLSMPM = SOLDFM = 0.
      SLSFM = SLSMM = SLMASM = SLINFM = SLFERM = 0.
      SLSCCM = 0.
      SLSMLM = 0.
      DRGM = .032
      DRPM = .012
      DRM1 = DRLM1 *DRGM
      DRM2 = DRLM2 * DRPM
      DFPM = 0.
      TOTMSM = 0.
      BRM = .8
      BRM2 = BRM
      BFM = BMM = 0.
      CBM = 0.
      PGFTBM = PCTABM = PIFNUM = PFMASM = PFINFM = 0.
      PATAFM = 1.
      RMOUM1 = RMOUM2 = RFOUM1 = RFOUM2 = 0.
      RFGTT = RFGTM = RFPTT = RFPTM = RMGTT = RMGTM = RMPTT = RMPTM = 0.
      PPFGTT = PPFPTT = PPMGTT = PPMPTT = 0.
      PPFGTM = PPFPTM = PPMGTM = PPMPTM = 0.
      RETURN
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      SUBROUTINE MODCRD
      COMMON /ACCOUN/ DRLAT,AMLAT,ACLAT,VLANDT,VLDTXT,TAXCT,ABSUT,
     1                DRLAM,AMLAM,ACLAM,VLANDM,VLDTXM,TAXCM,ABSUM,
     2                DRLAV,DCRU,FARMIC,DBTOUS,DCRDT,RCSTDT,EXPLIV,NCFR,
     3                ALPH1,TEC,TCEC,TRNSL3,TLF,TLFP,CPLF,RINT,RINTL,
     4                CREDT,DIR,C250,C253,C254,LT1,LT2,LT3,CBSTG,CSTGM,
     5                EPCRPJ,MCROPJ,PCROPL,PFCROP,
     6                EYLDCJ,YLDCU,YLDCL,YLDFC,DYLDCU,DYLDCL,DYLDFC
      REAL NCFR
      COMMON /CONTRL/ T,DT,DUM,IRUN,BEGPRT,PRTCHG,PRTVL1,PRTVL2,IPRINT,
     1                MAL,TMOU,TDO
      COMMON /LAND/   TGL,TTGL,TTGLL,TTGLU1,TTGLU2,TGLSF0,
     1                TRSL,TLMOD,TLMOD1,TLMOD2,TLMOD3,TTGLR,TGLR,
     2                TLCML,TLCBU,TLCRUP,TGLSF,TGLUIP,TLFC,TLC,
     3                XR1,R1,R2,PR2,PDR,CRM,RLM,RLMI,RLCRU,AUX1,AUX3,
     4                ARM1,ARM2,ARM3,A5,C9,GRT,CPLPT,XDEL,RPTN,GRE
      DIMENSION TRAIN1(4),TRAIN2(2),TRAIN3(10)
      DATA LT1,LT2,LT3,NOCY1,NOCY2,NOCY3 / 3, 1, 8, 4, 4, 4 /
      DATA C234,C235,C236,C257,E12,E13 / .8, .5, 1., .0005, 1.2, 1./
      DATA TC0,TC1,TC2,TCF,CRDMAX / 6., 10., 15., 16., 10000000. /
      DATA RPTN,EXTA / .2, 250. /
      TRNSL1 = TRNSL1+DT*(AUX5-BOUT1-TRAIN1(3)*(1.-A5))
      TRNSL2 = TRNSL2+DT*(BOUT1-BOUT2)
      TRNSL3 = TRNSL3+DT*(BOUT2-BOUT3)
      TRAIN1(3) = TRAIN1(3)*A5
      CALL BOXC(AUX5,BOUT1,TRAIN1,NCOUN1,NOCY1,LT1,SUMIN1)
      IF(LT2.LT.1)GO TO 50
      CALL BOXC(BOUT1,BOUT2,TRAIN2,NCOUN2,NOCY2,LT2,SUMIN2)
      GO TO 100
   50 BOUT2 = BOUT1
  100 CALL BOXC(BOUT2,BOUT3,TRAIN3,NCOUN3,NOCY3,LT3,SUMIN3)
      AUX5 = (CRM*ARM3*AMIN1(1., RLMI/(AMIN1(ARM1, ARM2)*ARM3)))*TCEC*
     1        (1.-RPTN)
      ALPH1 = C234+AMIN1(1.-C234, (1.-C234)*EXP(-C236*(PDR-C235)))
      CSINPH = CSINPH*RCSTDT
      CSIAPH = CSIAPH*RCSTDT
      CSPAPH = CSPAPH*RCSTDT
      CSPFGH = CSPFGH*RCSTDT
      CBSTG = CBSTG*RCSTDT
      CSIMAP = (1.-CPLF)*CPLPT*CSIAPH
      CSPLFG = CPLF*CSPFGH
      CSTGM = CPLF*CBSTG*2.*C253*C254/C250
      IF(MAL.EQ.1.OR.MAL.EQ.3)GO TO 108
      CSPLAP = (1.-CPLF)*(1.-CPLPT)*CSPAPH
      GO TO 110
  108 CSIMNP = (1.-CPLF)*(1.-CPLPT)*CSINPH
  110 TEC = CSIMNP+CSIMAP+CSPLAP+CSPLFG+CSTGM
      TCEC = ALPH1*TEC
      CRTREQ = TCEC*(1.-RPTN)/LT1
      ACRDTA = ACRDTA+DT*ACRDT
      CALL GRAPH(TC0,TC1,TC2,TCF,CRDMAX,T, ACRDT)
      DCRDT = TRNSL1/LT1
      CREDT = AMAX1(ACRDT-DCRDT, 0.)
      ARM1 = CREDT/CRTREQ
      ARM2 = NCFR*T1/(TCEC*RPTN)
      ARM3 = (NCFR-AMIN1(ARM1, ARM2)*TCEC*RPTN/LT1)*LT1/TCEC
      AUX7 = AUX7+(AUX6-AUX7)*DT/XDEL
      AUX9 = 1.-AUX7
      EXTR = C257*TPSL
      IF(EXTR.LE.0..OR.DCRDT.LE.0.)GO TO 120
      A5 = AMIN1(E12*EXTA/EXTR, 1.)*(AUX7+AUX9*AMIN1(E13*ACRDT/DCRDT,
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     1     1.))                                                          MODCRD     91
      GO TO 129                                                          MODCRD     92
  120 A5 = 1.                                                            MODCRD     93
  125 IF(AMIN1(ARM1,ARM2)*ARM3.LE.0.)GO TO 130                           MODCRD     94
      AUX6 = ARM3/(AMIN1(ARM1, ARM2)+ARM3)                               MODCRD     95
      GO TO 135                                                          MODCRD     96
  130 AUX6 = 0.                                                          MODCRD     97
  135 AUX8 = 1.-AUX6                                                     MODCRD     98
      IF(IPRINT.LT.1)RETURN                                              MODCRD     99
      PRINT900,T                                                         MODCRD    100
      PRINT905,TRNSL1,TRNSL2,TRNSL3,ARM1,ARM2,ARM3,BOUT1,BOUT2,BOUT3     MODCRD    101
      PRINT910,ALPM1,TEC,TCEC,CRTREQ,ACRDT,ACRDTA,DCRDT,CREDT            MODCRD    102
      PRINT915,EXTR,A5,AUX5,AUX6,AUX7,AUX8,AUX9                          MODCRD    103
      PRINT920,CSINPM,CSIAPM,CSPAPM,CSPFOM,CBSTG,CSIMAP,CSIMAP,CSPLAP,   MODCRD    104
     1         CSPLFG,CSTGM                                             MODCRD    105
      RETURN                                                             MODCRD    106
  900 FORMAT(36H2OUTPUT OF SUBROUTINE MODCRD AT TIME,F8.2)               MODCRD    107
  905 FORMAT(1H0,9X,6HTRNSL1,6X,6HTRNSL2,6X,6HTRNSL3,6X,4HARM1,8X,       MODCRD    108
     1       4HARM2,8X,4HARM3,8X,5HBOUT1,7X,5HBOUT2,7X,5HBOUT3/1H0,8X,   MODCRD    109
     2       9E12.4)                                                     MODCRD    110
  910 FORMAT(1H0,9X,5HALPM1,7X,3HTEC,9X,4HTCEC,8X,6HCRTREQ,6X,5HACRDT,   MODCRD    111
     1       7X,6HACRDTA,6X,5HDCRDT,7X,5HCREDT/1H0,8X,8E12.4)            MODCRD    112
  915 FORMAT(1H0,9X,4HEXTR,8X,2HA5,10X,4HAUX5,8X,4HAUX6,8X,4HAUX7,8X,    MODCRD    113
     1       4HAUX8,8X,4HAUX9/1H0,9X,7(E11.4,1X))                        MODCRD    114
  920 FORMAT(1H0,9X,6HCSINPM,6X,6HCSIAPM,6X,6HCSPAPM,6X,6HCSPFOM,6X,     MODCRD    115
     1       5HCBSTG,7X,6HCSIMAP,6X,6HCSIMAP,6X,6HCSPLAP,6X,6HCSPLFG,6X, MODCRD    116
     2       5HCSTGM/1H0,8X,10E12.4)                                     MODCRD    117
C          INITIAL VALUES FOR CREDIT                                     MODCRD    118
C                                                                        MODCRD    119
C                                                                        MODCRD    120
      ENTRY CRDSET                                                       MODCRD    121
      TRNSL1 = 0.                                                        MODCRD    122
      TRNSL2 = 0.                                                        MODCRD    123
      TRNSL3 = 0.                                                        MODCRD    124
      AUX5 = 0.                                                          MODCRD    125
      BOUT1 = 0.                                                         MODCRD    126
      BOUT2 = 0.                                                         MODCRD    127
      BOUT3 = 0.                                                         MODCRD    128
      R1 = 0.                                                            MODCRD    129
      A5= 1.                                                             MODCRD    130
