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OF DAIRY/FORAGE FARMING SYSTEMS IN
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A MULTIPURPOSE SIMULATION MODEL OF DAIRY/FORAGE FARMING SYSTEMS IN NORTHWESTERN SPAIN (GALICIA)

By

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ABSTRACT

A MULTIPURPOSE SIMULATION MODEL
OF DAIRY/FORAGE FARMING SYSTEMS IN
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Galician dairy farming is characterized by widespread inefficiencies due to a variety of reasons such as, small size of farms, poor management of herd and pasture, deficient sanitation, lack of modern equipment, lack of access to credit, and faulty marketing channels. All these deficiencies result in low returns to factors of production. The problems of Galician dairy farmers may be compounded by the eventual accession of Spain into the European Economic Community (EEC) which may result in an adverse change of input and output prices and create many other additional uncertainties.

Policy efforts to restructure the Galician dairy industry focus on the availability of underused resources, mainly land and labor, of the typical farm. Releasing the constraints blocking the full use of these resources, through the supply of credit and technical assistance in order to raise the level of efficiency of Galician farms, is

at the core of the policy-makers strategy.

The purpose of the research was to build a simulation model incorporating often dispersed knowledge about dairy systems to help researchers explore the production function of Galician dairy farms in order to produce prescriptions for short-term and long-term managerial problems in a timely and efficient way. The model was used in the assessment of growth strategies under a variety of assumptions regarding resource base, inflation rates, and credit programs, among others.

The dairy/forage simulation model has six components which, (1) set initial assets and update assets at the beginning of every year, (2) simulate grass and silage production, (3) keep track of herd demographics, (4) simulate feed disappearance, milk production and changes in body weight of animals, (5) match feed needs to feed availability and define feeding programs, and (6) elaborate financial accounts and other performance indicators.

Several types of experiments were conducted with the model. In the calving scheduling experiment it was found that winter calvings resulted in higher returns than fall calvings. For the winter calving season, average calving times closer to the onset of grazing resulted in higher returns. In the forage storage program experiment, the better results were found with a program consisting of withdrawing from grazing no more than 45 percent of pasture during three silage cuts. In the feeding rule experiment four feeding rules were investigated, the best being one consisting of supplying rations with the National Research Council (NRC) recommended concentration of metabolic energy (ME). Under the out-EEC market scenario, best results were obtained by supplying cows rations with only 96 percent of recommended concentration of ME. Under the in-EEC market scenario best results were produced by supplying cows rations with only 94 percent of recommended concentration of ME. In the growth experiment it was found that farm expansion under the current credit program was highly profitable. However, cash-flow deficits appeared during the first years due to the gradual nature of the grass yield buildup process in the reclaimed land.

The model promises to be of use in a wide variety of management analyses of farms with different land size and land structure. The model is especially well suited for exploring the production function of the dairy farm business, uncovering aspects of farm operation poorly known and orienting research towards areas of the business where more knowledge would yield the highest payoff in terms of enhanced efficiency and returns.

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PART I

INTRODUCTION, BACKGROUND, THEORY, AND METHODS

CHAPTER 1

Introduction

In the next few years the Spanish economy will be subjected to an intense shock as it joins the EEC. This event will imply a profound alteration of the economic and institutional environment in which Spanish industries and firms operate together with prices and costs, economic legislation, regulation mechanisms, scale of market, conditions of access to world markets, etc.

The entry of Spain into the EEC will likely affect every one of the economic sectors. However, it is generally felt that the agricultural sector will have the greatest problem. There are several reasons for this:

- The size of the Spanish agricultural sector relative to that of the EEC which means that in some subsectors (e. g., fruits and vegetables, olive oil, etc) EEC's output and budgetary problems will be increased by percentages in the 30-50 percent range.

- The comparative advantage of some Spanish agricultural subsectors --fruits and vegetables--is feared in some sectors of the Community.

- In both the EEC and Spain, subsectors more likely to be adversely affected by the integration are located in depressed areas in the Community (Languedoc in France, Mezzogiorno in Italy) and Spain (Galicia, Extremadura, Norte, Ebro).

- The resolution of conflicts between competitive sectors in Spain and in the EEC will require important structural changes that in the current depressed economic context will turn out to be costly in human and economic terms.

- In many aspects, Spanish agricultural production is inefficient compared to the Community.

Spanish concern focuses on those agricultural subsectors that will be adversely affected by the new price and cost structures resulting from the integration.

The agricultural activity in the most unfavorable position seems to be the cattle subsector which will likely be adversely affected by lower guaranteed prices for final output, together with higher prices for corn, soymeal, and other intermediate inputs.

The vulnerability of the Spanish cattle sector is due to too many small units (0-5 hectares or 0-5 animals) with low profititability that leads dairymen to keep herds with double (meat-milk) and sometimes triple (meat-milk-work) capability. This lack of specialization leads to low milk yields per cow. Poor sanitary standards also affect productivity. In addition, the low level of training of many dairymen leads to inefficient management and persistence of traditional practices of pasture and herd management. Rigidities in inter- and intragenerational transfer of resources, namely land, due especially to the high price land reaches independent of its ability to generate an income prevents farms from reaching efficient size and become specialized.

Given the gap in competitiveness between the EEC and the Spanish sector, the survival as commercial operations of many dairy units, the standards of living of dairymen, the level of imports related to the consumption and production of beef and veal meat, and milk products (corn, soymeal, young live animals, meat, milk) and many other considerations important for Spanish agricultural policy, will be affected by: a) the duration of the transition period for this industry; b) the effectiviness of policies designed to reduce the structural gap mentioned earlier and

c) the conditions under which accession is achieved.

The imminence of Spain's accession into the E.E.C. brings to the forefront as well the larger question of the overall allocative efficiency of the livestock sector in catering to consumers' needs.

It is a widely shared view among Spanish agricultural economists that past developments in the meat and milk sector that allowed achievement of self-sufficiency in final products resulted in an exaggerated reliance on industrial feedstuffs made up of mostly imported raw materials (corn, soymeal, see Table 1-1 for the trends of raw material imports.)

Table 1-1

Trends of Imports of Basic Feedstuffs,
Spain, 1935-80

Year	Corn (000 TM)	Soybean (000 TM)
1935	51.8	--
1960	68.3	--
1961	251.3	69.1
1962	305.7	214.1
1963	960.5	213.1
1964	1149.8	216.3
1965	1560.0	438.1
1966	2428.5	790.1
1967	2575.2	833.4
1968	2315.3	981.2
1969	2343.5	1143.8
1970	1972.0	1255.0
1971	2056.7	1339.2
1972	2382.7	1467.2
1973	2717.6	1215.7
1974	4102.6	1750.8
1975	4181.7	1936.4
1976	3540.2	2527.9
1977	4121.6	2260.7
1978	4358.9	1662.1
1979	4369.9	2621.4
1980	4525.7	3264.8

Source: Jose Colino: El Modelo Espanol de Desarrollo Ganadero y la Competitividad de las Producciones Carnicas del Sector Vacuno, Investigaciones Economicas, N 18, August, 1982.

The contention is that a pattern of regional specialization and production techniques adopted within the regional segments of the sector was induced by a questionable structure of incentives that penalized the development of existing internal forage resources.

Negative consequences of these developments are, among others, too high a level of foreign exchange spent on imported feeds and heightened sector instability due to fluctuations in exchange rates and on world prices of grains and soymeal.

Of course, an opposite argument can be constructed from the theory of comparative advantage. Given the structure of prices and incentives, regions specialized by using the cheapest input wherever they could be found. The rapid growth of the pork and poultry subsectors delivering an increasing supply at decreasing prices seems to confirm the soudness of the sector adjustment pattern.

Our research will focus on the dairy industry, and within that industry, the problems of a particular regional segment, Galicia, in northwest Spain.

We are concerned both with the impact that the entry of Spain in the EEC will have in the dairy industry and with the longstanding problems faced by the Galician dairy industry.

In the first part of this dissertation we will identify the problems facing the Spanish and the Galician dairy industry, and examine what new problems and opportunities accession to the EEC will bring to the industry. We also see what opportunities exist to face the challenge and what policy measures are being advocated and implemented. We look at the management problems of dairy farms in Galicia and at the alternative methods and analytical tools that may be utilized to handle those problems.

In the second part we describe the mathematical blueprint of the simulation model constructed to reach our research objectives and the efforts made to validate the model.

In the last part we report the experiments carried out on the model and a series of conclusions and final comments.

CHAPTER 2

Problem Definition. Scope and Nature of the Study

2.1. Development of the Spanish Dairy Economy. Outlook and Problems.

Following the rapid economic growth of the 60's and early 70's the demand for agricultural products greatly expanded and its composition changed profoundly, putting major strains on a traditional, agricultural sector. The result was higher prices that started a process of growth and change in the dairy industry.

In Table 2-1 we can see the evolution of dairy herds, milk production and milk yields per cow in Galicia and Spain from 1965 to 1978. The number of dairy cows in Spain and in Galicia grew rather slowly, but milk output has kept pace with demand via increases in yields as farmers substituted Holstein cows for the indigenous breeds while keeping herd numbers at roughly the same level. According to M. Rodriguez, R.-Zuniga, J. Ruiz-Huerta Carbonell and R. Soria Gutierrez [69], by 1976 Holstein cows were about 40% of the dairy cows in Galicia against only 21% in 1965. This substitution of local breeds for high yielding cows is the most significant way in which traditional Galician dairy farmers tried to expand their output. Milk yields per cow grew almost 2% per year increasing total milk production almost to self-sufficiency (table 2-2).

Table 2-1

Number of Dairy Cattle, Milk Production and Yield per Cow for Galicia and Spain, 1965-78.

Year	000 Head		Milk Pr (10 lit)		Yield (lt)	
	Galicia	Spain	Galicia	Spain	Galicia	Spain
1965	567.3	1495.1	839.1	3277.5	1479.1	2192.4
1966	--	1538.0	532.9	2644.1	--	1670.3
1967	--	1653.0	690.1	2923.4	--	1768.5
1968	620.5	1694.6	748.2	3271.9	1205.9	1930.9
1969	638.2	1781.2	769.3	3540.7	1205.4	1987.7
1970	630.1	1826.9	775.1	3715.4	1230.2	1945.0
1971	618.8	1861.0	730.6	3574.0	1180.8	1920.6
1972	603.9	1870.8	792.7	3790.5	1312.6	2026.3
1973	601.1	1935.1	1182.7	4791.6	1967.6	2476.3
1974	566.8	1825.5	987.0	4279.9	1741.4	2310.6
1975	536.7	1811.4	1124.9	4373.4	2096.0	2414.7
1976	555.4	1821.6	1163.1	5212.1	2094.0	2861.0
1977	635.0	1950.	1189.0	5353.6	1872.2	2746.0
1978	673.6	1950.	1317.7	5559.5	1956.2	2851.0
Growth rates%	1.23	1.92	3.28	3.85	2.02	1.89

Sources: - AEA Spanish Ministry of Agriculture, 1978.
- Selected Agricultural Statistics on Spain 1965-76, USDA, ESCS, Statistical Bulletin 630.
- DEA, CSIC, El Desarrollo Ganadero Espanol, Madrid 1979.

Table 2-2

Spanish Production of Cow-Milk, Degree of Self-Sufficiency (10^6 lt.), 1965-78.

Years	Production (1)	Imports (2)	Exports (3)	Consumption (4)= (1)+(2)-(3)	Degree of Self-sufficiency (5)= (1)/(4)x100
1965	3278	45.5	---	3326.5	98.5
1966	3709	48.6	---	3757.5	98.7
1967	3729	52.4	---	3781.4	98.6
1968	4015	91.5	---	4106.5	97.8
1969	4296	66.9	.7	4362.2	98.5
1970	4322	113.2	.8	4434.4	97.5
1971	4263	241.0	.6	4503.4	94.7
1972	4512	118.0	1.6	4628.4	97.5
1973	4792	96.9	3.3	4885.6	98.1
1974	4931	406.4	.5	5336.9	92.4
1975	4984	211.3	.5	5194.8	95.9
1976	5212	137.9	1.2	5348.7	97.4
1977	5354	124.8	2.3	5476.5	97.8
1978	5560				

Source: Jose Colino: "Galicia y la P.A.C.". Agricultura y Sociedad, July-September 1980

Climatic and resource factors and availability of pasture and grazing land had traditionally maintained the beef and dairy herds in the northern and western part of Spain (Galicia, Norte, Duero, Extremadura and Western Andalucia. See Map). These regions still account for about 80% of the total herd with the first two, Galicia and North, making up for about 46%

Milk production, however, has spread throughout the country as a shift in the relative prices of milk and dairy feed-mix has enhanced the profitability of a dairy industry without a forage base, allowing it to locate near major consumption centers. This enabled the industry to take advantage of available feedstuffs and of a particular structure of input and output prices to achieve a higher level of performance. By 1978 milk yields per cow in the rest of Spain were about 3280 kg which is 167% of the Galician yields. This disparity in yields reveals that Galicia remains a problem region. It also indicates that, given the size of the Galician dairy industry, improving the performance and efficiency of the Spanish dairy industry requires an increased effort toward enhancing the performance of the Galician dairy industry.

The current status of the negotiations between Spain and the EEC indicates the beginning of 1986 as a likely date for the entry to occur. After that date a transition period will begin with complete removal of the barriers between the spanish and the EEC markets only at the end of the transition periods.

The Spanish dairy industry will face an important shock, but a set of opportunities will also appear to the dairy farmers and overall efficiency of the industry will probably rise. The negative aspects of the adjustment stem from lower efficiency of the Spanish industry vis-a-vis the EEC.

According to many authors, the inefficiency is due to the small scale of the Spanish industry.

Table 2-3 below shows a set of performance indicators for selected countries of the EEC, Spain and Galicia.

Table 2-3

Characteristics of the Dairy Industry,
Selected EEC Countries, Spain and Galicia, 1977.