      DO 400 I=1,6                                                       MODCRD    131
      TRAIN1(I) = 0.                                                     MODCRD    132
  400 CONTINUE                                                           MODCRD    133
      DO 410 I=1,IC                                                      MODCRD    134
      TRAIN3(I) = 0.                                                     MODCRD    135
  410 CONTINUE                                                           MODCRD    136
      TRAIN2(1) = 0.                                                     MODCRD    137
      TRAIN2(2) = 0.                                                     MODCRD    138
      NCOUN1 = 0                                                         MODCRD    139
      NCOUN2 = 0                                                         MODCRD    140
      NCOUN3 = 0                                                         MODCRD    141
      SUMIN1 = 0.                                                        MODCRD    142
      SUMIN2 = 0.                                                        MODCRD    143
      SUMIN3 = 0.                                                        MODCRD    144
      CRM = 0.                                                           MODCRD    145
      ARM1 = 0.                                                          MODCRD    146
      ARM2 = 0.                                                          MODCRD    147
      ARM3 = 0.                                                          MODCRD    148
      RLM1 = 0.                                                          MODCRD    149
      NCFR = 0.                                                          MODCRD    150
      AUX6 = 0.                                                          MODCRD    151
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      AUX7 = 0.                                                         MODCRD   112
      ACRDT = 0.                                                        MODCRD   113
      ACRDTA = 0.                                                       MODCRD   114
      VDR = 0.                                                          MODCRD   115
      CSINPH = 576.                                                     MODCRD   116
      CSIAPH = 574.                                                     MODCRD   117
      CSPAPH = 660.                                                     MODCRD   118
      CSPFGH = 590.                                                     MODCRD   119
      CBSTG = 0.5                                                       MODCRD   120
      CPLF = 0.                                                         MODCRD   121
      CSTGH = CPLF*CBSTG*2.*C253*C254/C255                              MODCRD   122
      CSPLFG = CPLF*CSPFGH                                              MODCRD   123
      CSIMAP = (1.-CPLF)*CPLPT*CSIAPH                                   MODCRD   124
      IF(MAL.EQ.1.OR.MAL.EQ.3)GO TO 500                                 MODCRD   125
      CSPLAP = (1.-CPLF)*(1.-CPLPT)*CSPAPH                              MODCRD   126
      CSIMNP = 0.                                                       MODCRD   127
      GO TO 510                                                         MODCRD   128
  500 CSIMNP = (1.-CPLF)*(1.-CPLPT)*CSINPH                              MODCRD   129
      CSPLAP = 0.                                                       MODCRD   130
  510 TEC = CSIMNP+CSIMAP+CSPLAP+CSPLFG+CSTGH                           MODCRD   131
      TCEC = TEC                                                        MODCRD   132
      RETURN                                                            MODCRD   133
      END                                                               MODCRD   134
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      SUBROUTINE AGACC                                                  AGACC     2
      COMMON /ACCOUN/ DPLAT,AMLAT,ACLAT,VLANDT,VLDTXT,TAXCT,AGSUT,     ACCOUN    2
     1                DPLAM,AMLAM,ACLAM,VLANDM,VLDTXM,TAXCM,AGSUM,     ACCOUN    3
     2                DPLAV,DCRU,FARMIC,DITOUS,PCRDT,RCSTAT,EXPLIV,NCFR, ACCOUN   4
     3                ALPM1,TPC,TCEC,TRISC3,TLF,TLFP,CPLF,RINT,RINTL,  ACCOUN    5
     4                C0EFT,D14,C25,.C253,C254,LT1,LT2,LT3,C8STG,CSTGM, ACCOUN   6
     5                EPCMMJ,PCHOPU,PCHOPL,PFCROP,                     ACCOUN    7
     6                EVLPCU,TLOCU,VLDCL,VLPFC,DYLDCU,DYLDCL,DYLDFC    ACCOUN    8
      REAL NLFM                                                         ACCOUN    9
      COMMON /CATTLE/ PFGT,PLMT,PFPT,PMLT,PWPT,TOPOPT,TOPOPM,          CATTLE    2
     1                PFGM,     PFPM,PMLM,PWPM,TOPOPM,VACAPL,AUXL12,   CATTLE    3
     2                SLFERT,SLSCCT,SDLOFT,SLSMLT,SLSPT,SLSPTP,FEMSCT, CATTLE    4
     3                SLFERM,SLSCCM,SDLOFM,SLSMLM,SLSPM,SUPR,FEMSCM,   CATTLE    5
     4                PPFGTT,PPFPTT,PPMGTT,PPMPTT,PPFGTM,              CATTLE    6
     5                PPFPTM,PPMGTM,PPMPTM,RFGTT,RFPTT,                CATTLE    7
     6                RMGTT,RMPTT,RFGTM,RFPTM,RMGTM,RMPTM,             CATTLE    8
     7                TPMT,TDMAT,TDMM,TDMMP,TDMAM,PATADT,DMM,DMT,PFLACT, CATTLE  9
     8                YMAT,PA,PAP,PAPP,PRAT,EXPL,UNEXPL,CT202,C214,C244 CATTLE   10
      COMMON /CUNTMI/ T,DT,DUM,IRUN,BEGPRT,PRTCHG,PRTVL1,PRTVL2,IPRINT, C=5     1
     1                MAL,TMDU,TDD                                     C=5      2
      COMMON /LAND/   TGL,TTGL,TTGLL,TTGLU1,TTGLU2,TGLSFC,             LAND     2
     1                TPSL,TLMOD,TLMOD1,TLMOD2,TLMOD3,TTGLM,TGLR,      LAND     3
     2                TLCPL,TLCRU,TLCRUP,TGLSF,TGLUIP,TLFC,TLF,        LAND     4
     3                X31,R1,R2,PR2,PDR,CRM,RLM,RLMT,RLCRU,AUX1,AUX3,  LAND     5
     4                ARM1,ARM2,ARM3,A5,C9,CRT,CPLPT,XDEL,RPTM,CRE     LAND     6
      DIMENSION BINCRA(12,4),CAINCA(12,4),CLINCA(12,4),EGADEA(12,4),   AGACC     7
     1          ETXCA(12,4),EVLDTA(12,4),SINCRA(12,4),TMINCA(12,4)     AGACC     8
      DIMENSION BINCR(12),CAINCR(12),CAPBIP(12),CLINCR(12),EGASER(12), AGACC     9
     1          ELOAN(12),ETCEC(12),SINCR(12),TMINCR(12),TXCP(12),     AGACC    10
     2          VLTXTP(12),EQLM(4),VAL36(4)                            AGACC    11
      DATA C222,C223,C248,C259 / .47,4.,.5,.4 /                         AGACC    12
      DATA C251,C252,C253,C254,C261,C262,C263/1.2,.9,40.,3.,.25,.75,.3/ AGACC    13
      DATA C264,C267,C268,C26V,C270,C271/.00030001, 5*1. /              AGACC    14
      DATA C274,C275,C276 /3*.15 /                                      AGACC    15
      DATA C277,C278,C279 / 1., 1., 3.1 /                               AGACC    16
      DATA DEL5,DEL6,DEL12,DEL13,DEL14 / 5*5. /                         AGACC    17
      DATA DEL19,DEL20,DEL21,DEL22 / 4*5. /                             AGACC    18
      DATA DIFF36,SMALL36,R36 / 1., 7., 3 /                             AGACC    19
      DATA EQLM / 110., 170., 150., 170. /                              AGACC    20
      DATA VAL36 / 4.7, 4.55, 4.6, 4.6 /                                AGACC    21
      DATA SVAC,SVAT,SVALM,AGSUBM,STGLM / 3*1., 2*0. /                  AGACC    22
      DATA RINT,RINTL,IPM,DIR,RCST / .14, .14, 12, .15, .12 /           AGACC    23
      DATA SMTAX,SMTAX,EQLT,TAXLND / 10., 50., 35., .0042 /             AGACC    24
      DATA VLDCU1,VLDCL1,VLDFC1 / 1.11, 1.56, 8.3 /                     AGACC    25
      DATA DYLDCU,DYLDCL,DYLDFC/ 1.65, 2.9, 10. /                       AGACC    26
      DATA PRM,EXLMIN / 1., 200000000. /                                AGACC    27
      DATA SINCRA / 1., 1., 1.15, 1.45,1.65, 2*1.9, 5*2.,               AGACC    28
     1              2*1., 1.15, 1.7, 2., 2.25, 2.45, 5*2.6,           AGACC    29
     2              2*1., 1.5, 2.7, 3.2, 3.9, 6*4.,                   AGACC    30
     3              2*1., 1.5, 2.7, 3.2, 3.9, 6*4. /                  AGACC    31
      DATA TMINCA / 1.1, 1.2, 2*1.25, 3*1.35, 5*1.4,                    AGACC    32
     1              1.2, 1.22, 1.29, 1.36, 1.43, 1.46, 1.53, 5*1.57,  AGACC    33
     2              1.3, 1.37, 1.57, 1.9, 2., 2.2, 6*2.28,            AGACC    34
     3              1.37, 1.39, 1.6, 1.82, 2.2, 7*2.4 /               AGACC    35
      DATA ETXCA /  1.1, 1.16, 1.19, 1.21, 1.26, 1.27, 1.28, 5*1.3,    AGACC    36
     1              1.1, 1.25, 1.3, 1.33, 1.35, 1.36, 1.37, 5*1.4,    AGACC    37
     2              1.1, 1.35, 1.6, 2., 2.4, 2.55, 6*2.6,             AGACC    38
     3              1.1, 1.35, 1.6, 2., 2.4, 2.55, 6*2.6 /            AGACC    39
      DATA EVLDTA / 3*1., 3*1.2, 6*1.3,                                 AGACC    40
     1              3*1., 3*1.25, 6*1.35,                              AGACC    41
     2              3*1., 3*1.3, 6*1.4,                                AGACC    42
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     3               3*1., 3*1.32, 6*1.42 /                                  AGACC      43
      DATA ECADEA / 1., 1.5, 2., 9*2.5,                                      AGACC      44
     1              1., 1.6, 2.5, 2.8, 9*3.,                                 AGACC      45
     2              1.1, 2., 2.8, 3., 8*3.4,                                 AGACC      46
     3              1.1, 1.9, 2.7, 2.9, 8*3.3 /                              AGACC      47
      DATA CAINCA / 1.17, 1.27, 1.42, 1.42, 3*1.57, 5*1.67,                  AGACC      48
     1              1.17, 1.32, 2*1.47, 3*1.62, 5*1.77,                      AGACC      49
     2              1.2, 1.67, 1.97, 2.47, 2.87, 3.07, 6*3.27,               AGACC      50
     3              1.2, 1.67, 1.97, 2.47, 2.87, 3.07, 6*3.27/               AGACC      51
      DATA CLINCA / 2*1., 2*1.25, 3*1.4, 5*1.5,                              AGACC      52
     1              2*1., 2*1.25, 3*1.4, 5*1.5,                              AGACC      53
     2              1., 1.3, 1.6, 1.6, 2., 7*2.5,                            AGACC      54
     3              1., 1.2, 1.4, 1.6, 1.8, 7*2.2 /                          AGACC      55
      DATA BINCRA / 0., .05, .15, 0., .15, 2*0., .1, 4*0.,                   AGACC      56
     1              0., .08, .22, 2*.15, .1, 2*.05, 4*0.,                    AGACC      57
     2              0., .35, .45, .5, .4, 2*.2, 5*0.,                        AGACC      58
     3              0., .35, .45, .5, .4, 2*.2, 5*0. /                       AGACC      59
      TAXCTL = TAXCTL+(TAXCHT-TAXCTL)*DT/DEL12                               AGACC      60
      VLTXTL = VLTXTL+(VLTXHT-VLTXTL)*DT/DEL13                               AGACC      61
      IF(T.LT.7.)GO TO 15                                                    AGACC      62
      PKOW = TABEXE(VALT6,S*ALL36,DIFF36,K36,T)                              AGACC      63
      TAXCT1 = (PHGT*C222+P*PI)*C223*PKJR                                    AGACC      64
      TAXCT2 = FEMSCT*C277+SFTAX+SLSHLT*C278*SMTAX                           AGACC      65
   15 CONTINUE                                                               AGACC      66
      TAXCT3 = C279*TOPOPT                                                   AGACC      67
      TAXCT = TAXCT1+TAXCT2+TAXCT3                                           AGACC      68
      TAXCHT = TAXCT/TTGLR                                                   AGACC      69
      CTLBLT = CTLBLT+RCSTDT                                                 AGACC      70
      VETRAC = VETRAC+RCSTDT                                                 AGACC      71
      VETRAD = VETRAC+(1.+(PATADT+C244)/(1.+C244))                           AGACC      72
      CSTANTL = CSTANTL+(CSTANT-CSTANTL)*DT/DEL20                            AGACC      73
      CSTANT = CTLBLT+VETRAD                                                 AGACC      74
      CLNDTL = CLNDTL+(CLNDT-CLNDTL)*DT/DEL21                                AGACC      75
      CLNDT = CLNDT+RCSTDT                                                   AGACC      76
      OPCLAT = TOPOPT+CSTANT                                                 AGACC      77
      OPCLNT = TTGLR+CLNDT+C267                                              AGACC      78
      YAT = SLSPT+PAP                                                        AGACC      79
      YMT = GMT+PRM                                                          AGACC      80
      AGSUT = AGSUBT+TTGLR                                                   AGACC      81
      CAPDET = EQLT+TTGLR+C268                                               AGACC      82
      ASVLNT = VLANDT+C248                                                   AGACC      83
      VLDTXT = ASVLNT+TAXLNC                                                 AGACC      84
      ASVMT = ASVLNT/(TTGLR+C278)                                            AGACC      85
      VLTXMT = VLDTXT/(TTGLR+C271)                                           AGACC      86
      ACLAT = OPCLAT+OPCLNT+TAXCT+CAPDET+VLDTXT                              AGACC      87
      AMLAT = YAT+YMT+AGSUT                                                  AGACC      88
      FARILT = ARLAT+ACLAT                                                   AGACC      89
      VLANDT = AMAX1(SVALT+TTGLR, FARILT/RINT)                               AGACC      90
      VLNDMT = VLANDT/(TTGLR+C269)                                           AGACC      91
      EPAP = EPAP+(PAPP-EPAP)*DT/DEL5                                        AGACC      92
      ESLSPT = ESLSPT+(SLSPTP-ESLSPT)*DT/DEL6                                AGACC      93
      EGMT = FEXT+PFLACT+CT202+YMAT                                          AGACC      94
      TCLATL = TCLATL+(TCLAT-TCLATL)*DT/DEL19                                AGACC      95