Country	Numbers of Cows (000)	Mean Size of Farm (cows/ farm)	Milk Product. (000TM)	Milk Yields (kg/cow)	Consumpt Fluid Milk (kg/pers)	Consumpt Dairy Products (kg/pers) 1973
Germany	5417.	10.4	22523.	4158.	85.5	24.4
France	7510.	13.0	25142.	3348.	91.2	18.5
Holland	2245.	27.0	10599.	4721.	141.8	23.9
U.K.	3327.	44.3	15168.	4559.	142.4	21.6
Ireland	1484.	12.4	4151.	2797.	225.8	26.5
Italy	2945.	6.5	9456.	3211.	72.1	12.2
Spain	1950.	3.3	5345.	2746.	93.1	6.8
Spain w/o Galicia	1315.	5.4	4156.	3167.		
Galicia	635.	2.7	1189.	1872.		

Source: Jose Colino: Galicia y la P.A.C., Agricultura y Sociedad, July-September 1980

If Galicia is disregarded, Spain shows the smallest mean farm size (Table 2-3). This size, however, is not much below those of Italy, Ireland, Germany and France. The heterogeneous structure of the EEC dairy industry can be further observed in Table 2-4. We can see there that about

57% of all farms in the EEC had less than 10 cows per farm and that only about 10% were larger than 30 cows per farm which can be considered the threshold for efficient sized farms. Furthermore, J. Colino [18] tells us that about 38% of the EEC dairy farms have less than 5 cows per farm. Milk yields per cow show high variation among countries. Given the low level of intra-EEC trade in fluid milk we can conclude that disparities of farm structure and performances have not resulted in the dairy industry of any country taking over the fluid milk market of any other country. Clearly the deficiency in Spanish dairying is largely associated with the Galician dairy industry.

Table 2-4

Distribution of Dairy Farms in the EEC Countries by Numbers of Dairy Cows (in thousands). December 1977

Countries	<10	10-20	20-30	30-50	>50	Total
Germany	302	146	48	20	2	518
Belgium	26	22	10	7	1	66
Denmark	16	18	10	10	3	57
France	273	186	75	35	7	576
Holland	18	18	16	19	12	83
Ireland	70	24	12	9	5	120
Italy	390	36	13	8	6	453
Luxemburg	1	1	1	0	1	4
U.K.	12	10	10	16	24	72

Source: E. Diaz Patier: la Ganaderia Espanola ante la Integration en la C.E.E., Revista de Estudios Agrosociales N 116, July-September, 1981.

Another reason why the entry of Spain into the EEC will have a negative effect on the Spanish dairy industry is because of the shifts in prices of inputs and outputs that will allegedly occur after accession. The price of milk, it is asserted, will fall, and the price of concentrates will rise squeezing out the profitability of many small farms.

A study carried out in 1980, by E.W.F. Peterson, A. Pelach Paniker, H.M. Riley and V. Sorenson [60] for the USDA established the difference in prices paid and received by Spanish farmers under two scenarios, Spain in and out of the EEC, for several commodities for the year 1979 Table 2-5 below shows these two scenarios.

We can see in Table 2-5 that had Spain been a member of the EEC in 1979 the dairy farmers would have experienced a reduction of 8% in the price obtained by their main output and an increase of 11% in the price of a critical, not readily substitutable, input, when compared to the Spain out of the EEC situation.

Table 2-5

Prices Paid and Received by Spanish Farmers under two Alternative Scenarios, 1979.

Prices Paid by Farmers as of 1979				
Product	Units	Spain out EEC	Spain in EEC	% Change
Feefstuffs	pts/kg			
Barley	,,	11.6	13.75	+18.5
Corn	,,	13.5	15.15	+12.
Sorghum	,,	12.5	14.80	+18.4
Feed Compounds				
Cattle Fattening	,,	16.3	18.1	+11.
Dairy Compound	,,	16.8	18.5	+11.
Beef Feed-mix	,,	12.0	14.5	+20.8
Live Animals	(pts/head)			
Young Calf	40 kg lwt	16500.	15800.	-4.2
Dairy Cow	(head)	60000.	60000.	--
Prices Recieved by Farmers, as of 1979				
Product				
Corn	(pts/kg)	13.55	13.65	+.74
Barley	,,	11.30	13.36	+18.3
Beet	(pts/kg lwt)	136.55	133.8	-2.0
Veal	,,	165.35	165.35	--
Cow milk	(pts/lt)	19.30	17.75	-8.0

Source: E.W.F. Peterson, A. Pelach Paniker, H.M. Riley, V.L. Sorenson. Spain's Entry into the European Community Effects on the Feedgrain and livestock Sectors. USDA, ERS, FAE Report 180.

The figures of Table 2-5 were obtained for the year 1979 and were consequently dependent on the exchange rate alignments corresponding to that year. However, from that period the currencies of many countries have experienced large changes in their values and the 1979 in EEC scenario shown in Table 2-5 was by 1980-81 apparently no longer relevant. According to Jose Colino [18] by 1980/81 the EEC indicative price was about 22.26 pts/lt for milk with 3.7% of fat matter. During the same period the Galician dairy farmer was getting between 20. and 21.25 pts/lt for milk with 3.4% of fat matter. These same currency realignements have, however, resulted in a major increase, much higher likely than what Peterson et al. considered in 1980, in the prices of the imported feedstuffs (corn and soybeans).

Entry into the EEC will likely result in a change in the pattern of international and interregional trade for the Spanish and the Galician dairy industry. It is considered (E. Diaz Patier [26], Jose Colino [18]) that the southwest French dairy industry will have the comparative advantage in the Spanish northeast milk market displacing from that market the Galician and North dairy industry. On the other hand, simultaneous entry, as it is likely, of Spain and Portugal into the EEC will mean that the Galician dairy industry will gain access to an important and undeveloped milk market. For a market of about 10 million people the

Portuguese dairy industry produced in 1978 about 55% of the Galician milk output. In 1973 the consumption of milk per capita in Portugal was 57.4 lt against 93.1 in Spain (the data above comes from J. Colino [18]). The existence of a large and undeveloped market with respect to which the Galician dairy industry has locational advantage provides an excellent oportunity for the Galician dairy farmers.

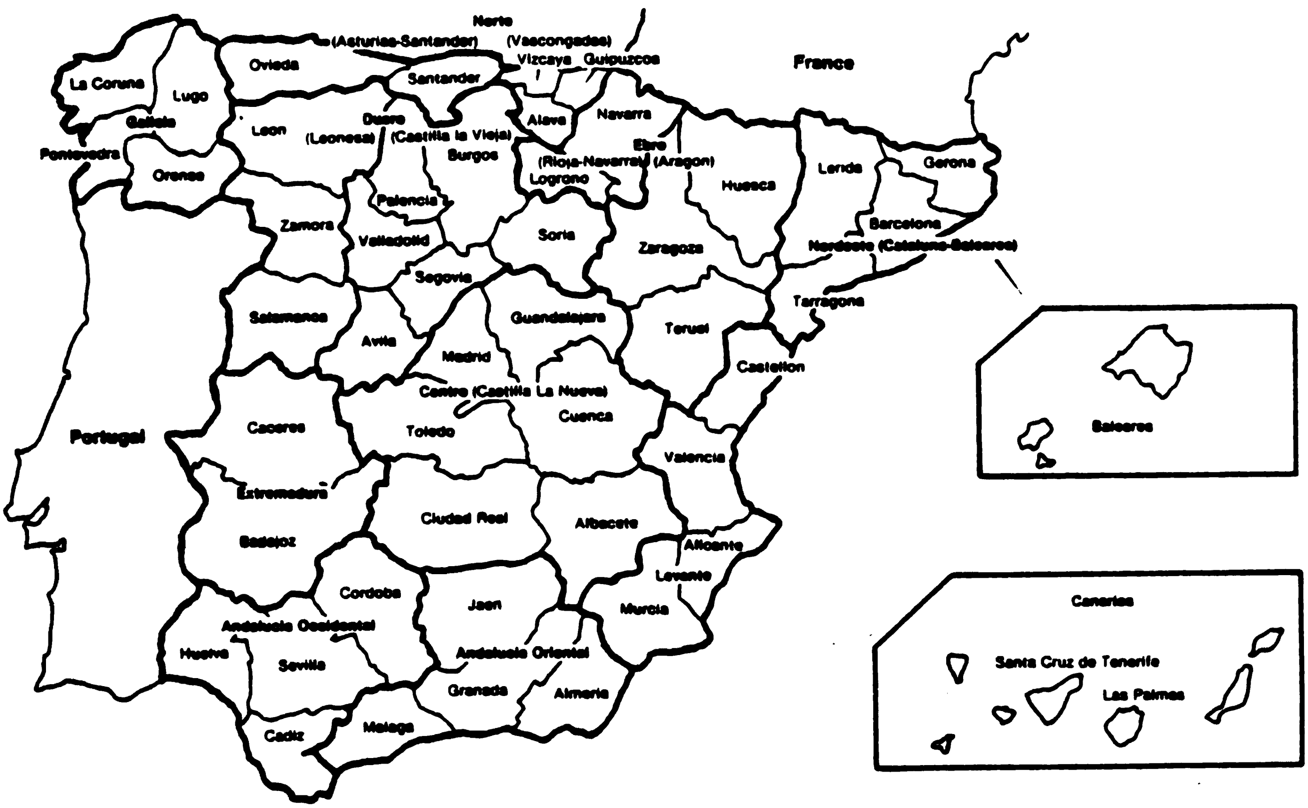
Another positive aspect of the entry for the Spanish dairy farmers comes from the difference in price support mechanisms between the EEC and Spain. Although both systems guarantee minimum prices for the farmers, the Spanish system does not guarantee that all milk produced by the farmers will be acquired by the processing industry. Only about 50 to 60 % of milk output in Galicia is purchased by the milk processing industry, the rest being converted into cheese by the farmers, fed to the calves or consumed in the farm, all suboptimal uses of milk from the farmers point of view. The Spanish farmers work under some sort of global output constraint which has many distributional effects (the smaller farmers are more negatively affected than the larger) but which has meant that no surplus disposal problems, and the implicit budgetary costs, have resulted from the price support mechanism. The change in regime, if no structural change occurs in the EEC price support mechanism, will release the marketing constraint and, providing that the quality conditions are met, will result in increased revenues for the Spanish, especially Galician farmers.

2.2. The Galician Dairy Industry Problem. Diagnostics and Prescriptions.

On the basis of total annual rainfall, Galicia is the wettest region of Spain, but it is located in the crossroad between an oceanic and Mediterranean climate and suffers from a summer dry spell affecting its southern part. Lack of rain during the summer and low temperature during the winter result in a typical pasture growth pattern with a high peak during the spring and a lower peak during the fall and very little or no production the rest of the year.

Population is about 2,700,000 people, 375,000 of whom are farmers (most of them dairy and/or beef farmers). Regional income per capita ranges between 60 and 83% of the national average. Agricultural income-per capita is much lower, perhaps half of the non-agriculture level.

Figure 2-1: Map of Spain



Galicia has an extension of almost 3 million Has. out of which slightly more than half a million are allocated to annual crop cultivation and almost as much to pasture. There are about 900,000 Has of forest and, most importantly, almost 800,000 Has of underdeveloped (although not unused) scrub land, most of which is communal or public land. There are around 1 million head of cattle in the region, of which about 635,000, are dairy cows. Thus the region has an important place in the national cattle subsector. It keeps 23% of total cattle and accounts for roughly 14% of total slaughter, and is also a major exporter of feeder cattle to other regions. It produces around 22% of total milk output.

Galician agriculture suffers from a variety of structural ills: too many small farms, farms too fragmented, farmers too old, deficient herd and pasture management techniques, low cattle sanitary standards, lack of capital and lack of access to credit, very little technical assistance, and inefficient marketing channels. According to the 1972 census (which gives rather unreliable figures) the average number of dairy cows per farm was 2.7 and about 264,000, or 68% of the total farms had fewer than 4 Has.

Table 2-6 below gives the farm size structure for the year 1977.

Table 2-6

Galician Farm Size Structure, 1977

Size	N Farms	N Head	Head/Farm
0- 3 Ha	113145.	226634.	2.00
3- 5 Ha	47272.	154632.	3.27
5-10 Ha	53865.	254452.	4.72
10-20 Ha	28144.	194456.	6.90
20-50 Ha	6643.	66387.	10.00
>50 Ha	375.	14271.	38.05
	249444.	910832.	3.65

Source: C. Rodriguez Epelde, C. Posada Naria, R. Gonzalez Santillana, la Produccion de leche en Galicia, mimeo.

As we can see in Table 2-6 the stocking rate is very low for all farm sizes with more than 64% of all farms having fewer than 4 heads per farm.

The figures in Table 2-6 come from census and global statistics that are considered somewhat unreliable. More reliable information has been obtained by E. Diaz Patier and F. Sineiro wh0 conducted extensive surveys in 1979 and 1980 of various municipal districts all over Galicia [27] [28]. The first survey, in 1979, was made in the Inner Galician Plateau, a quite homogeneous area. The second survey drew data from various municipal districts all over the region. Table 2-7 below show the internal farm structure of the average farm.

From Table 2-7 we can obtain two different measures of the stocking rate. If we consider the total size of the farm the stocking rates are .63 and .56 cows/ha for the 1st and 2nd survey data respectively. If we disregard the underused bushland area the stocking rates rise to 1.97 and 1.37 cows/ha which gives a different picture of farm efficiency.

The surveys provide information on a large number of socioeconomic factors characterizing the Galician farms. Most important among them is the degree of adoption of a series of technical equipment and practices that reflect the degree of modernization of the farms. Table 2-8 shows the rate of adoption of modern equipment and practices.

Table 2-7

Distribution by Land Type of the Average Farm Area In Galicia, 1979, 1980.