      TCLAT = ACLAT/TTGLR                                                    AGACC      96
      TPLAT = EPAP+(SLSPT+(PRM+EGMT)/TTGLR+AGSUBT                            AGACC      97
      DWLAT = (TPLAT-TCLATL)+TCDIR                                           AGACC      98
      IF(T.LT.TMCH)GO TO 706                                                 AGACC      99
      CAPT = TLF+C293+C294/C295                                              AGACC     100
      IF(STUMG.LT.CAPT)GO TO 100                                             AGACC     101
      RPCAPT = 0.                                                            AGACC     102
      RLINPS = 0.                                                            AGACC     103
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      GO TO 110                                                         AGACC   104
  108 HPCAPT = (CAPT-STORG)*CMSTG*2./C252                               AGACC   105
      STORG = STORG*DT*(CAPT-STORG)/C252                                AGACC   106
      RLINPS = (CAPT-STORG)*SISLB*2./C252                               AGACC   107
  110 CONTINUE                                                          AGACC   108
      ALOANA = ALOANA*DT*ALPAM                                          AGACC   109
      ALREPA = ALREPA*DT*ALPCM                                          AGACC   110
      DRTOUS = ALOANA-ALREPA                                            AGACC   111
      ALINT = DRTOUS*RINTL                                              AGACC   112
      ALOAN = AMI 1(DCAPT, CREDT)                                       CM7       7
      ALREP = TRNSL3/LT3                                                AGACC   114
      TAXCM1 = (PMGM*C222*P*PM)*C223*PMGR                               AGACC   115
      TAXCM2 = FEMSCM*C277*SFTAX*SLSMLM*C278*SMTAX                      AGACC   116
      TAXCM3 = C279*TPRPM                                               AGACC   117
      TAXCM = TAXCM1*TAXCM2*TAXCM3                                      AGACC   118
      CSTANM = CSTAMM*RCSTDT                                            AGACC   119
      CLNDM = CLNDM*RCSTDT                                              AGACC   120
      OPCLAM = TOPGPM*CSTANM                                            AGACC   121
      CSRFGM = CSRFGM*RCSTDT                                            AGACC   122
      CSHARV = CSHARV*RCSTDT                                            AGACC   123
      OPCLAM = TLMOD*CLNDM*(1.-CPLF)*TLFP*CSRFGM*TLF*CSHARV*C293*C294   AGACC   124
      YAM = SLSPM*PAP                                                   AGACC   125
      YMM = GMM*PRM                                                     AGACC   126
      AGSUM = AGSUM*(TLMOD*TMSL)                                        AGACC   127
      CAPDEM = TLMOD*GLMIMAL)                                           AGACC   128
      ASVLNM = VLANDM*C248                                              AGACC   129
      VLDTXM = ASVLNM*TAXLND                                            AGACC   130
      ASVMM = ASVMM/(TLMOD*TMSL)                                        AGACC   131
      VLTXMM = VLTXMM/(TLMOD*TRSL)                                      AGACC   132
      ACLAM1 = OPCLAM*OPCLAM*CAPDEM*VLDTXM                              AGACC   133
      ACLAM = ACLAM1*TAXCM*ALI(T*ALREP*(TCEC*ALPHI*CSTGM)*TRSL/(3.*XDEL)  AGACC   134
     :        *HPCAPT                                                   AGACC   135
      ARLAM1 = YAM*YMM*AGSUM                                            AGACC   136
      ARLAM = AMLAM1*ALPAM                                              AGACC   137
      FARILM = APLAM-ACLAM                                              AGACC   138
      VLANDM = AMAX1(VLNDMT*(TRSL*TLMOD),(ARLAM1-ACLAM1*TAXCM)/RINT)    AGACC   139
      VLNDMM = VLANDM/(TLMOD*TRSL)                                      AGACC   140
      DO 120 I=1,LT1                                                    AGACC   141
      ELOAN(I) = TCEC*(1.-PPTM)/LT1                                     AGACC   142
  120 CONTINUE                                                          AGACC   143
      ICEC = 3.*XDEL                                                    AGACC   144
      DO 125 I=1,ICEC                                                   AGACC   145
      ETCEC(I) = TCEC/ICEC                                              AGACC   146
  125 CONTINUE                                                          AGACC   147
      TCREC = TCEC*(1.-PPTM)                                            AGACC   148
      DO 130 I=1,LT1                                                    AGACC   149
      EDBSER(I) = TCREC*RINTL*I/LT1                                     AGACC   150
  130 CONTINUE                                                          AGACC   151
      IL2 = LT1+LT2                                                     AGACC   152
      IF(LT2.LT.1)GO TO 135                                             AGACC   153
      I2 = LT1+1                                                        AGACC   154
      DO132 I=I2,IL2                                                    AGACC   155
      EDBSER(I) = EDBSER(LT1)                                           AGACC   156
  132 CONTINUE                                                          AGACC   157
  135 I3 = IL2+1                                                        AGACC   158
      IL3 = IL2+LT3                                                     AGACC   159
      UNPBAL = TCREC                                                    AGACC   160
      YPAYMT = TCREC/LT3                                                AGACC   161
      DO 138 I=I3,IL3                                                   AGACC   162
      UNPBAL = UNPBAL-YPAYMT                                            AGACC   163
      EDBSER(I) = YPAYMT+UNPBAL*RINTL                                   AGACC   164
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138 CONTINUE                                                          AGACC   165
    IF(T.EQ.TMOD)PRINT979                                             AGACC   166
    DRLAM = 0.                                                        AGACC   167
    DO 150 I=1,IPH                                                    AGACC   168
    ETXC = TAXCTL*TXCP(I)                                             AGACC   169
    EVLDTX = VLTXTL*VLTXTP(I)                                         AGACC   170
    ECADEM = EQLT*C268*CAPDTP(I)                                      AGACC   171
    EOPCLM = CSTANTL*CAINCR(I)/GRE                                    AGACC   172
    EOCLNM = CLNDTL*CLINCR(I)                                         AGACC   173
    TCLAM = EDHSER(I)+ETCEC(I)+EOPCLM+EOCLNM+ETXC+EVLDTX+ECADEM       AGACC   174
    TRLAM = EPAP*(SINCR(I)+ESLSPT*BINCR(I)+AUXL12)+TMINCR(I)*PRM+EQMT/ AGACC   175
   1        TTGLM+ELOAN(I)+AGSUBM                                     AGACC   176