Land Type	1st Survey (1979) Ha	%	Cows	2nd Surveys (1980) Ha	%	Cows
Irrigated Pasture	.46	5.36		.70	7.54	
Nonirrigated Pasture	.81	9.44		1.08	11.63	
Artificial Pasture	.23	2.68		.27	2.90	
Cropland	1.28	14.92		1.74	11.73	
Bushland	5.80	67.60		5.50	59.20	
Total	8.58	100.	5.48	9.29	100.	5.21

Source: E.Diaz Patier & F. Sineiro Garcia. Factores que limitan la Utilizacion de las Tierras a Monte. Estudio de una Zona de la Meseta Inrerior Gallega. Communicaciones INIA, Serie: Economia y Sociologia Agrarias, N 7, 1979.
----. Factores que limitan la Utilizacion de las Tierras a Monte. II Analysis de Ocho Municipios en Diferentes Zonas de Galicia. Communicaciones INIA. Serie: Economia y Sociologia Agrarias, N 11, 1981.)

C.Rodriguez Epelde, C. Posada Naria, and R. Gonzalez Santillana [68] made a detailed account of the problems plaguing the Galician dairy farms. They distinguish two major types of problems: (a) Socio-economic; (b) Technical. Among the socioeconomic problems they make a further distinction:

i) Structural: Small size, excessive fragmentation, dispersion of plots, defficient electrification, bad roads.

ii) Economic: Lack of resources, expensive loan conditions and not enough credit.

iii) Social: Farmers too old, lack of training, inefficient marketing channels.

Among the technical problems they also distinguish:

i) Low forage production due to bad choice of crops and varieties, inadequate and insufficient fertilization, poor management of crops.

ii) Low cattle productivity caused by poor genetic endowment, poor feeding, poor reproduction management, lack of sanitary control, deficient installations.

iii) Low product quality due to poor milking procedures, inadequate milking installations, poor milk handling and conservation procedures.

iv) Investments poorly planned. Inadequate mechanization and buildings. Bad choice of investments.

Table 2-8

Rate of Adoption of Modern Practices
by Farmers in Galicia in 1979.

Practice	N of Farmers	%
Tractor	155	39.23
Milker	29	7.34
Modern Barn	89	22.55
Silo	40	10.12
Artificial Pasture	155	39.23
Hybrid Corn	95	24.05
Total # of Farmers	395	

Source: E. Diaz Patier [25]

Adoption of modern practices has been slow which contributes to the low stocking rates and low milk yield per cow of the Galician dairy industry.

To solve these problems many authors recommend the concentration of efforts on the 5-20 hectares farm strata which amount as we saw in Table 2-6 to about 87000 farms. The general opinion is that rational development of the underused resources (especially land and labor) of these farms will result in a Galician dairy industry able to withstand the feared EEC competition and able to take advantage of new opportunities that the accession will generate. The extent of the chronic structural and technical problems that we just mentioned require, however, more than a token structural policy for those opportunities to be realized.

By the late 1970's the decision-making establisment started to take a look at the basic constraints blocking the growth of the subsector. During those years several agencies within the Ministry of Agriculture were dealing with some of the structural problems of the industry: the IRYDA, Instituto de Reforma y Desarrollo Agrario (Institute for Agrarian Reform and Development) addressed the problem of excessive parcellation and small size of farms through a land consolidation and land improvement program. The SEA, Servicio de Extension Agraria (Agricultural Extension Service) provides -- among other tasks performed -- credit to finance the settlement of young farmers. The Ministry of Agriculture also offers through its diverse departments a panoply of subsidies, health programs, investment tax credit, insurance programs, etc, that have a direct bearing on the subsector. Finally and most importantly, because dealing exclusively with the livestock sector, the ADG, Agencia de Desarrollo Ganadero (Agency for Livestock Development), created in 1969 to implement a credit program funded by the World Bank, has since administred a supervised credit and technical assistance program which stresses the development, until now neglected, of the pasture and grazing lands.

Research, conducted by the regional experimental stations of the INIA, Instituto National de Investigaciones Agrarias (National Institute for Agricultural Research) has also increasingly focused on the technical problems of land reclamation and pasture and grazing land development and by now, at least in what concerns the northwest and north of the country, a set of technical recipes exist that can be delivered by the extension service to the farmers.

In 1980 the ADG completed a diagnostic study which attempted an assessment of the potential for improvement of the sector in every agricultural region. By constructing a set of synthetic farm growth models (based on the research produced by the experimental station) for every regional situation it estimated the credit needs for each farm situation on the basis of which a national credit plan for the period 1980-1984 was designed. The ADG plan calls (for all Spain) for the formulation of 2515 farm plans for the five-years period, with a total required funding of 19486 million pts (about $130 million; $1 = 150 pts) of which 3899 millions pts ($26 million or 20% of the total) should be contributed by the farmers themselves. Loan conditions are: length, 12 years, 3 years grace period and interest rate of 13% (with an inflation rate roughly the same or slightly higher).

The potential for development estimated by the ADG diagnostic study is shown in Table 2-9.

Table 2-9

Potential Increase in Productivity in Galicia in Thousands of Equivalent Cows, 1980.

Increase in Productivity of Forage Crops	97.1
Increase in Productivity of Natural Pastures	207.9
Increase in Productivity of Upgraded Bushland	294.4
Total :	599.4

Source: Agencia de Desarrollo Ganadero, II- Galicia, 1980.

The potential for development and improvement in Galicia is high. The ADG diagnostic study found that through modest (and reachable) increases in the productivity of existing crop and pasture land and reclamation of part of the existing scrub land, feed resources might grow to allow increases in the number of cattle of about 435,000 breeding cows.

Technical recipes are now available to convert the scrub into pasture lands and many farmers are aware of them. For historical reasons, however, a great share of the scrub land is still common property tied by a very complex status which gives use rights but not exchange rights to communal right holders. Common property land accounts, according to some estimates, for about 32% of total land. Reclamation of that extension, now technically feasible, and enlargement to more efficient size of many farms faces first of all a direct legal obstacle.

Division of communal lands among communal title holders should, by allowing many farms to reach efficient size, lead to a Pareto-Optimal improvement, and is currently underway in many places. However, legal and administrative problems (investigation of who holds what rights within each community, etc.), high transaction costs in getting farmers together to agree on the division, etc., has slowed the division process considerably.

In summary, we can analytically envision three patterns of structural change which have taken or may take place in Galicia concurrently.

(a) A continuation of the off-farm migration process affecting family farm workers (and many farm operators). This process has been going on since the early 50's and accelerated during the 60's and early 70's as labor salvage value rose following the general economic growth in Spain and Europe. Concentration of land did not ensue however due to high population pressure, lack of capital and high land prices and because many migrant farm operators retained their land holdings (probably as a hedge against inflation, among other reasons). This process slowed considerably during the late 70's and early 80's as economic growth halted in Europe and Spain and high unemployment rates settled in. Galician farm population grew older as young people left the sector en masse (and the region and country) during this period.

This off-farm migration pattern may resume any time economic conditions allow it to proceed, given the existing gap between farm and non-farm income per capita, although it is questionable whether a pool of young people to draw from still exists in the sector.

In any case, the rigidities and imperfections of the land market may block any major farm restructuring through the buying and selling of land as people leave agriculture.

(b) In-farm structural change. For example, the upgrading of underused land resources controlled by farmers as they adopt new technologies and follow a vertical growth strategy. Supply of credit, research, extension and education will play a major role in this process of improvement of physical and human resources. This type of structural change appears to be the focus of current policy programs like the ADG credit/technical assistance program.

(c) Mobilization of common-property land resources through division or any other means which would result in increasing average farm size. After the institutional process is over an in-farm vertical-growth structural change as described in

(b) above may ensue. Obviously the solution -- characteristics, timing -- to the institutional problem is a critical element in the development of this pattern of change.

Process (b) will be at the center of our research. Upgrading the bushland hectareage and expanding the dairy herd of the typical farm will require a profound change in the management practices. A new technology encompassing new crops, improved fertilization, production of silage, forage conservation policies, cattle management practices, feeding regimes, health management, milking procedures, etc, has to be developed and evaluated by the experimental station researchers, mastered by the extension agents, conveyed to the farmers and learned by them. The process will pose significant technical and financial problems. Detailed and refined information regarding the best management practices to follow and the likely consequences of any recommended growth strategy is required. The production of that refined information is the object of this research.

CHAPTER 3

Theoretical Framework.
The Dairy/Forage Farm Management Problem
in the Galician Setting

We have seen in the last Chapter that improving the performance and productivity of the Galician dairy industry calls for a strategy focusing on a particular group of farms. Those between 5 and 20 hectares are to be brought to a higher level of performance following a vertical growth path.

The target group of farms are characterized for having an important proportion of their resources, mainly labor and land underused. The strategy calls then for supplying enough credit, and under such conditions, farmers can upgrade their underused land and acquire complementary inputs, -machinery, buildings, more dairy cows, etc- , so that output per hectare and unit of labor will increase, average costs will be reduced and the general efficiency of the industry will rise.

Putting a traditional dairy farm through the modernization process involves more than just acquiring new inputs. Managing a medium size modern dairy farm is a difficult problem, and quite different from that of managing a traditional dairy farm, which requires a good deal of information to be collected and processed by the manager in order for good decision-making to be made. Consequently, it is not only the physical assets of the farm that must be upgraded and added to; the management skills of the farmers must also be improved if the growth process is going to be successful.

Recognizing the management problem of the growth strategy, the ADG plan provides for technical assistance to accompany the supply of credit to the target farms. Under a market environment which has tightened lately, and which will further do so when the entry is completed, sound technical and managerial advice is critical for a viable growth process and good economic performance to result.

The production of good technical and managerial advice to be provided to the target group of farmers is the task of researchers in the experimental station, the ADG, and the extension service. The agronomic, biological, nutritional and economic problems present in the operation of modernization farms are, however, not trivial at all. There is also the complementary need for information that could orient the research into those areas where the payoffs are highest, so that scarce research resources are most efficiently spent. Attempting to meet these two needs is the goal of this research.

We can distinguish four types of technical and managerial problems or set of problems involved in the operation of dairy farms: (i) Cropping and forage conservation problems; (ii) Herd management problems; (iii) Feeding policy problems; (iv) Equipment selection problems. A fifth additional problem relevant to our case is: (v) Growth management problems. We will now examine these problems, the forms they take in the Galician context, the analytical methods used and answers obtained by previous research that dealt with them.

(i) Cropping and forage conservation problems.

The cropping and forage conservation problems arise from the different seasonal pattern of grass production and feed requirements from the herd. In Galicia, as we will later see in more detail, seasonal grass growth follows a two-peak curve, with a high peak at mid-May and a low peak between mid-October and mid-November. During the summer there is little or no production of grass, lack of water being the cause. On the other hand, feed requirements follow the biological and productive status of the cows. They take a smoother path than grass growth and peak between 6 and 10 weeks after parturition. The two seasonal patterns of grass growth and feed requirements can be articulated by setting the calving date of the herd so that the heaviest feed requirements during the year coincide with the high peak of the grass growth curve. Finding the optimal mean calving time in this context requires a process of trial and error that if done via real experimentation would be very costly.

A related problem to finding the best mean calving time is deciding on an appropriate forage conservation policy. Whatever the ideal mean calving time is, it will always happen that during the year there will be periods of feed surplus and periods of feed deficit. The way to transfer feed from surplus periods to deficit periods is by reserving a portion of pasture for grass silage production during the peak periods and giving that surplus feed to the cows during the deficit periods. The number of silage cuts to make and the proportion of pasture to be reserved for silage are critical decision variables that must be determined. As with finding the optimal mean calving time a trial and error procedure must be followed.

Another more typical agronomic problem is finding the optimal fertilizer application rate for the cropping program. Since usually a market price for grass does not exist, matching the instrumental marginal value product of fertilizer in the production of milk with the price of fertilizer, as classical production economics would tell us to do, is not a trivial problem. Given the complexities of the dairy's imperfect substitutability relationship with concentrates, a whole systems experimentation is once again called for.

Designing an efficient rotation plan which results in a high utilization of the grass produced by the cows represents an important problem also.

Finally, we saw in the previous chapter that the typical dairy farm has a small but important portion of its land that can support a cropping program. Information is now available (Jaime LLoveras, [44]) on alternative cropping patterns for several locations in Galicia. Nevertheless a whole system experimentation would likely be necessary in order to see how the different cropping alternatives fit into the whole system.

(ii) Herd management problems.

The single most important herd management problem is finding the optimal stocking rate. However, as we will see shortly, making that determination requires consideration of the forage production problem and determining the optimal rate of consumption of forage and concentrates on an annual basis.

An important herd management problem that we already mentioned is fixing the mean calving time which would set the pattern of feed requirements throughout the year. Also, setting the length of the calving and lactation periods is critical if slippage between the grass growth curve and the optimal feed requirements curve is to be avoided. The rate of weight gain, and hence the nutrition programs, of growing calves and heifers for replacement is important in order to shorten the time for the heifers first freshening, i. e., the time at which they will become productive. This, of course, can also be considered a feeding problem.

Deciding when to replace older cows or cows with reproductive and productive problems requires close attention from the manager. Healthy cows may also be replaced by heifers in first lactation if the expected marginal returns per unit of time of the old cow are less than the expected average returns per unit of time of the heifer (J. Hlubik [36]).

(iii) Feeding policy problems

Dairy scientists, nutritionists, economists and others have spent a great deal of time searching for a solution to the feeding problem which, stated succintly, consists of finding the optimal rate of concentrate and forage to feed the cows. Optimal often means those rates that will result in the highest returns over feed costs.

The way of looking at the feeding problem has varied over the past years as new analytical techniques developed and deeper understanding of the biology of the dairy cow was achieved.

In the beginning (i.e., during the 40s and 50s) it was the production function approach. The concepts of diminishing returns and substitutability or complementarity of outputs were concepts that the economist was familiar with from the theoretical point of view. The feeding problem would be easily resolved provided that field research would come out with a neat, well-behaved production function linking concentrate and forage consumption rates to milk yield. Once the production function is known it would be a matter of finding the expansion path or least-cost-input combination in the input space and then the high profit point in the total physical product and marginal physical product spaces where the input would be a composite of the inputs in their least-cost combination (J.C. Redman [66]).

The experimental issues emerging from the production function approach were aptly stated by J.D. Coffey and W.D. Toussaint [15].

> "(i) Are the marginal rates of substitution between hay and grain constant or changing?; (ii)

> Does the principle of diminishing returns apply to milk production? (iii) What is the economic significance of the feed-milk relationship?"

Researchers were able to find production functions which showed diminishing returns and slightly curved concentrate-forage isoquants. On the basis of this finding they moved to find the optimal input combination rate and the optimal feeding rate, i.e., the high profit output point. However, the fits were not as good as expected, variances of coefficients were high, and many important variables were not included in the regression, especially body weight changes, which likely resulted in biased estimates. Also the regressions contemplated the feeding problem on an annual data basis or only a small phase of the lactation cycle of the cows.

A way of dealing with the shortcomings of the first experiments was to include in the regression all the supposedly omitted variables so as to improve the quality of the fits. E.O. Heady, J.P. Madden, N.L. Jacobson and A.E. Freeman [34] incorporated into the analysis many other variables: stage of lactation, cow ability, body weight, index of inbreeding, age of cow. L.M. Hoover, R.L. Kelley, G.M. Ward, A.M. Feyerherm, and R. Chaddha [37] added body weight change and environmental temperature as new regressors. The regressions explained up to 85% of the variation in milk yield. The results were promising enough, apparently, to confirm the soundness of the production function approach. According to Heady et al.[34]:

> "The study, while not considered final in respect to coefficients for numerous variables, suggests that with further research, many aspects of dairy cattle breeding, nutrition and management can be incorporated into a single estimated production function".

A shift to another analytical technique considered more adequate in dealing with the feeding problem was announced earlier, by Coffey & Toussaint [15]. After critically looking at the research conducted by the proponents of the production function approach they concluded that (i) there was a wide range of feeding over which returns are not affected very much; (ii) Hay-grain isoquants are almost linear; (iii) Optimum rations lie near the stomach-capacity limit for most prices of hay, grain and milk; (iv) Feeding cows hay, free choice, results in greater returns than for limited feeding when body weight changes are considered. Based on these considerations they recommended the use of linear programming techniques to tackle the dairy feeding problem.

The advice was heeded by many researchers. In 1969 G.W. Dean, D.L. Bath and S. Olayide [23] developed a linear program to maximize income above feed costs for dairy cattle. The model took advantage of the accumulated knowledge produced by dairy and nutritional scientists concerning the nutritional requirements of the dairy cow for milk production, body maintenance, etc. Feeds were connected to milk yield not in the direct way emphasized by the production function approach but as carriers of a variety of nutrients that the cow metabolism would allocate to various tasks, mainly body maintenance and milk production.

The model simultaneously selects the concentrate and forage components of the ration, the roughage-concentrate ratio, level of feeding per cow, and quantity of milk production maximizing income over feed costs. The model works on a per cow per day basis but considering its static nature is only applicable to a short phase of the lactation cycle since the milk production curves incorporated in the model are only valid for a particular stage of the lactation cycle.

Improved knowledge about the nutritional requirements of the dairy cow resulted in a refined, although essentially similar, model that D.L. Bath and L.F. Bennett [6] report on in 1980. They report an increased awareness of the limitations of the model which is only valid for the first phase, from parturition time to the peak of lactation, of the lactation cycle. The model resolves, for that particular period and for a particular cow, the problem of choosing the components of the concentrate and forage portions of the ration, which is an important problem for drylot large-scale dairy farms without a cropping system that purchase most of their feedstuffs.

We know, and will see later in more detail, that cows differ in their milk production ability, that for every cow annual milk yield increases substantially from the first to the sixth lactation falling slightly in the seventh lactation, and that during the lactation cycle daily milk yield follows a defined path, rising steeply in the first 6 to 8 weeks after parturition time, reaching a peak, and then falling at a slower rate, in an almost linear fashion, from peak time to the end of lactation.

These facts mean that for an LP model such as the one developed by Dean, Bath et al. to be capable of providing useful information on a whole system basis, a collection of models should be constructed, ideally, for every cow ability, every lactation number, and every distinct stage of the lactation cycle. Implementation of such a collection of models for managing a dairy farm would be, by time and cost considerations, prohibitive.

In a simulation model designed to handle the cow replacement problem, J. Hlubik [36] gets around the lactation stage problem by incorporating in a simulation biological dairy cow model an LP feed selection model similar to Dean & Bath 's model which is solved once every month during the annual production cycle. His model is, however, a single cow model and would not be able to deal with the whole farm system management problem.

The newest approach to tackle the dairy farm technical and management problems is based on the systems approach. Improved knowledge about the biology of the dairy cow has resulted in the conceptualization of the milk production process as a complex, dynamic, nonlinear, biological process that would fit into simple, static, linear, analytic frameworks only with great difficulty.

A.C. Bywater and J.B. Dent [11] see the milk production process in the following light:

> "milk production (...) is a continuous sequence of events involving more than one output (i.e., milk, progeny and body tissue). It is an enterprise in which present decisions within a herd greatly influence the spectrum of future decision opportunities.
>
> The relationship between feed intake and milk yield is not a simple one and is conformed by factors within the animal and in the feed on offer.
>
> Level of intake, stage of lactation. growth requirements, pregnancy and body energy status all have a profound effect on the way the cow uses the energy available to her."

We will follow this new philosophy in our research, taking advantage of the accumulated knowledge about the biology of the dairy cow as it is collected in the National Research Council guidelines [55] and in the relevant literature on dairy systems.

The feeding problem takes a simpler form in the Galician context. Only two feeds are considered: (a) Commercial concentrates with a constant nutrient content. (b) Forage, in form of grass grazed and silage, whose nutritional quality varies throughout the year. We can conceptualize the daily feeding problem in this case as a simple two activities, three-contraints, linear program. The activities are concentrate consumption and forage consumption. The constraints are metabolic energy requirements, crude protein requirements, and the dry matter intake upper bound. The system of equations must be solved every day (or week) since the constraints shift from one day to the next due to the changes in the biological status of the cow, in the lactation curve, in the dry matter intake and in the nutritional quality of the forage. Furthermore, no market exists for the forage input and consequently no price, requiring, as we will see in more detail in the next chapters, an iterative procedure to find the best concentrate-forage feeding rule.

We had mentioned earlier that the feeding problem, the forage production problem and finding the optimal stocking rate were interrelated problems. Let us now see that in more detail. The following system of equations, on an annual basis, will help us in our discussion. Let Y be total milk production, LC total lactating cows, y milk yield, c concentrate consumption per cow, f forage consumption per cow, dmi dry matter intake per cow, a herd mean age, F total forage production, H total hectareage, yf yields of forage per hectare, n fertilizer rate per hectare:

$$Y = LC * y \qquad (1)$$

$$y = h\ (c,f,a) \qquad (2)$$

$$dmi = c + f \qquad (3)$$

$$f = F\ /\ LC \qquad (4)$$

$$F = H * yf \qquad (5)$$

$$yf = g\ (n) \qquad (6)$$

Given (3) we can rewrite (2) as:

$$y = h\ (c,\ dmi-c,\ a) \qquad (2a)$$

(4) can be rewritted as:

$$LC = F\ /\ f \qquad (4a)$$

or taking into account (5) and (6)

$$LC = H * g\ (n)\ /\ f \qquad (4b)$$

We have now the reduced system:

$$Y = LC * y \qquad (1)$$

$$y = h\ (c,\ dmi-c,\ a) \qquad (2a)$$

$$f = dmi - c \qquad (3a)$$

$$LC = H * g\ (n)\ /\ f \qquad (4b)$$

In this system, where a, dmi, and H are given, we can see that deciding on the two values c and n will completely determine the rest of the variables. Given c we obtain milk yield from (2a), we also determine forage consumption per cow, f, in (3a). This value of f together with the fertilizer application rate n will fix the stocking rate, LC, in (4b). The prices of milk, concentrate, and fertilizer, will determine the optimal concentrate-forage ratio, forage production per hectare and stocking rate in an interrelated fashion as we have said.

(iv) Equipment selection problems.

Making a sound selection of the equipment most adequate for a dairy farm taking into account its size and labor endowment, is critical toward enhancing the profitability of the farm business and the viability of the growth process. The choice usually encompasses a wide variety of alternatives regarding housing type, milking systems, feeding machinery, manure disposal systems, tractor size and machinery complements for the cropping program, etc. Every machinery selection will result in a labor requirements profile during the year that must be matched with the labor available in the farm. Every alternative involves a stream of costs and benefits over its life, and a budgeting procedure would need to be followed in order to find the best alternative for every type of farm.

Also, it is critical to evaluate the profitability of irrigation schemes that will raise the grass growth curve during the summer. Such investment would radically alter the forage and feeding problem conditions as we have envisioned them in the pages above and would allow the stocking rate to be increased substantially and total farm output to rise.

Solving the machinery selection and the investment decision problems is, when using the classical budgeting approach, a costly undertaking. Thus the need arises for an analytical tool that can get the budgeting job done more efficiently.

(v) Growth problems.

The providers of technical and managerial information will be required to come out with sound prescriptions for the four types of problems examined above. Furthermore, these problems will have to be faced in the context of a growth process that will require careful and sound long-term forward planning.

S.B. Harsh, L.J. Connor and G.D. Schawb [33] state a set of prior conditions that must exist before a farm is capable of undertaking a growth process. These are:

1. A farm must be profitable or potentially profitable.

2. A minimum starting size is necessary in order to generate savings or to attract outside capital.

3. Some underutilized resources need to be available to combine with newly acquired inputs.

4. Additional resources must be procurable for the farm operator, especially capital.

U. Renborg [67] also stresses the existence of unused resources within the firm as an opportunity for growth to occur. He also points out the new managerial and skill abilities required to manage the new larger farm.

The ADG strategy and the group of target farms toward which the growth strategy is addressed seem to comply with that set of prerequisites. Underused resources, land and labor, do exist and a minimum starting size is envisioned in the ADG strategy. The credit and managerial constraints are also accounted for in the ADG strategy.

Nevertheless, a forward detailed look of the farm business as it grows is necessary in order to assess the viability of the growth process and the profitability of the investment. Checking to see whether the funds allocated to the growth program return a payoff high enough is neccessary if misallocation and outright waste of resources is to be avoided.

In the Galician dairy farm growth process the timing of the investment, the evolution of output growth and the financial conditions of the loans taken by the farmers have profound influences in the outcome of the growth process. Accurate projection of output and input use during the life of the investment requires paying careful attention to the demographic evolution of the dairy herd since, as we have seen, milk potential depends on the age of the cow (lactation number). The solvency and the liquidity of the farm business are dimensions of business performance that must be closely monitored during the growth process.

In the Galician case the land reclamation part of the project which is the foundation of the growth process will determine the evolution of the economic performance of the farm during the life of the investment.

Upgrading bushland into seeded pasture and having it producing at a level commensurate with fully developed pasture is a process that takes, according to F. Sineiro

[73], at least four to five years. This means that the capacity of the land to support a larger dairy herd will rise in pace with the grass yields on developing pasture. The timing of the investments, especially the building up of the dairy herd, the conditions of the loan, and the market environment, are all factors that will influence the outcome of the growth process.

The growth process is likely to take place in a context of constant medium to high inflation rates that must be taken into account in the process of designing growth plans for the target group of farms.

A final set of managerial problems emerges from the uncertain, climatic, biological, political,and economic environment surrounding the farm business. The growth strategies should be checked for probable undesired developments in the farm firm 's environment. Climatic and biological randomness, especially, must be considered by the providers of managerial advice.

Finally, considering the multiplicity of problems, technical and managerial, that Galician dairy farms face, the variety of farm types considered, and the dimension of the aggregate problem, i.e., modernizing a target group of about 85000 farms, efficient use of scarce research and extension services calls for efficient, labor-saving, analytical procedures that would produce timely and sound prescriptions adapted to local farm conditions.

CHAPTER 4

Methods

In this chapter we will first list a set of stylized facts concerning Galician dairy/forage farm systems that a comprehensive analytical framework should be able to handle. Second, we will examine and compare briefly optimizing versus nonoptimizing approaches to tackle the problems. Third, we will describe the system simulation modelling approach which is our method choice for this research endeavor.

4.1. Methodological Requirements of the Research.

A comprehensive consideration of the problems involved in the management of Galician dairy/forage systems should be able to:

1. Project the seasonal pattern of grass yields (kg DM/ha) throughout the year for the different types of pasture: irrigated, nonirrigated.

2. Keep track of changes in nutritional quality of the different types of forages during the year.

3. Handle alternative forage conservation policies.

4. Incorporate yield-fertilizer response functions for the various crops produced by the farm.

5. Keep track of the dairy herd age composition both throughout the year and between years in a dynamic way.

6. Handle such alternative herd management policies as setting calving dates, lactation cycle length, heifers first freshning date, etc.

7. Accurately track the productive and reproductive cycle of the cows throughout the year: pregnancy, lactation, calving period, open period, dry period.

8. Handle such herd replacement policies, as culling rates, and purchase of breeding stock.

9. Project removals of cows from the herd for a variety of reasons: disease, reproductive and productive performance, disinvestment decisions, etc.

10. Handle the complex biology of the dairy cow in detail. This means consideration of the temporal patterns of milk production (lactation curve), dry matter intake, body weight as they evolve throughout the different stages of

the production-reproduction cycle of the dairy cow.

11. Project metabolic energy and net energy requirements for maintenance, weight gain, pregnancy along with milk production requirements and crude protein requirements of the animals making up the dairy herd.

12. Handle the previous problems for the typical cow, growing calf and heifer in every age cohort.

13. Project the growth trajectory of the growing calves and replacement heifers.

14. Project aggregate feed requirements and feed availability during the year. Supplement the on-farm produced feed with commercial concentrates during energy deficit periods thoughout the year.