    DRLAM = DRLAM+(TRLAM-TCLAM)/(1.+DIR)**I                           AGACC   177
    IF(T.NE.TMOD)GO TO 150                                            AGACC   178
    PRINT980,EDHSER(I),ETCEC(I),EOPCLM,EOCLNM,ETXC,EVLDTX,ECADEM,     AGACC   179
   1         SINCR(I),TMINCR(I),ELOAN(I),TRLAM,TCLAM                  AGACC   180
150 CONTINUE                                                          AGACC   181
200 CONTINUE                                                          AGACC   182
    DRLAV =(DRLAT+TTGLR+DRLAM*(TLMOD+TRSL))/TGLR                      AGACC   183
    ASVLNC = VLANDC*C25*                                              AGACC   184
    VLDTXC = ASVLFC*TAXLND                                            AGACC   185
    ASVHC = ASVLNC/TLC                                                AGACC   186
    VLTXHC = VLDTXC/TLC                                               AGACC   187
    TRCRU = EPCRPU+FYLDCU                                             AGACC   188
    CSTHCU = CSTHCU*RCSTDT                                            AGACC   189
    CSTHCL = CSTHCL*RCSTDT                                            AGACC   190
    CSTHFC = CSTHFC*RCSTDT                                            AGACC   191
    CSTHU =  CSTHCU*(1.+C274*(YLDCU-YLDCU1)/(DYLDCU-YLDCU1))          AGACC   192
    CSTHL = CSTHCL*(1.+C275*(YLDCL-YLDCL1)/(DYLDCL-YLDCL1))           AGACC   193
    CSTHF = CSTHFC*(1.+C276*(YLDFC-YLDFC1)/(DYLDFC-YLDFC1))           AGACC   194
    TCCRUL = TCCRUL+(TCCRU-TCCRUL)*DT/DEL22                           AGACC   195
    TCCRU = CSTHU *VLTXHC                                             AGACC   196
    DCRU = (TRCRU-TCCRUL)*TCDIR                                       AGACC   197
    ARCRU = TLCRU*YLDCU*PCRUPU                                        AGACC   198
    ARCRL = TLCRL*YLDCL*PCRUPL                                        AGACC   199
    ARFC = TLFC*YLDFC*PFCRDM                                          AGACC   200
    ACCRU = TLCRU*CSTHU                                               AGACC   201
    ACCRL = TLCRL*CSTHL                                               AGACC   202
    ACFC = TLFC*CSTHF                                                 AGACC   203
    FARICC = ARCRU+ARCRL-ACCRU-ACCRL                                  AGACC   204
    FARIFC = ARFC-ACFC                                                AGACC   205
    FARMICA = FARMICA+DT*FARMIC                                       AGACC   206
    FARMIC = FARICC+FARIFC+VLDTXC                                     AGACC   207
    VLANDC = AMAX1(VLNDMT*TLC, FARMIC/RINT)                           CW2       7
    VLNDHC = VLANDC/TLC                                               AGACC   209
    GINC = YAT+YMT+YAM+YMM                                            AGACC   210
    ALPH2 = C261+(C262-C261)*EXP(-C263*C264*AMAX1(GINC-EXLMIN, 0.))   AGACC   211
    EXPLIV = AMAX1(ALPH2*GINC, EXLMIN)                                AGACC   212
    IF(IPRINT.LT.1)RETURN                                             AGACC   213
    PRINT900,T                                                        AGACC   214
    PRINT904,DRLAV,DCRU,TRCRU,TCCRUL,TCCRU,ARCRU,ACCRU,CSTHU,CSTHCU,  AGACC   215
   1         GINC                                                     AGACC   216
    PRINT908,FARMIC,FARMICA,VLANDC,ASVLNC,VLDTXC,ARCRL,ACCRL,CSTHL,   AGACC   217
   1         CSTHCL,ALPH2                                             AGACC   218
    PRINT912,FARICC,FARIFC,VLNDHC,ASVHC,VLTXHC,ARFC,ACFC,CSTHF,CSTHFC, AGACC   219
   1         EXPLIV                                                   AGACC   220
    PRINT920,DRLAT,TRLAT,TCLATL,TCLAT,ESLSPT,EPAP,EQMT,FARILT         AGACC   221
    PRINT924,ARLAT,ACLAT,YAT,YMT,AGSUT,CPCLAT,OPCLMT,TAXCT,CAPDFT     AGACC   222
    PRINT928,CSTANT,CSTANTL,CTLBLT,VETRAD,VETRAC,CLNDT,CLNDTL,VLANDT, AGACC   223
   1         ASVLNT,VLDTXT                                            AGACC   224
    PRINT932,PKRM,TAXCT1,TAXCT2,TAXCT3,TAXCMT,VLNDMT,ASVMT,VLTXMT    AGACC   225
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      IF(T.LT.THUR)RETURN
      PRINT954,DRLAM,FARILM,ARLAM,ACLAM,ARLAM1,ACLAM1,CAPT,RPCAPT,STORG,
     1         RLIMPS
      PRINT958,YAM,YMM,AGSUM,ALOAN,ALOANA,ALREP,ALREPA,DBTOUS,ALINT
      PRINT962,OPCLAM,OPCLM1,CSTANM,CLNDM,CSRFGM,CSHARV,VLANDM,ASVLMM,
     1         VLDTXM
      PRINT966,TAXCM,TAXCM1,TAXCM2,TAXCM3,TAXCTL,CAPDEM,VLTXTL,VLNDMM,
     1         ASVMM,VLTXMM
      RETURN
900 FORMAT(36H2OUTPUT OF SUBROUTINE AGACC AT TIME,F8.2)
904 FORMAT(1H0,9X,5HDRLAV,7X,6HDCRU,8X,5HTRCRU,7X,6HTCCRUL,6X,5HTCCRU,
     1         7X,5HAPCRU,7X,5HACCRU,7X,5HCSTMU,7X,6HCSTHCU,6X,4HOINC/
     2         1H0,8X,10E12.4)
908 FORMAT(1H0,9X,6HFARMIC,6X,7HFARMICA,5X,6HVLANDC,6X,6HASVLNC,6X,
     1         6HVLDTXC,6X,5HARCRL,7X,5HACCRL,7X,5HCSTML,7X,6HCSTHCL,6X,
     2         5HALPH2/1H0,8X,10E12.4)
912 FORMAT(1H0,9X,6HFARIC,6X,6HFARIFC,5X,6HVLNDMC,6X,5HASVMC,7X,
     1         6HVLTXMC,6X,4HARFC,8X,4HACFC,8X,5HCSTMF,7X,6HCSTHFC,6X,
     2         6HFXPLIV/1H0,8X,10E12.4)
920 FORMAT(1H0,9X,5HDRLAT,7X,5HTRLAT,7X,6HTCLATL,6X,5HTCLAT,7X,
     1         6HISLSPT,6X,4HFPAP,8X,4HEONT,8X,6HFARILT/1H0,8X,8E12.4)
924 FORMAT(1H0,9X,5HARLAT,7X,5HACLAT,7X,3HYAT,9X,3HYMT,9X,5HAGSUT,7X,
     1         6HOPCLAT,6X,6HOICLIT,6X,5HTAXCT,7X,6HCAPDET/1H0,8X,9E12.4)
928 FORMAT(1H0,9X,6HCSTANT,6X,7HCSTANTL,5X,6HCTLBLT,6X,6HVETRAD,6X,
     1         6HVETRAC,6X,5HCLNDT,7X,6HCLNDTL,6X,6HVLANDT,6X,6HASVLNT,
     2         6X,6HVLDTXT/1H0,8X,10E12.4)
932 FORMAT(1H0,9X,4HPEGR,8X,6HTAXCT1,6X,6HTAXCT2,6X,6HTAXCT3,6X,
     1         6HTAXCHT,30X,6HVLNDMT,6X,5HASVMT,7X,6HVLTXMT/1H0,8X,5E12.4,
     2         24X,3E12.4)
954 FORMAT(1H0,9X,5HDRLAM,7X,6HFARILM,6X,5HARLAM,7X,5HACLAM,7X,
     1         6HARLAM1,6X,6HACLAM1,6X,4HCAPT,8X,6HRPCAPT,6X,5HSTORG,7X,
     2         6HRLIMPS/1H0,8X,10E12.4)
958 FORMAT(1H0,9X,3HYAM,9X,3HYMM,9X,5HAGSUM,7X,5HALOAN,7X,6HALOANA,6X,
     1         5HALREP,7X,6HALREPA,6X,6HDBTOUS,6X,5HALINT/1H0,8X,9E12.4)
962 FORMAT(1H0,9X,6HOPCLAM,6X,6HOPCLM1,6X,6HCSTANM,6X,5HCLNDM,7X,
     1         6HCSRFGM,6X,6HCSHARV,18X,6HVLANDM,6X,6HASVLMM,6X,6HVLDTXM/
     2         1H0,8X,6E12.4,12X,3E12.4)
966 FORMAT(1H0,9X,5HTAXCM,7X,6HTAXCM1,6X,6HTAXCM2,6X,6HTAXCM3,6X,
     1         6HTAXCTL,6X,6HCAPDEM,6X,6HVLTXTL,6X,6HVLNDMM,6X,5HASVMM,7X,
     2         6HVLTXMM/1H0,8X,10E12.4)
970 FORMAT(1H1,6HFDRSFR,5X,5HETCEC,6X,6HELPCLM,5X,6HEOCLMM,5X,
     1         4HFTXC,7X,6HFVLDTX,5X,6HECADEM,5X,5HSINCR,6X,6HTPINCP,5X,
     2         5HELOAN,6X,5HTRLAM,6X,5HTCLAM)
980 FORMAT(1H0,12F11.3)
      ENTRY ACSET
C
C                 CRUPS
C
      RCSTDT = 1.+CT+PCST
      VLANDC = 962448800.
      CSTMCU = 562.
      CSTMCL = 1097.
      CSTMFC = 723.
      VLDCU = VLDCU1
      EVLDCU = VLDCU
      VLDCL = VLDCL1
      VLDFC = VLDFC1
      TCCRU = CSTMCU*VLANDC*C888*TAXLND/TLC
      TCCRUL = TCCRU
      FARMIC = 0.
      FARMICA = 0.
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C                                                                       AGACC   287
C                     TRADITIONAL LIVESTOCK                             AGACC   288
C                                                                       AGACC   289
      PKOR = 0.                                                         AGACC   290
      TAXCT1 = 0.                                                       AGACC   291
      TAXCT2 = 0.                                                       AGACC   292
      TAXCHT = C279*TOPRPT/TTULH                                        AGACC   293
      TAXCTL = TAXCHT                                                   AGACC   294
      CTLRLT = 18.4                                                     AGACC   295
      VETHAC = 6.1C                                                     AGACC   296
      CSTANT = CTLRLT*VETHAC                                            AGACC   297
      CSTANTL = CSTANT                                                  AGACC   298
      CLNDT = 35.4                                                      AGACC   299
      CLNDTL = CLNDT                                                    AGACC   300
      VLDTXT = 37AC.CC.                                                 AGACC   301
      VLTXHT = VL**CT/(TTGLR*C278)                                      AGACC   302
      VLTXTL = VLTXHT                                                   AGACC   303
      TCLAT = TOPRPT*CSTANT/TTGLR*CLNDT*C267*TAXCHT*BOLT*C268*VLTXHT    AGACC   304
      TCLATL = TCLAT                                                    AGACC   305
      EPAP = 907.                                                       AGACC   306
      ESLSPT = SLSPT/TTGLR                                              AGACC   307
      VLANDT = 107(.CC8.8.                                              AGACC   308
      AGSUBT = C.                                                       AGACC   309
C                                                                       AGACC   310
C                     MODERN LIVESTOCK                                  AGACC   311
C                                                                       AGACC   312
      ALOANA = C.                                                       AGACC   313
      ALOAN = 0.                                                        AGACC   314
      ALREPA = 0.                                                       AGACC   315
      ALREP = C.                                                        AGACC   316
      STORG = C.                                                        AGACC   317
      AGSUM = C.                                                        CM1       3
      CSHARY = 6.25                                                     AGACC   318
      CSREGM = 57C.                                                     AGACC   319
      CSTANM = 50.                                                      AGACC   320
      CLNDM = 100.                                                      AGACC   321
      VLANDM = 0.                                                       AGACC   322
      VLDTXM = C.                                                       AGACC   323
      TAXCM = 0.                                                        CM3       1
      YAM = 0.                                                          AGACC   324
      YMM = C.                                                          AGACC   325
      ARLAM = C.                                                        AGACC   326
      ACLAM = C.                                                        AGACC   327
      DRLAM = C.                                                        AGACC   328
      TCDIP = C.                                                        AGACC   329
      DO 1020 I=1,IPM                                                   AGACC   330
      ELOAN(I) = 0.                                                     AGACC   331
      ETCEC(I) = 0.                                                     AGACC   332
      EMBSER(I) = C.                                                    AGACC   333
      TCDIP = TCDIM+1./(1.+DIM)**I                                      AGACC   334
1020 CONTINUE                                                           AGACC   335
      IF(MAL.EQ.0) RETURN                                               AGACC   336
      DO 1060  I=1,IPM                                                  AGACC   337
      SINCM(I) = SINCMA(I,MAL)                                          AGACC   338
      TMINCP(I) = TMINCA(I,MAL)                                         AGACC   339
      TXCP(I) = ETXCA(I,MAL)                                            AGACC   340
      VLTXTP(I) = EVLDTA(I,MAL)                                         AGACC   341
      CAPDTP(I) = ECAPEA(I,MAL)                                         AGACC   342
      CAINCP(I) = CAPCA(I,MAL)                                          AGACC   343
      CLINCP(I) = CLINCA(I,MAL)                                         AGACC   344
      BINCP(I) = BINCMA(I,MAL)                                          AGACC   345
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 1060 CONTINUE                                                          AGACC  346
      RETURN                                                            AGACC  347
      END                                                               AGACC  348
```

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      SUBROUTINE MODRAT                                                 MODRAT     2
      COMMON /ACCOUN/ DRLAT,AMLAT,ACLAT,VLANDT,VLDTXT,TAXCT,AGSUT,     ACCOUN     2
     1                DRLAM,AMLAM,ACLAM,VLANDM,VLDTXM,TAXCM,AGSUM,     ACCOUN     3
     2                DRLAV,DCRU,FARMIC,DBTOUS,DCRDT,RCSTDT,EXPLIV,NCFR,ACCOUN     4
     3                ALPM1,TEC,TCEC,TAXSL3,TLF,TLFP,CPLF,RINT,RINTL,  ACCOUN     5
     4                CREDT,DIR,C250,C253,C254,LT1,LT2,LT3,CBSTG,CSTGM,CM7        1
     5                EPCRPJ,PCBOPU,PCROPL,PFCROP,                     ACCOUN     7
     6                EYLDCJ,YLDCU,YLDCL,YLDFC,DYLDCU,DYLDCL,DYLDFC    ACCOUN     8
      REAL NCFR                                                         ACCOUN     9
      COMMON /CATTLE/ PFGT,PFMT,PFPT,PMGT,PMPT,TOPOPT,TOPOPR,          CATTLE     2
     1                PFGM,     PFPM,PMGM,PMPM,TOPOPM,VACAPL,AWXL12,   CATTLE     3
     2                SLFERT,SLBCCT,SOLDFT,SLSMLT,SLSPT,SLSPTP,FEMSCT, CATTLE     4
     3                SLFERM,SLBCCM,SOLDFM,SLSMLM,SLSPM,BUPB,FEMSCM,   CATTLE     5
     4                PPFGTT,PPFPTT,PPMGTT,PPMPTT,PPFGTM,              CATTLE     6
     5                PPFPTM,PPMGTM,PPMPTM,RFGTT,RFPTT,                CATTLE     7
     6                RMGTT,RMPTT,RFGTM,RFPTM,RMGTM,RMPTM,             CATTLE     8
     7                TONT,TONAT,TONM,TONMP,TONAM,PATADT,OMM,OMT,PFLACT,CATTLE     9
     8                YMAT,PA,PAP,PAPP,PRAT,EXPL,UNEXPL,CY202,C214,C244 CATTLE    10
      COMMON /CONTRL/ T,DT,DUM,IRUN,BEGRT,PRTCHG,PRTVL1,PRTVL2,IPRINT, CM5        1
     1                MAL,TMOD,TDO                                     CM5        2
      COMMON /LAND/   TGL,TTGL,TTGLL,TTGLU1,TTGLU2,TGLSF0,             LAND       2
     1                TRSL,TLMOD,TLMOD1,TLMOD2,TLMOD3,TTGLR,TGLR,      LAND       3
     2                TLCRL,TLCRU,TLCRUP,TGLSF,TGLUIP,TLFC,TLC,        LAND       4
     3                XR1,R1,R2,PR2,PDR,CRM,RLM,RLMI,RLCRU,AUX1,AUX3,  LAND       5
     4                ARM1,ARM2,ARM3,A5,C9,GRT,CPLPT,XDEL,RPTM,GRE     LAND       6
      DATA      CL1,E7,E8,E9,E11 /     .03, 1., .15, .5,.5 /          MODRAT     7
      DATA E31,E32,E33,E81,E91 / 4000., 2000., .3, 2., .3 /            MODRAT     8
      DATA TE0,TE1,TE2,TEF,EXMAX / 5., 7., 11., 131., 500. /           MODRAT     9
      GRT = TTGLR/TOPOPT                                               MODRAT    10
      IF(DRLAV.GE.DCRU)GO TO 200                                       MODRAT    11
      XTLU = TGLUIP                                                    MODRAT    12
      GO TO 210                                                        MODRAT    13
  200 XTLU = TLCRUP                                                    MODRAT    14
  210 IF(T.GT.DT)GO TO 220                                             MODRAT    15
      CL1 = PLCRU*ABS(DCRU)/(XTLU*(DCRU-DRLAV))                        MODRAT    16
      PRINT920,CL1                                                     MODRAT    17
  920 FORMAT(5HCCL1=,F11.4)                                            MODRAT    18
      GO TO 230                                                        MODRAT    19
  220 RLCRU = CL1*XTLU*(DCRU-DRLAV)/ABS(DCRU)                          MODRAT    20
  230 AUX1 = AMIN1(RLCRU, 0.)                                          MODRAT    21
      AUX3 = AMAX1(RLCRU, 0.)                                          MODRAT    22
      IF(T.LT.TMOD)GO TO 300                                           MODRAT    23
      ETCAM = T-TMOD                                                   MODRAT    24
      RLM = RLM*(R2-RLM)*DT/XDEL                                       MODRAT    25
      R2 = R2*(XR1-R2)*DT/XDEL                                         MODRAT    26
      R1 = R1*(CRM-R1)*DT/XDEL                                         MODRAT    27
      XR1 = R1+A5                                                      MODRAT    28