15. Handle alternative feeding rules.

16. Keep track of the financial status, i.e., solvency, liquidity, earning ability of the farm business.

17. Be able to assess in a capital budgeting way a variety of equipment and investment alternatives. Project the implications of these equipment alternatives on labor requirements and match labor demand with labor supply determining labor deficits or surpluses during the year.

18. Accurately simulate the growth process of the farm

business under a variety of credit conditions and alternative market environments paying particular attention to the financial implications (on solvency and liquidity especially) of the growth process.

19. Be able to incorporate climatic, biological, and market uncertainties.

4.2. Optimizing versus Nonoptimizing Models.

Two alternative types of analytical tools or models are widely used in the study of complex farming systems, optimizing models and simulation, or nonoptimizing, models. The distinction is, of course, not a sharp one. Optimizing models can be used in a simulated mode (e.g. parameterization of LP models) and simulation models, depending upon their size, can be optimized using a variety a optimal control or nonlinear programming algorithms.

In principle, any farming system's situation can be put in optimizing (LP) format or simulation format. Apparently, from the long history of LP applications, only imagination can limit the capacity of LP to handle problems. A variety of classical constraints on the technique (J. Roy Black & J. Hlubik [7]) like divisibility, proportionality, additivity (independence), exclusive activities, nonstochasticity of parameters have been released through new techniques:

Separable programming, integer programming, quadratic programming, chance constrained programming, stochastic programming, etc.

As we saw earlier, there is a variety of programming approaches to dealing with the feeding problem on a stage of lactation basis. We also saw (Chapter 2) that handling the dairy farm management in a comprehensive way, i.e., all cow ages, all lactation stages, required a large collection of LP models that would be too costly to operate. Although the LP technique provides an efficient way of solving the feeding problem where there is a large set of feeds from which to choose, in our case only two types of feeds are involved, and the nutritional quality of one of the feeds changes during the year. As we will see later, the feeding problem of the Galician dairy farms can be tackled with a simple set of time-varying equations, and no complex LP solutions are needed.

The growth processes of farming systems have also been studied within a programming framework. Recursive (T. Heidhues [35]) and polyperiod programming have been the most used techniques when the production activities of the farm can be cast in a static, annual format. However, accounting in an LP model for the intra-annual and between years dynamic evolution of the dairy herd, keeping track of age cohorts, weights, nonlinear lactation curves and dry matter intakes, and events like parturition, pregnancy, end of lactation, etc, although not impossible, (J. Hlubik ' s partial solution [36]) would result in a matrix of a prohibitive size.

In summary, casting the dairy/forage system as we have envisioned it earlier, in a programming framework, would be, in our opinion, an arduous, costly and inefficient way of studying the dairy/forage farming situation as it exists in Galicia. The rigidity of the LP framework would make it difficult to handle the "continuous sequence of events... an enterprise in which present decisions within a herd greatly influence the spectrum of future decision opportunities", which, in the words of A.C. Bywater and J.B. Dent [11] characterize the dairy farms. It is the flexibility of the simulation approach in dealing with dynamic processes, its free-format characteristics and the absence of need for a solution algorithm which make it suitable to our research problem.

4.3. System Simulation Modeling Approach.

The core of the system simulation is a model or set of models of the structure and processes constituting a system within which a specific set of problems is encountered and related sets of objectives have to be attained. The approach typically includes problem formulation, mathematical modeling, conversion of the mathematical into a computer model, model testing and refinement, and simulation, which is the application stage.

T.H. Naylor, J.L. Balintfy, D.S. Burdick and K. Chu [56] define simulation as a technique:

> "That involves setting up a model of a real situation (system) and then performing experiments on the model."

J.R. Anderson [4] defines it:

> "Numerical manipulation of a symbolic model over time."

Both are concise definitions that aptly capture the essence of the simulation modeling approach.

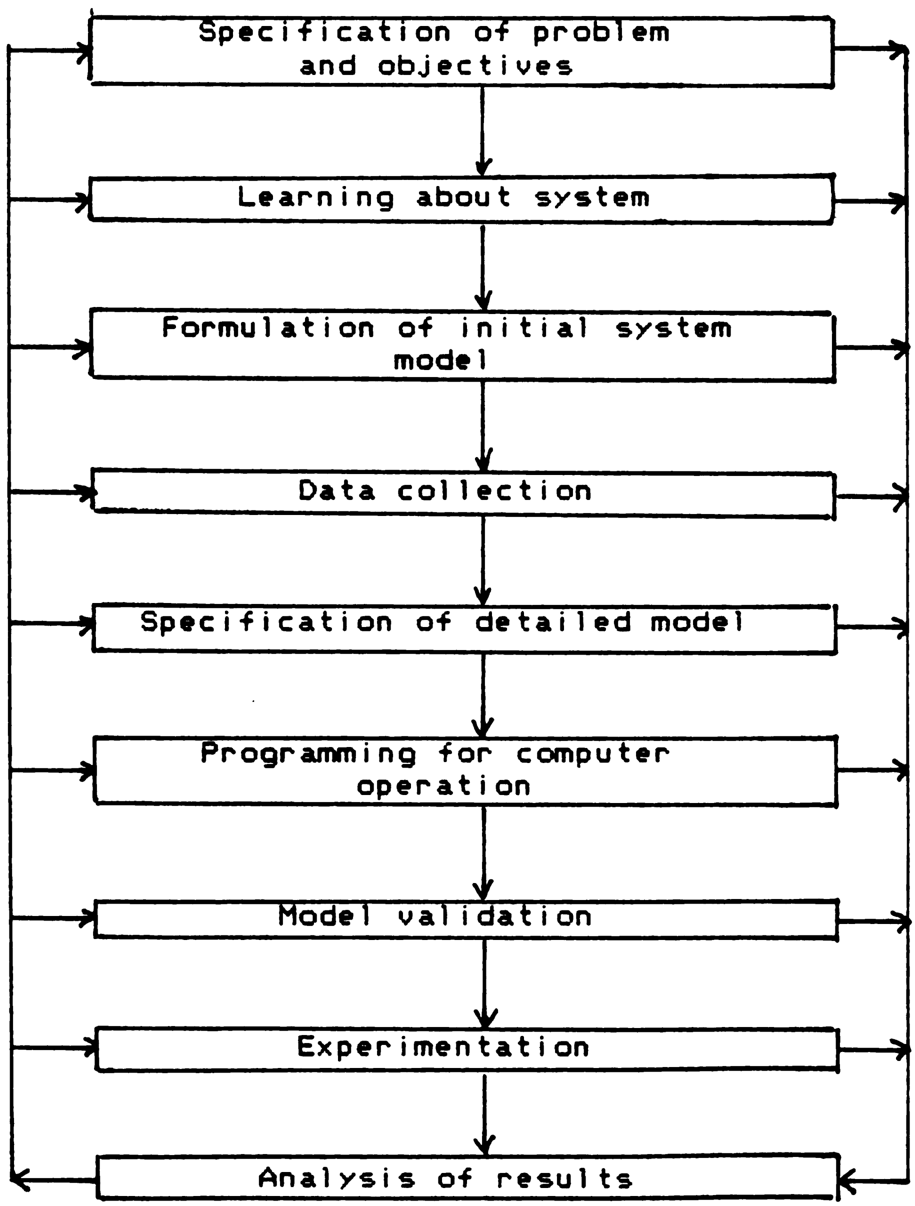
The system simulation approach can be characterized as a general, flexible, iterative, adaptive, and problem-investigating process. It is general with respect to philosophies, techniques, kinds and sources of data and information. Its flexibility rests in the building-block organization of its models, allowing for the development and incorporation of new components and the substitution of simpler components by more disaggregated ones as necessary for particular analysis. It also allows for the use of a wide range of modeling techniques from different disciplines. The iterative process traces the likely consequences of specific decisions and policies across a wide variety of dimensions of interest to decision-makers (such as time, space, income class). Through interaction with analysts and decision-makers, then, additional policy options may be defined for testing and modification in the models themselves. It is an adaptative approach in that improved knowledge about data, parameters, and structural relations can be progressively incorporated into the models. Finally, the approach focuses on the investigation of and search for solutions to actual problems. Positive and normative knowledge is required for this, and the approach is especially useful whenever an objective function encompassing the various goals of the decision-makers cannot be defined.

In addition to their primary contribution to policy assessment and design, system simulation models can make three other noteworthy contributions. First, during the modeling stage, a deeper understanding is gained by analysts and decision-makers of the structure and behavior of the socioeconomic system. Second, simulation analysis provides important insights about research priorities in three ways: (1) in the indication of data collection priorities (through sensitivity analysis), (2) in the identification of structural relationships and behavioral patterns about which theoretical disciplinary knowledge is lacking, and (3) in the identification of technical and scientific research areas with high potential investment payoffs. Third, a system simulation model can work as a sort of laboratory in which new knowledge and hypotheses about parameters and structural relationships can be tested.

In the Fig 4-1 below we can see a diagrammatic representation (taken from A. Wright [79]) of the stages involved in a simulation study.

Typically, the system simulation approach consists in an iterative process involving two steps: system analysis and system synthesis which are repeated several times until convergence, to a desired degree, between the operation of the real system or situation and the model is achieved.

Figure 4-1: Simulation Modelling Stages



Following the specification of the problem and the research objectives, a simulation study starts by collecting information, quantitative and qualitative, about the operation of the system. In this phase of data collection, knowledge about the system is drawn from a variety of disciplines that treat the system from different points of view. Disciplinary information is, however, not always, regretfully, of the type required for a complete simulation of the system. The heterogenous and incomplete information, theoretical and empirical, obtained is used, together with necessary assumptions required to fill the knowledge gaps, to create a synthetic model of the system. The simulation model, once validated, i.e., successfuly compared to the operation of the real system, is used in an experimental, analytical, mode enabling the analysts to learn about the detailed operation of the real system under a variety of circumstances, and changing values of the assumptions made (sensitivity analysis). The experimentation and the sensitivity analysis often uncover areas of model operation very sensitive to some of the hypotheses made earlier during the model construction phase. The controversial model operation draws the attention to those areas of the model (unknown parameters and deficient equations) causing it, thus orienting the disciplinary, analytical research into high payoff aspects of system operation. The orientation of the arrows in Figure 4-1 shows the iterative process of the approch and the possibility of going from one stage to any other when need arises.

The new analytical research ideally results in improved knowledge of the system that is incorporated into the model. New validation and experimentation follows and so on in an unending, iterative process. The direction of the arrows in Fig 4-1 illustrates this iteration process of the technique.

CHAPTER 5

Research Objectives

The main objective of this research is to create an analytical tool, i.e., a simulation model, which would incorporate, in an integrative manner, the existing, often dispersed, knowledge about dairy systems. The model should be able to help researchers explore the production function of Galician dairy farms in order to produce sound prescriptions for a wide range of short-term and long-term managerial problems in a timely and efficient way.

More precisely, our research objectives are:

1. To construct a general dairy/forage simulation model that can tackle the stylized facts of Galician dairy systems as they have been specified in Chapter 3.

2. To study on the basis of the simulation model and for a small-scale dairy farm situation a variety of short-term management practices concerning calving dates, forage conservation policies and feeding rules under alternative market conditions.

3. To assess on the basis of the simulation model the growth processes of dairy/forage farming systems under a variety of assumptions regarding resource base, inflation rates, and credit programs, with particular attention to the financial implications of the growth processes.

The model, whose development and validation is described in Part II, is used, when performing the experiments, in a searching mode. By this we mean that the optimal input combination or the best management practices are found by having the control variables of interest (e.g., daily concentrates fed to animals, calving dates, etc) change within a relevant range of values, running the model, and finding, in an empirical way and on the basis of performance variables previously selected, which value of the control variable is best.

PART II

MODEL DEVELOPMENT

CHAPTER 6

Model Overview

6.1. Introduction.

The Galicia Dairy Model is an interlinked set of submodels which attempts to simulate the complex biological, technical and economic relationships and processes which characterize the operation of the dairy/forage farming systems in Galicia. Being a system simulation model it describes these processes dynamically as they take place through time. Being a model that is a less than perfect representation of reality, it focuses on a subset of the total set of processes typifying the system. The requirements of the research, the limitations and criteria of the researcher, and the availability and quality of technical data account for the limitation of the model.

The mathematical model has been converted into computer code using FORTRAN. The solution interval, DT, is 1/50th of a year with output, state, and rate variables being generated every 7.3 days.

Three major processes and their interactions constitute the core of the model: (a) Forage production simulated in submodel FORAGE ; (b) Herd demographics simulated in submodel DHERD and (c) Nutritional requirements and processes simulated in submodel NUTIMP. These three submodels interact through a feed accounting and diet design mechanism, FEEDACC, with the economic impacts and other performance indicators summarized in a fith component, FINACC. The initial plant and investments are defined in submodel PLTAINV which provides the initial conditions to model execution.

Figure 6-1 shows a macroview of the overall model and the major interactions taking place among the six components. The flowchart in Figure 6-2 shows the computational flow of the model. This chapter provides a textual description of the six components stating their input-output connections and the internal processes modelled.