      PDR = (DRLAM-DRLAT)/ABS(DRLAT)                                   MODRAT    29
      E3 = E31-E32*EXP(-E33*ETCAM)                                     MODRAT    30
      PR1 = AMAX1(E7*(1.-EXP(-E8*(PDR-E9))), 0.)                       MODRAT    31
      CALL GHAPH(TE0,TE1,TE2,TEF,EXMAX,T,EXT1)                         MODRAT    32
      RLMPI = E3*PR1*EXT1                                              MODRAT    33
      RLMDI = PR1*TTGL*TLMOD/TGL0                                      MODRAT    34
      RLMI = RLMPI+RLMDI                                               MODRAT    35
      PR2 = AMAX1(E11*(1.-EXP(-E81*(E91-PDR))), 0.)                    MODRAT    36
      CRM = AMAX1(AMIN1(RLMI, AMIN1(ARM1, ARM2)*ARM3), 0.)             MODRAT    37
      GRM = (TLMOD-TRSL)/TOPUPM                                        MODRAT    38
      GRR = TOLH/TOPOPR                                                MODRAT    39
  300 CONTINUE                                                         MODRAT    40
      IF(IPRINT.LT.1)RETURN                                            MODRAT    41
      PRINT900,T                                                       MODRAT    42
```

```
      PRINT910,GR,RLCRU,AUX1,AUX3                                        MODRAT      43
      IF(T.LT.TMOD)RETURN                                                MODRAT      44
      PRINT950,PDR,EJ,PR1,EX1,RLMPI,RLMDI,RLMI,PR2,CRM                   MODRAT      45
      PRINT955,R1,R2,XR1,RLM,GRM,GRR                                     MODRAT      46
      RETURN                                                             MODRAT      47
  900 FORMAT(36H2OUTPUT OF SUBROUTINE MODRAT AT TIME,F8.2)               MODRAT      48
  910 FORMAT(1H0,9X,3HGR,9X,5HRLCRU,7X,4HAUX1,8X,4HAUX3/1H0,9X,4(E11.4,  MODRAT      49
     1       1X))                                                        MODRAT      50
  950 FORMAT(1H0,9X,3HPDR,9X,2HEJ,10X,3HPR1,9X,4HEX1,8X,5HRLMPI,7X,      MODRAT      51
     1       5HRLMDI,7X,4HRLMI,8X,3HPR2,9X,3HCRM/1H0,9X,9(E11.4,1X))     MODRAT      52
  955 FORMAT(1H0,9X,2HR1,10X,2HR2,10X,3HXR1,9X,3HRLM,9X,3HGRM,8X,3HGRR/  MODRAT      53
     1       1H0,9X,6(E11.4,1X))                                         MODRAT      54
      ENTRY MODSET                                                       MODRAT      55
      TGL0 = TGL                                                         MODRAT      56
      RETURN                                                             MODRAT      57
      END                                                                MODRAT      58
```

```
      SUBROUTINE CRTACC                                                 CRTACC     2
      COMMON /ACCOUN/ DRLAT,AMLAT,ACLAT,VLANDT,VLDTXT,TAXCT,AGSUT,     ACCOUN     2
     1                DRLAM,AMLAM,ACLAM,VLANDM,VLDTXM,TAXCM,AGSUM,     ACCOUN     3
     2                DRLAV,DCRU,FARMIC,DMTOUS,DCRDT,RCSTDT,EXPLIV,NCFR, ACCOUN    4
     3                ALPM1,TFC,TCEC,TAXSL3,TLF,TLFP,CPLF,RINT,RINTL,  ACCOUN    5
     4                CREDT,DIR,C250,C293,C254,LT1,LT2,LT3,CBSTC,CSTQM, CW7      1
     5                EPCMPU,PCROPU,PCROPL,PFCROP,                     ACCOUN     7
     6                EYLDCU,YLDCU,YLDCL,YLDFC,DYLDCU,DYLDCL,DYLDFC    ACCOUN     8
      REAL NCFR                                                         ACCOUN     9
      COMMON /CATTLE/ PFLT,FEMT,PFPT,PMJT,PMPT,TOPOPT,TOPOPR,          CATTLE     2
     1                PFLM,     PFPM,PMJM,PMPM,TOPOPM,VACAPL,AUXL12,   CATTLE     3
     2                SLFERT,SLSCCT,SOLOFT,SLSMLT,SLSPT,SLSPTP,FEMSCT, CATTLE     4
     3                SLFERM,SLSCCM,SOLOFM,SLSMLM,SLSPM,BUPB,FEMSCM,   CATTLE     5
     4                PPFGTT,PPFPTT,PPMJTT,PPMPTT,PPFGTM,              CATTLE     6
     5                PPFPTM,PPMGTM,PPMPTM,RFJTT,RFPTT,                CATTLE     7
     6                RMGTT,RMPTT,RFGTM,RFPTM,RMGTM,RMPTM,             CATTLE     8
     7                TDRT,TDMAT,TDNM,TDNMP,TDNAM,PATADT,OMM,OMT,PFLACT, CATTLE   9
     8                YMAT,PA,PAP,PAPP,PRAT,EXPL,UNEXPL,CT202,C214,C244 CATTLE    10
      COMMON /CONTRL/ T,DT,DUM,IRUN,BEGPRT,PRTCHG,PRTVL1,PRTVL2,IPRINT, CW5      1
     1                MAL,TMCU,TDD                                     CW5        2
      COMMON /LAND/   TGL,TTGL,TTGLL,TTGLV1,TTGLV2,TGLSF0,             LAND       2
     1                TMSL,TLMOD,TLMOD1,TLMOD2,TLMOD3,TTGLR,TGLR,      LAND       3
     2                TLCRL,TLCRU,TLCRUP,TGLSF,TGLVIP,TLFC,TLC,        LAND       4
     3                X01,M1,M2,PR2,PDR,CRM,RLM,RLMI,RLCRU,AUX1,AUX3,  LAND       5
     4                ARM1,ARM2,ARM3,A5,C9,CRT,CPLPT,XDEL,HPTH,CRE     LAND       6
      DIMENSION VAL51(5),VAL52(7)                                       CRTACC     7
      DATA C239,C272,C273,C281,C282 / .1, 1., 1., 2.0, .032 /           CRTACC     8
      DATA SMALL51,DIFF51,K51 / 4., 1., 4 /                             CRTACC     9
      DATA SMALL52,DIFF52,K52 / 4., 1., 6 /                             CRTACC    10
      DATA VAL51 / 12.77, 13.5, 13.5, 14.5, 15.76 /                     CRTACC    11
      DATA VAL52 / 117., 115.5, 127., 147., 164., 163.5, 174. /         CRTACC    12
      DATA AL1,EXCHM1 / .0728, 15.76 /                                  CRTACC    13
      DATA HPB1,HPBC1,HPBR,HPBCR / 174., 588., .11, .384 /              CRTACC    14
      DATA POP0 / 154157E8. /                                           CRTACC    15
      DATA CREPM,PEOCR,RINTC / 1., .5, .1 /                             CW6        1
      CREPP = CREP                                                      CRTACC    17
      CREP = AMAX1(CREPP+CDEB, 0.)                                      CRTACC    18
      CINT = RINTC*CDEB                                                 CRTACC    19
      CDER = CDER+DT*(CLOAN-CREPP)                                      CRTACC    20
      CCDT = DMTOUS*(RINT-RINTL)+CDEB*(RINT-RINTC)                      CRTACC    21
      POP = POP0*EXP(C282*T)                                            CRTACC    22
      PERCAP = C2M1*(SUPB-EXPL-UNEXPL)/POP                              CRTACC    23
      ARLSK = ARLAT+AMLAM+CLOAN                                         CRTACC    24
      ACLSK = ACLAT+ACLAM+CREP+CINT                                     CRTACC    25
      FARILA = FARILA+DT*FARIL                                          CRTACC    26
      FARIL = ARLSK+ACLSK                                               CRTACC    27
      DSREVL = DSREVL+DT*FARIL*EXP(-DIR*T)                              CRTACC    28
      FARMIA = FARMIA+DT*FARMI                                          CRTACC    29
      FARMI = FARIL+FARMIC                                              CRTACC    30
      VLAND = VLANDT+VLANDM                                             CRTACC    31
      VALCAP = VACAPL+VLAND                                             CRTACC    32
      VLDTAX = VLDTAT+VLDTXM                                            CRTACC    33
      VLANDM = VLAND/(TGLR*C272)                                        CRTACC    34
      VLDTXM = VLDTAX/(TGLR*C273)                                       CRTACC    35
      CCMLDX = VLDTAM/VLANDM                                            CRTACC    36
      GOVREVA = GOVREVA+DT*GOVREV                                       CRTACC    37
      GOVREV = TAXCT+TAXCM*VLDTAX                                       CRTACC    38
      EQPOS = VLAND*VACAPL-CDEB-DMTOUS                                  CRTACC    39
      ACRDTC = PERCAP*POPS                                              CRTACC    40
      CRDAV = AMIN1(PEOCR*EQPOS, ACRDTC)                                CRTACC    41
      NCFP = AMAX1(FARIL*C239*FARMIC-EXPLIV, 0.)                        CRTACC    42
```

```
      TDCRDC = AMAX1(.FARIL*C239+FARMIC*EXPLIV, 0.)                    CRTACC     43
      CLOAN = AMIN1(CRDAV, TDCRDC)                                     CRTACC     44
      IF(T.LT.4.)GO TO 300                                             CRTACC     45
      IF(T.GT.8.)GO TO 290                                             CRTACC     46
      EXCHR = TABLIF(VAL91,SMALL91,DIFF91,K91,T)                       CRTACC     47
      GO TO 295                                                        CRTACC     48
  290 EXCHR = EXCHR+DT*RCHEX                                           CRTACC     49
  295 RCHEX = AL1*EXCHRI*EXP(AL1*(T-8.))                               CRTACC     50
  300 FOREXA = FOREXA+DT*FOREX                                         CRTACC     51
      IF(T.LT.4)GO TO 320                                              CRTACC     52
      IF(T.GT.10.)GO TO 310                                            CRTACC     53
      WPB = TABLIF(VAL92,SMALL92,DIFF92,K92,T)                         CRTACC     54
      GO TO 320                                                        CRTACC     55
  310 IF(T.GT.14.)GO TO 315                                            CRTACC     56
      WPB = WPBI*(1.+WPBR*(T-10.))                                     CRTACC     57
      GO TO 320                                                        CRTACC     58
  315 WPBC = WPBCI*(1.+WPBCR*(T-10.))                                  CRTACC     59
      WPB = WPBC/4.3                                                   CRTACC     60
  320 IF(T.EQ.7.)EXSUB = .15                                           CRTACC     61