Figure 6-1: Model Block Diagram

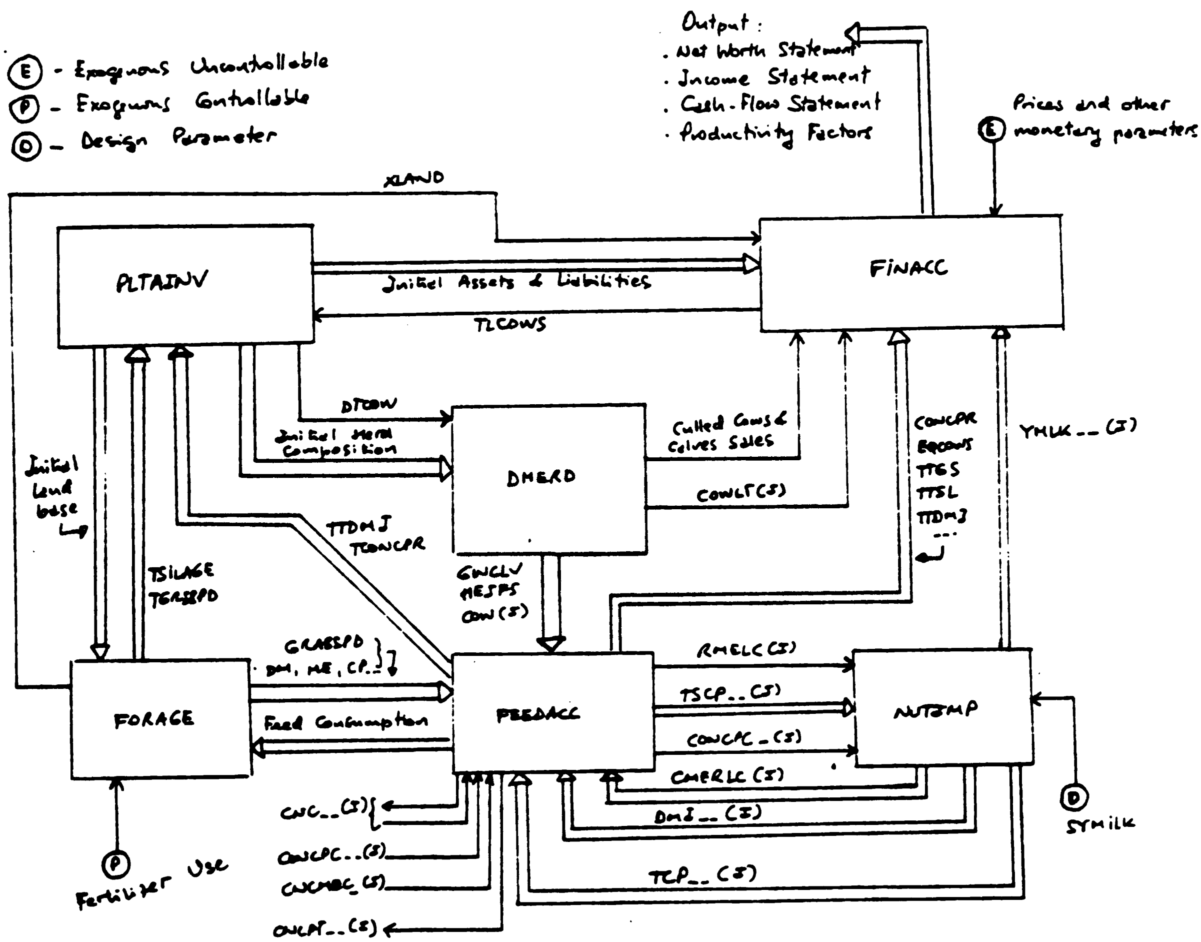
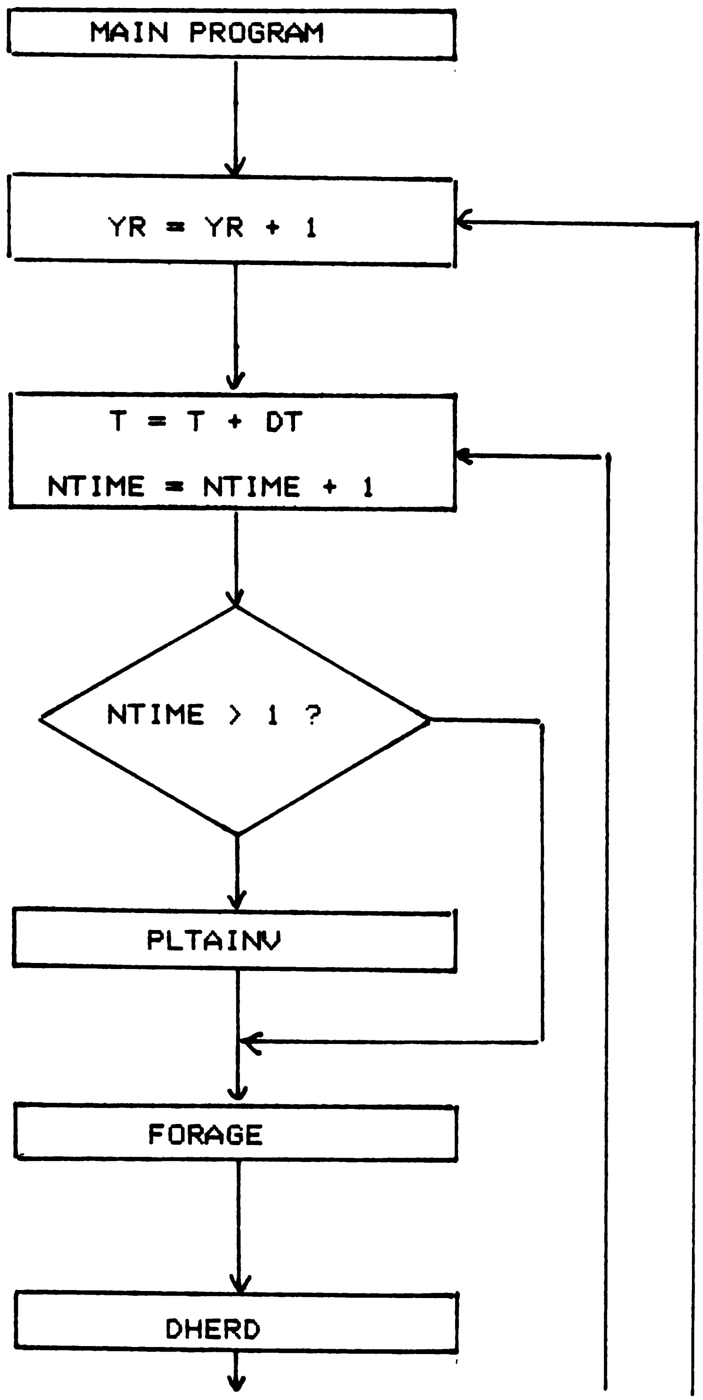
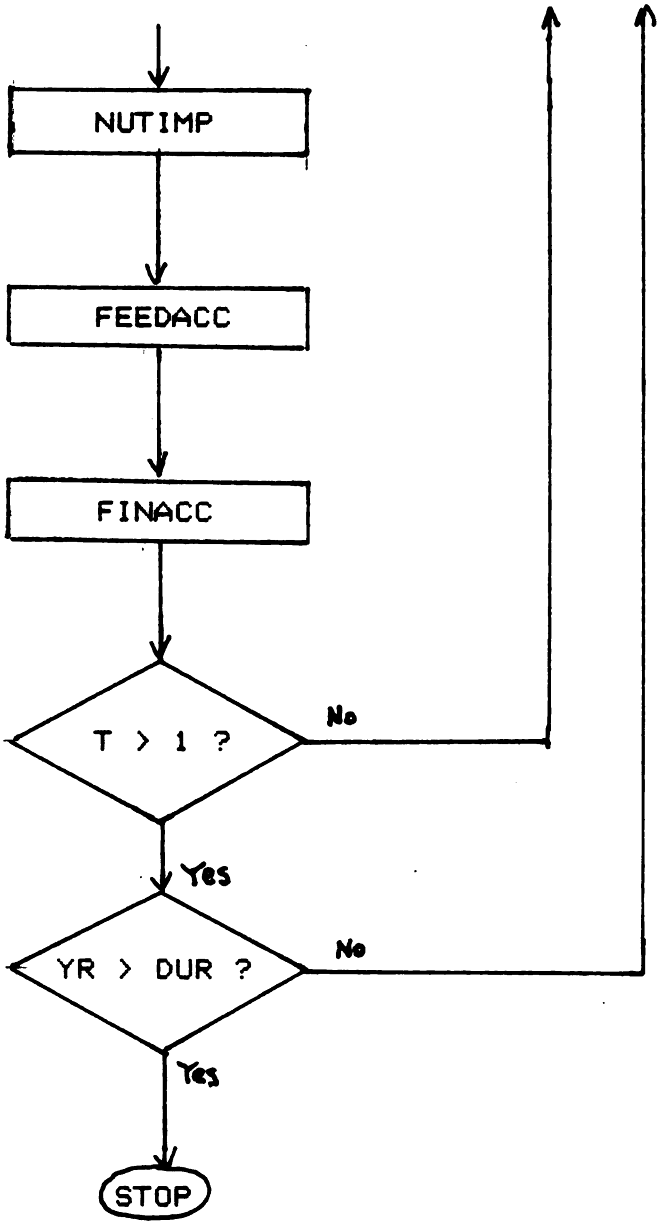


Fig 6-2: Dairy Model Flowchart




NUTIMP
FEEDACC
FINACC
T > 1 ?
No
Yes
YR > DUR ?
No
Yes
STOP

6.2. The Dairy and Forage Farm Setting.

The dairy/forage farming systems in Galicia are characterized, as we mentioned in Chapter 2, by their small scale and by the diversity of the land assets controlled by each farm operator. As emerges from the extensive surveys made by Diaz-Patier and Sineiro in 1979 and 1980, ([27],[28]) every farmer controls a set of plots with varying productivity potential and which are put to uses according to that potential. The model recognizes this by using these land categories:

i) Cropland.

ii) Natural Pasture:
  . Irrigated
  . Non-irrigated

iii) Improved Pasture.

iv) Bushland.

In the process of vertical development of the farm the bushland is upgraded to a productivity level comparable to that of the improved pasture. However, that upgrading process takes time, approximately 4 years, and land at differents stages in its upgrading process must be accounted for in the model. That means that four more land categories have to be considered. In all, the model accounts, then, for 9 land types.

6.3. The PLTAINV Subsystem.

The PLTAINV subsystem defines the initial plant and equipment of the farming system being simulated. It sets the types and amounts of land, the size and age composition of the herd, and the types and values of the assets, i. e., farm buildings, machinery and land structures controlled by the owner or manager. For the growth experiments, the subsystem can fix the amount of initial investment and the debt burden involved in its financing under varying assumptions concerning use of internal funds.

It also determines, by checking the production of feed on the farm, and as a function of the feeding strategy and the consumption of dry matter per cow, the size of the herd for the following year. This means that the size of the herd depends on the production on the farm and on the amount of concentrate given to the cows per year. If feed production on the farm increases, or cows are given more concentrate per year, the herd can be, ceteris paribus, expanded. Given that farmers cannot buy forage, the size of the herd is limited consequently by the production of feed on the farm, which depends on fertilizer use and hence on the price of fertilizer, and by the amount of concentrate fed to the cows, which depends on the price of concentrate.

Figure 6-1 shows that PLTAINV sends the starting assets and liabilities to FINACC. It also sends the desired dairy herd size at the beginning of every year and the initial herd composition to DHERD, and the initial land endowment to FORAGE. It receives previous year data from FEEDACC on total dry matter and concentrate consumption (TTDMI, TCONCPR), total silage and grass production (TSILAGE, TGRSSPD) from FORAGE and the number of total lactating cows (TLCOWS) from FINACC.

6.4. The FORAGE Subsystem.

The FORAGE subsystem performs a series of computations related to the production of various types of feed, providing information about their total dry matter production and metabolic energy (ME from now on) and crude protein (CP from now on) content.

The subsystem generates yields through a fertilizer response mechanism for the different types of land and different types of crops. It simulates the seasonal pattern of grass and other crops production. It computes the area used for grass-silage production and total grass silage production. It calculates production of other forages. It computes and keeps track of the ME and CP content in each type of forage. Finally, the FORAGE subsystem interacts with the FEEDACC subsystem to keep track of available supplies of the different farm produced feeds as time evolves.

Figure 6-1 shows that FORAGE receives the initial land endowment from PLTAINV and sends back total silage production and total grass production (TSILAGE,TGRSSPD), sends feed availability, dry matter and ME and CP contents, to FEEDACC and receives from the latter the amounts of feed consumed in each period thus enabling it to keep track of feed availability for the next period. A major exogenous input (decision variable) to this component is fertilizer use.

6.5. The DHERD Subsystem.

The DHERD subsystem simulates the demographic dynamics of the dairy herd which is disaggregated into several age cohorts.

It computes births, deaths and involuntary removals, (caused by disease or accident), for the herd. It simulates herd stabilization strategies, i. e., it determines retention of female calves for replacement, cow cullings and marketings of unwanted animals. It keeps track of the several animal cohorts throughout the years. It also monitors the status of the heifers and dairy cows providing the numbers of cows in each age cohort lactating, pregnant or dry during each time period.

The DHERD component receives the initial herd composition from PLTAINV, sends numbers of growing calves (GWCLV), heifers (HEIFS), and cows in each age cohort to FEEDACC, and also sends the number of culled cows, animal sales, and number of cows lactating in each period to FINACC.

6.6. The NUTIMP Subsystem.

The NUTIMP subsystem tracks the nutritional requirements (energy and protein requirements mainly) of the several types of animals in the herd as they go through various biological stages.

This component simulates the interrelationships between dry matter intake, energy and protein requirements, milk production, and weight condition, setting net energy and crude protein requirements for weight maintenance, pregnancy, milk production and weight gain or loss. It keeps track of animal weights, a critical state variable, during the year as they change following the normal productive-reproductive cycle of each animal and the manager-selected feeding strategy.

This subsystem operates in two alternative modes. In mode (a), NUTIMP sets the concentration of metabolic energy in the ration , dry matter intake and total crude protein requirement per animal per time period for FEEDACC. In mode (b), it sends to FEEDACC dry matter intake and total crude protein requirements, but receives from FEEDACC the concentration of metabolic energy in the ration. It sends milk yield per animal and period to FINACC. An important design parameter in this subsystem is the potential annual milk yield of mature cows, SYMILK.

6.7. The FEEDACC Subsystem.

The FORAGE, DHERD, and NUTIMP components interface with each other through the FEEDACC subsystem which performs the feed accounting throughout the year, matching feed demand to feed availability.

In performing the feed accounting this mechanism computes diets for the several types of animals in the herd, determining dry matter requirements and energy and protein content of the rations fed. The quantity of concentrate in the ration, which sets the energy and protein concentration of the diet, is also determined in this part of the model, according to the feeding strategy selected by the manager.