      EXMAR = WPB*EXCHR*(1.+.8*EXSUB)*PA                               CRTACC     62
      FOREX = WPB*EXPL                                                 CRTACC     63
      SUBSE = FOREX*EXCHR*EXSUB                                        CRTACC     64
      SUBSA = SUBSA+DT*SUBS                                            CRTACC     65
      SUBS = SUBSE*CCDT+AGSJP+AGSUM                                    CRTACC     66
      IF(IPRINT.LT.1)RETURN                                            CRTACC     67
      PRINT900,T                                                       CRTACC     68
      PRINT910,CREP,CINT,CDEB,EQPOS,CRDAV,CLOAN,TDCRDC,NCFR,CCDT       CRTACC     69
      PRINT920,FARIL,FARILA,FARMI,FARMIA,DSREVL,ARLSK,ACLSK,POP,PERCAP CRTACC     70
      PRINT930,VALCAP,VLAND,VLDTAX,VLANDM,VLDTXM,COMLDX,GOVREV,GOVREVA CRTACC     71
      PRINT940,SUBS,SUBSA,SUBSE,RCHEX,EXCHR,FOREX,FOREXA,EXMAR,WPB     CRTACC     72
      RETURN                                                           CRTACC     73
  900 FORMAT(36H2OUTPUT OF SUBROUTINE CRTACC AT TIME,F8.2)             CRTACC     74
  910 FORMAT(1H0,9X,4HCREP,8X,4HCINT,8X,4HCDEB,8X,5HEQPOS,7X,5HCRDAV,7X,  CRTACC 75
     1       5HCLOAN,7X,6HTDCRDC,6X,4HNCFR,8X,4HCCDT/1H0,8X,9E12.4)    CRTACC     76
  920 FORMAT(1H0,9X,5HFARIL,7X,6HFARILA,6X,5HFARMI,7X,6HFARMIA,6X,     CRTACC     77
     1       6HDSREVL,6X,5HARLSK,7X,5HACLSK,7X,3HPOP,9X,6HPERCAP/1H0,  CRTACC     78
     2       8X,9E12.4)                                                CRTACC     79
  930 FORMAT(1H0,9X,6HVALCAP,6X,5HVLAND,7X,6HVLDTAX,6X,6HVLANDM,6X,    CRTACC     80
     1       6HVLDTXM,6X,6HCOMLDX,6X,6HGOVREV,6X,7HGOVREVA/1H0,8X,     CRTACC     81
     2       8E12.4)                                                   CRTACC     82
  940 FORMAT(1H0,9X,4HSUBS,8X,5HSUBSA,7X,5HSUBSE,7X,5HRCHEX,7X,5HEXCHR,  CRTACC 83
     1       7X,5HFOREX,7X,6HFOREXA,6X,5HEXMAR,7X,3HWPB/1H0,8X,9E12.4) CRTACC     84
C                                                                      CRTACC     85
C         INITIAL VALUES FOR INVESTMENT ACCOUNTING                     CRTACC     86
C                                                                      CRTACC     87
      ENTRY CRTSET                                                     CRTACC     88
      EXSUB = 0.                                                       CRTACC     89
      FARIL = 0.                                                       CRTACC     90
      FARILA = 0.                                                      CRTACC     91
      FARMI = 0.                                                       CRTACC     92
      FARMIA = 0.                                                      CRTACC     93
      GOVREV = 0.                                                      CRTACC     94
      GOVREVA = 0.                                                     CRTACC     95
      DSREVL = 0.                                                      CRTACC     96
      SUBS = 0.                                                        CRTACC     97
      SUBSA = 0.                                                       CRTACC     98
      FOREX = 0.                                                       CRTACC     99
      FOREXA = 0.                                                      CRTACC    100
      EXCHR = 0.                                                       CRTACC    101
      WPB = 0.                                                         CRTACC    102
      CREP = 0.                                                        CRTACC    103
```

```
CDEB = 0.                                                       CATACC  104
CLOAM = 0.                                                      CATACC  105
DUTOUS = 0.                                                     CATACC  106
RETURN                                                          CATACC  107
END                                                             CATACC  108
```

```
      SUBROUTINE GRAPH(T0,T1,T2,TF,VMAX,T,OUT)                    GRAPH     2
      IF(T-T0)40,40,10                                            GRAPH     3
   10 IF(T-T1)50,50,20                                            GRAPH     4
   20 IF(T-T2)60,60,30                                            GRAPH     5
   30 IF(T-TF)70,70,40                                            GRAPH     6
   40 OUT = 0.                                                    GRAPH     7
      RETURN                                                      GRAPH     8
   50 OUT = VMAX*(T-T0)/(T1-T0)                                   GRAPH     9
      RETURN                                                      GRAPH    10
   60 OUT = VMAX                                                  GRAPH    11
      RETURN                                                      GRAPH    12
   70 OUT = VMAX*(TF-T)/(TF-T2)                                   GRAPH    13
      RETURN                                                      GRAPH    14
      END                                                         GRAPH    15
```

```
      FUNCTION TABLIE(VAL,SMALL,DIFF,K,DUMMY)                          TABLIE     2
      DIMENSION VAL(1)                                                 TABLIE     3
      DUM = AMIN1(AMAX1(DUMMY-SMALL,0.0),FLOAT(K)*DIF)                 TABLIE     4
      I = 1.+DUM/DIFF                                                  TABLIE     5
      IF(I.EQ.K+1)I=K                                                  TABLIE     6
      TABLIE = (VAL(I+1)-VAL(I))*(DUM-FLOAT(I-1)*DIFF)/DIFF+VAL(I)     TABLIE     7
      RETURN                                                           TABLIE     8
      END                                                              TABLIE     9
```

```
      FUNCTION TABEXE(VAL,SMALL,DIFF,K,DUMMY)                          TABEXE     2
      DIMENSION VAL(1)                                                 TABEXE     3
      DUM = DUMMY*SMALL                                                TABEXE     4
      I = MIN0(MAX1(1.,DUM/DIFF+1.),K)                                 TABEXE     5
      TABEXE = (VAL(I+1)-VAL(I))*(DUM-FLOAT(I-1)*DIFF)/DIFF+VAL(I)     TABEXE     6
      RETURN                                                           TABEXE     7
      END                                                              TABEXE     8
```

```
      SUBROUTINE DELDT(RINR,ROUTR,CROUTR,DEL,IDT,DT,K)                  DELDT     2
      DIMENSION CROUTR(1)                                               DELDT     3
      DEL1 = DEL*FLOAT(IDT)/(FLOAT(K)*DT)                               DELDT     4
      ROUTR = 0.                                                        DELDT     5
      DO 2 J=1,IDT                                                      DELDT     6
      RIN = RINR/FLOAT(IDT)                                             DELDT     7
      DO 1 I=1,K                                                        DELDT     8
      ABC = CROUTR(I)                                                   DELDT     9
      CROUTR(I) = ABC+(RIN-ABC)/DEL1                                    DELDT    10
    1 RIN = ABC                                                         DELDT    11
    2 ROUTR = ROUTR+CROUTR(K)                                           DELDT    12
      RETURN                                                            DELDT    13
      END                                                               DELDT    14
```

```
      SUBROUTINE DELAY(RINR,ROUTR,CROUTR,DEL,DT,K)                    DELAY     2
      DIMENSION CROUTR(1)                                             DELAY     3
      DEL1 = DEL/(FLOAT(K)*DT)                                        DELAY     4
      RIN = RINR                                                      DELAY     5
      DO 10 I=1,K                                                     DELAY     6
      ARC = CROUTR(I)                                                 DELAY     7
      CROUTR(I) = ARC+(RIN-ARC)/DEL1                                  DELAY     8
   10 RIN = ARC                                                       DELAY     9
      ROUTR = CROUTR(K)                                               DELAY    10
      RETURN                                                          DELAY    11
      END                                                             DELAY    12
```

```
      SUBROUTINE BDXC(BINR,BOUTB,TRAIN,NCOUNT,NOCY,LT,SUMIN)                BDXC
      DIMENSION TRAIN(LT)                                                   BDXC
      NCOUNT = NCOUNT+1                                                     BDXC
      SUMIN = SUMIN+BINR                                                    BDXC
      IF(NCOUNT.NE.NOCY)RETURN                                              BDXC
      BOUTB = TRAIN(LT)/FLOAT(NOCY)                                         BDXC
      DO 10 I=2,LT                                                          BDXC
   10 TRAIN(I-1) = TRAIN(I)                                                 BDXC
      TRAIN(LT) = SUMIN                                                     BDXC
      SUMIN = 0.                                                            BDXC
      NCOUNT = 0.                                                           BDXC
      RETURN                                                                BDXC
      END
*EOR
*EOR
```

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BIBLIOGRAPHY

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