FEEDACC performs the interfacing functions in the model and in so doing interacts with all other subsystems. It receives dry matter intake, ME and CP content of feedstuffs from FORAGE, sending back feed consumption. It receives numbers of growing calves (GWCLV), heifers (HEIFS), and cows (COW(I)) from DHERD. Operating in mode (a), as described above, it receives recommended concentration of ME, dry matter intake, and total CP requirements per animal from NUTIMP. In mode (b), it receives from NUTIMP dry matter intake and total CP requirements and sends back to NUTIMP the ME concentration of the diet. Finally, it sends total concentrate purchases per period (CONCPR) to FINACC and total concentrate purchases per year and total dry matter consumed in previous year (TCONCPR,TTDMI) to PLTAINV.

6.8. The FINACC Subsystem.

The FINACC Subsystem applies prices to inputs, outputs, and assets summarizing the financial performance of the farm during the period under study. It performs two general functions: i) financial accounting, ii) computation of a variety of system performance indicators.

Sales, purchases, farm production expenditures and general financial transactions are accounted for here. The three basic financial accounting documents of a firm are elaborated in this part of the model: 1) the net worth statement, 2) the income statement and 3) the sources and uses of funds statement.

The performance indicators generated in this subsystem are typical productivity and financial factors used commonly for farm diagnostic analysis.

FINACC receives initial assets and liabilities from PLTAINV sending back the number of lactating cows during the previous year (TLCOWS).It also receives cows culled, animal sales and cows lactating (COWLT(I)) from DHERD, concentrate purchases (CONCPR) from FEEDACC, and milk yield per cow from NUTIMP.

CHAPTER 7

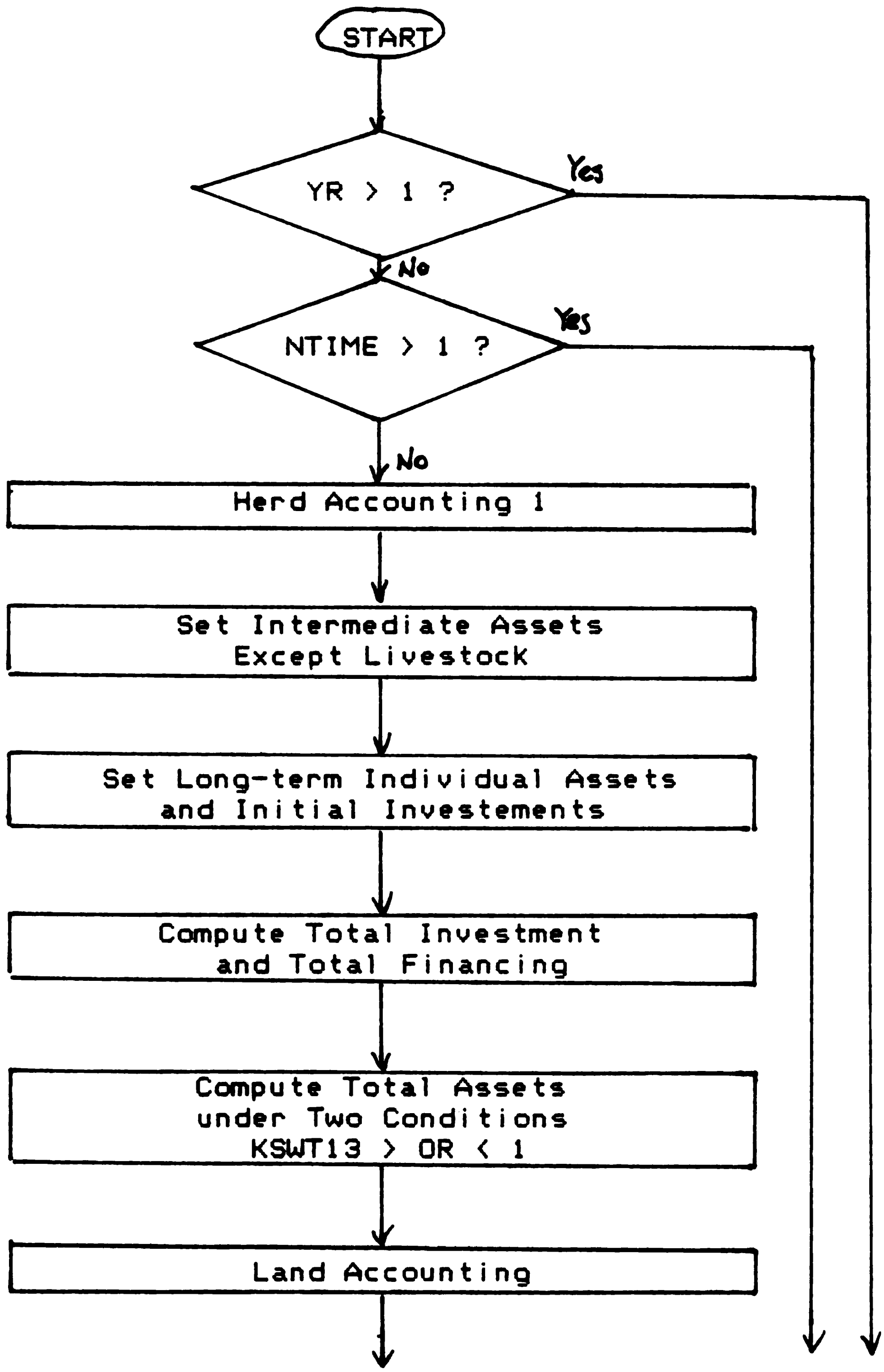
The PLTAINV Subsystem

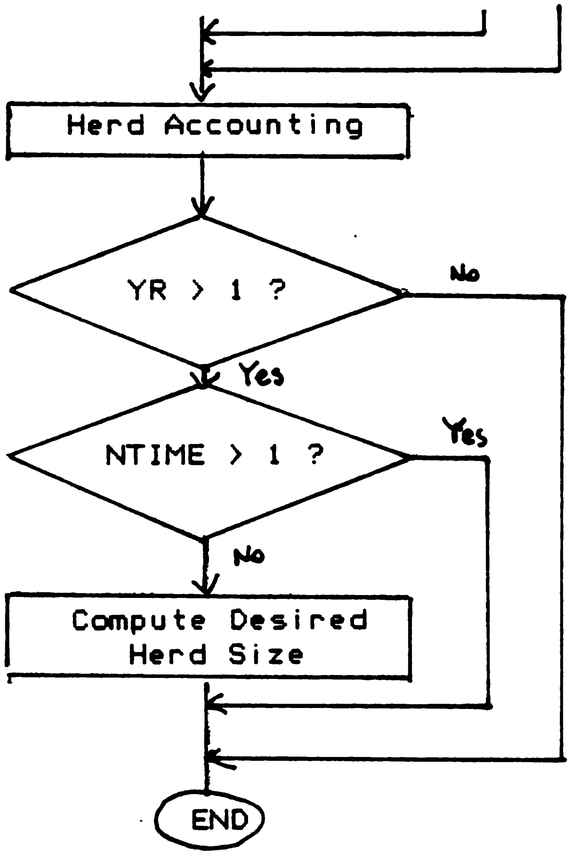
The PLTAINV subroutine sets initial conditions for the model. It is called once at the beginning of each run and once at the beginning of every year. It makes a set of simple computations related to the calculation of the initial conditions needed by the other subroutines to operate.

The flow of computation thoughout this subroutine, which can be seen in Figure 7-1 is controlled by two switchs or logical operators: KINVST and KSWT13 which can take only one out of two possible values >1 or <=1.

The first thing PLTAINV does is set the initial herd composition prior to major investments in livestock or otherwise for development purposes. It then adds up the number of cows in each age bracket.

Figure 7-1: PLTAINV Flowchart




Herd Accounting
YR > 1 ?
No
Yes
NTIME > 1 ?
Yes
No
Compute Desired Herd Size
END

$$TCOW = \sum_I COW(I) \qquad I = 1,7 \qquad (7.1)$$

TCOW = Total cow numbers

COW(I) = Number of cows in cohort I

Next, it sets intermediate assets other than livestock under two investment conditions

(a) No investment in equipment

If KINVST =< 1

$$EQUIPMT = EQPOLD \qquad (7.2)$$

(b) Investments in equipment are made

If KINVST > 1

$$EQUIPMT = EQPOLD + EQPNEW \qquad (7.3)$$

EQUIPMT = Equipment assets hold (pts)

EQPOLD = Old equipment assets held prior to farm development process (pts)

EQPNEW = New equipment purchased for farm development (pts)

Next, PLTAINV computes long-term assets, farm land, building structures, land improvements, and also, breeding stock purchases.

If KSWT13 =< 1 then

FARMLD = (PAST+PASTATO)*PRPAST+RBRSLND*PRBRSL+ (7.4)

PASTIRO*PRIRRPS+PASTNIO*PRNIRPS+

CRLANDO*PRCRLND

If KSWT13 > 1 then FARMLD = 0.

FARMLD	=	Farm land value (pts)
PAST	=	Brushland already developed (ha)
PASTATO	=	Improved pasture owned (ha)
PRPAST	=	Price of improved pasture (pts/ha)
RBRSLND	=	Bushland owned (ha)
PRBRSL	=	Price of bush land (pts/ha)
PASTIRO	=	Irrigated pasture owned (ha)
PRIRRPS	=	Price of irrigated pasture (pts/ha)
PASTNIO	=	Non-irrigated natural pasture owned (ha)
PRNIRPS	=	Price of non-irrigated natural pasture (pts/ha)
CRLANDO	=	Cropland owned (ha)
PRCRLND	=	Price of cropland (pts/ha)

Next, the scale of a set of production facilities are set according to technical coefficients from [52].

Following the flow of computation the subroutine calculates the total value of asset improvements under two conditions determined by the value taken by switch KINVST.

If KINVST =< 1, there is no investment and the value of asset improvements is determined as:

ASSIMPR = (PAST+PASTATO)*DCSTPS+PASTIRO*CSTIRR (7.5)

ASSIMPR = Asset improvements value (pts)

PAST = Total developed pasture (ha)

PASTATO = Total improved pasture owned (ha)

DCSTPS = Development cost of pasture (pts/ha)

PASTIRO = Total irrigated pasture owned (ha)

CSTIRR = Investment cost of irrigated pasture (pts/ha)

On the other side, if KINVST > 1, an integrated plan of farm development is implemented and the different items in the investment plan are valuated as follows. First, investment in buildings and other structures is:

BLDAOTH = FENCES*PASTBD*PRFNC+WTPOINT*PRWTP+ (7.6)
STALLS*PRSTLLS+STABLE*PRSTBL+
HLTHRM*PRHLRM+SILOPLT*PRSILPF+
MNRWELL*PRMWELL+PARLORM*PRPARM

BLDAOTH = Investment in building and other facilities (pts)

FENCES = Length of fences installed (km/ha)

PASTBD = Pasture land being developed (ha)

PRFNC = Price of fencing (pts/km)

WTPOINT = Waterpoints (units)

PRWTP = Price of waterpoints (pts/unit)

STALLS = Stalls (units)

PRSTLLS = Price of stalls (pts/unit)

STABLE = Stable (units)

PRSTBL = Price of stable (pts/unit)

HLTHRM = Sanitary facilities (units)

PRHLRM = Price of sanitary facilities (pts/unit)

SILOPLT = Silo and platform (unit)

PRSILPF = Price of silo and platform (unit)

MNRWELL = Manure pit (unit)

PRMWELL = Price of manure pit (pts/unit)

PARLORM = Milking parlor (unit)

PRPARM = Price of milking parlor (pts/unit)

Investment expenditures involved in converting brushland into pasture are:

DVLNDIN = PASTBD*DCSTPS (7.7)

DVLNDIN = Total investment in land development (pts)

PASTBD = Land being developed (ha)

DCSTPS = Development costs of pasture (pts/ha)

Investments involved in expanding the dairy herd are:

BRDSINV = (DTCOW-TCOW-HEIFS)*PCOWLT1 (7.8)

BRDSINV = Breeding stock investment (pts)

DTCOW = Desired total lactating cows (head)

TCOW = Total lactating cows from previous years (head)

HEIFS = Total mature heifers going into production next period (head)

PCOWLTS = Price of pregnant heifers entering first lactation (pts/head)

The value of asset improvements is now:

ASSIMPR = (PAST+PASTATO)*DCSTPS+PASTIRO*CSTIRR+DVLNDIN

. (7.9)

All variables are defined as on previous pages.

Initial investments in asset improvements and buildings and other structures are saved for later computations.

ASIMPII = ASSIMPR (7.10)

ASIMPII = Initial investments in asset improvements (pts)

BLAOTII = BLDAOTH (7.11)

BLAOTII = Initial investment in buildings and other structures (pts)

Now, total initial investment and loan financing are calculated:

TIINVST = EQPNEW+BLDAOTH+DVLNDIN+BRDSINV (7.12)

TIINVST = Total initial investment (pts)

EQPNEW, BLDAOTH, DVLNDIN, BRDSINV, as above

Now, the amount of total initial investments financed with own funds is:

OWNFNDS = TIINVST*(1.-OMEGA) (7.13)

TSLOAN = TIINVST-OWNFNDS (7.14)

TSLOAN = Total loan financing (pts)

OWNFNDS = Total internal financing (pts)

OMEGA = Proportion of total initial investment internally financed

BLLOAN = GAMMA*TSLOAN (7.15)

BLLOAN = Total long term loan borrowed (pts)

GAMMA = Proportion of TSLOAN long-term financed (0< GAMMA <1.)

BILOAN = TSLOAN-BLLOAN (7.16)

BILOAN = Total intermediate borrowings (pts)

Long term assets at the beginning of period are computed under two conditions depending on whether farmland is considered or not.

If KSWT13 < 1 then

TLASSTS = FARMLD+ASSIMPR+BLDAOTH (7.17)

If KSWT13 > 1 then

TLASSTS = ASSIMPR+BLDAOTH (7.18)

TLASSTS = Total long-terms assets (pts)

Land accounting is performed next

PASTAT = PASTATO+PASTATR (7.19)

PASTAT = Total improved pasture available (ha)

PASTATR = Improved pasture rented (ha)

PASTIR = PASTIRO+PASTIRR (7.20)

PASTIR = Total irrigated pasture available (ha)

PASTIRR = Irrigated pasture rented (ha)

PASTNI = PASTNIO+PASTNIR (7.21)

PASTNI = Total natural pasture available (ha)

PASTNIO = Natural pasture owned (ha)

PASTNIR = Natural pasture rented (ha)

CRLAND = CRLANDO+CRLANDR (7.22)

CRLAND = Total cropland available (ha)

CRLANDO = Cropland rented (ha)

CRLANDR = Cropland rented (ha)

Herd composition is recomputed as an investment process may have taken place.

If KINVST =< 1 then HEIFS as well as TCOW keep their previous values.

If KINVST > 1 then

HEIFS = HEIFS+(DTCOW-TCOW-HEIFS) (7.23)

HEIFS = Heifers (head)

$$TCOW = \sum_{I} COW(I) \qquad I=1,7 \qquad (7.24)$$

Equations (7.1) to (7.24) are computed only once at the beginning of every run. Equations (7.25) to (7.27) below are computed once at the beginning of every year except for the first year. That set of equations computes for the current year and as a function of the feeding strategy (i.e. ratio of concentrate to dry matter intake in ration) and of the on-farm forage production the desired size of the dairy herd, thus setting in motion cattle investment/disinvestment processes.

$$FNDPC = (TTDMI-TCONCPR)/TLCOWS \tag{7.25}$$

FNDPC = Forage needs per cow during last year (kg DM/cow/year)

TTDMI = Total dry matter consumption by the herd in previous year (kg dM/year)

TCONCPR = Total concentrate consumption by the herd in previous year (kg DM/year)

TLCOWS = Total cows lactating in previous year (head)

$$DSDLCOW = (TSILAGE+TGRSSPD)/FNDPC \tag{7.26}$$

DSDLCOW = Desired lactating cows (head)

TSILAGE = Total silage production during the previous year (kg DM/year)

TGRSSPD = Total grass production during the previous year (kg DM/year)

The desired total cows are constrained to be an integer number and to be no greater than the number of cows that the existing facilities can handle.

$$DTCOW = Min \{ INT(DSDLCOW), STALLS \} \tag{7.27}$$

DTCOW = Constrained desired lactating cows (head)

INT(__) = Integer value function

The reason for allowing the desired herd size to be recomputed every year is because of the progressive buildup in productivity of the bushland developed that will not achieve its final potential until the fith year. The herd size recomputation permits increasing availability of feed to support a larger herd.

CHAPTER 8

The FORAGE Subsystem

The FORAGE subroutine simulates the production of forages on the farm, monitoring quantity and quality, contents of energy (Mcal/kg DM) and crude protein (gr CP/kg DM), of every forage available during the year.

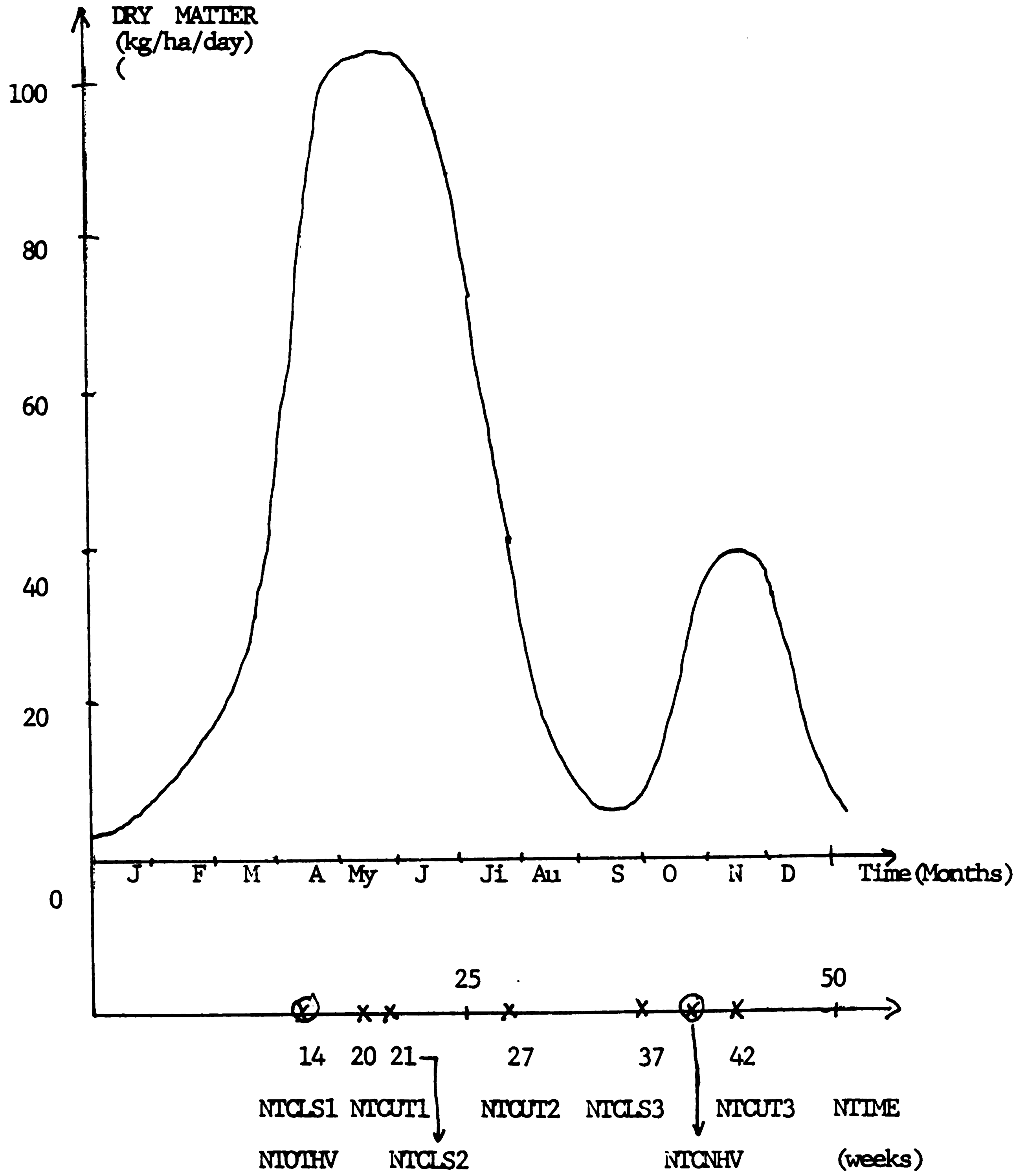
The FORAGE subroutine accounts for the seasonal pattern of grass production and hence of forage availability. This seasonality in feed avaibility together with a parallel seasonality in feed demand, emerging from the herd demographics and the nutritional requirements set by the productive-reproductive cycle of the dairy cows, constitute the main management problem of dairy farming in Galicia, which is finding the optimal matching of feed supply to feed demand throughout the year.

8.1 Forage Production, Facts and Assumptions.

Grass production in Galicia is subjected to an important seasonality due to varying climatic factors during the year. Figure 8-1 shows the availability of daily grass production throughout the year. There is a peak in spring and another one, at quite a lower level, in the fall. Grass growth is halted or diminished twice in the year; in the summer because of lack of water, and in the winter because of low temperature and/or lack of sunlight. Although this seasonal pattern can be said to be representative of the whole of Galicia, there are locational variations. Humid summers in the north give grass production in that season, and milder winters in the south and the west allow some grass production there.

Herd and pasture management on Galician dairy farming give a major role to rotational grazing during the year. The biological cycle of the dairy herd is managed to match peak feed requirements (one to two months after parturition) to feed supply, which peaks at mid-spring. A recommended reproductive strategy has consequently being to concentrate births at the end of winter (February and March) so as to take advantage, as feed requirements rise, of increasing daily grass production.

Figure 8-1: Daily Grass Production Profile



Events take place in the model according to the biological timing of grass and other crops growth and according to the particular pasture management strategy adopted. Although the feed requirements show also a definite shape throughout the year, feed demand does not experience as much fluctuation as feed supply. It is a primary concern of the manager, in matching feed supply and demand, to conserve the feed surplus during periods in which supply exceeds demand and feed this surplus to the herd at other moments in the year when demand exceeds supply.

As shown in Figure 8-1, there are two periods in the year that we can expect a feed surplus to happen. In spring and fall two production peaks occur. Feed deficits are the rule in summer and winter.

An adequate feed conservation policy is critical to the profitability of the farm. Feed conservation is done by withdrawing from grazing the amounts of pasture which may be thought to be in excess over the feed requirements, letting the grass in the conserved area grow and then cut for silage, once the nutritional quality of the grass, which is a major concern in the feed conservation strategy, starts to decline. The quality of silage (ME and CP content) is of considerable importance in meeting the nutritional requirements of the dairy cows. Quality is determined, among other factors, by the timing of harvest.

The ME of the grass decreases slowly as grass growth proceeds until it starts blooming in mid-spring; after that digestibility (ME) and CP fall rapidly. (Mercedes Cebrian del Moral [14]). On the other hand daily dry matter production of grass follows an opposite pattern, being low at the beginning of the spring and accelerating as the season progresses. A major trade off between dry matter yield and quality emerges here and the recommendation from knowledgeable professionals is to cut when blooming starts.

The model allows the manager to withdraw pasture for grass silage production during three periods during the year: (a) From the beginning of the grazing season, that is in early March, to the spring peak in production when blooming starts; (b) From the spring peak to the end of spring growth; (c) During the fall production period.

The manager has freedom to choose whether to do all three silage cuttings, two, one, or none at all, to select the times to withdraw the pasture and to harvest the grass produced in each cutting, and the proportion of each type of pasture to reserve for grass silage production on each cutting.

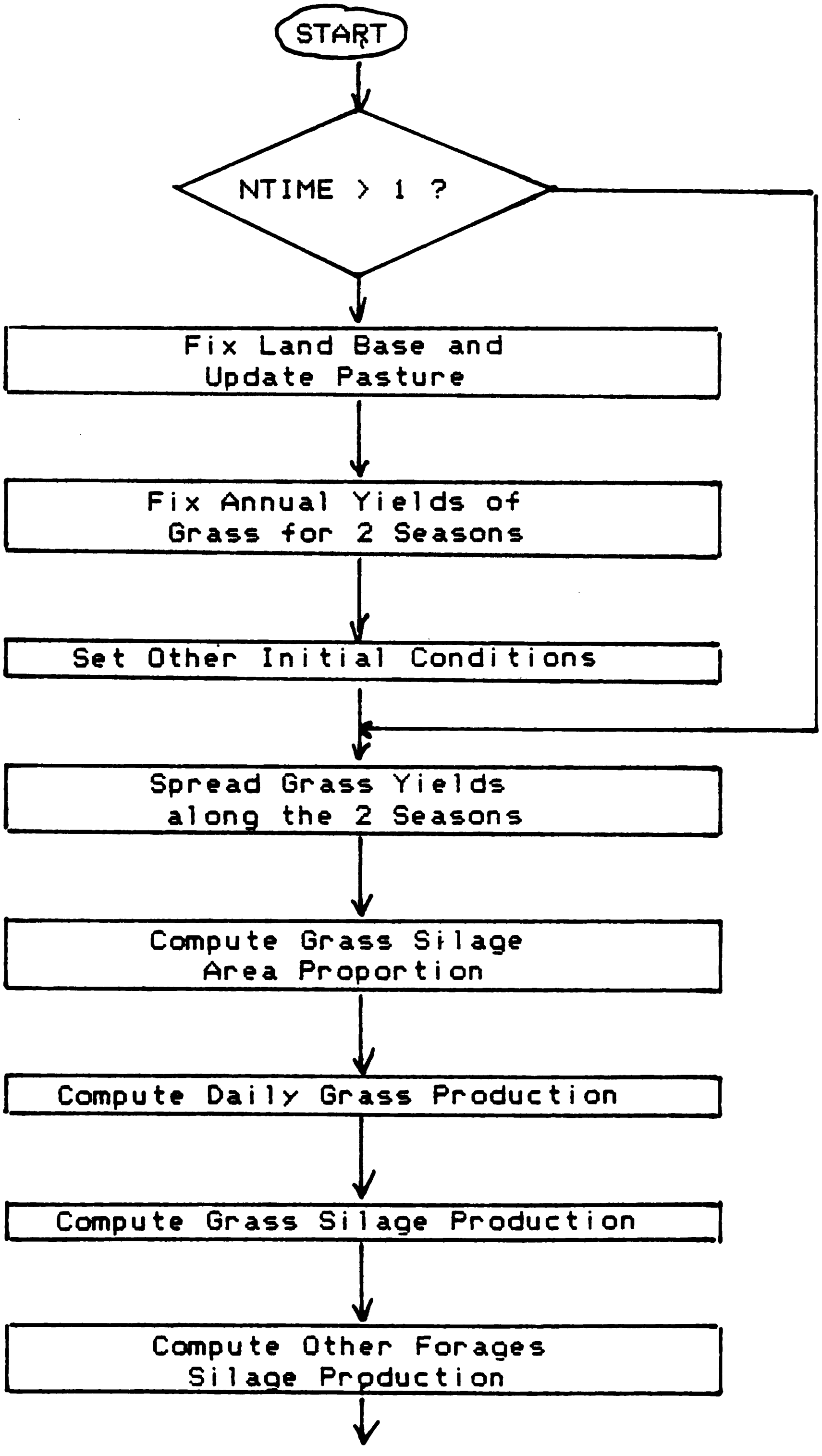
Besides pasture management, the manager has to decide the crops to grow on the cropland plot. Several crop rotations can be practised on the cropland (Jaime Lloveras [44]), the best alternative being a function of soil quality (as Lloveras shows in his article). In our model we select an annual rotation of oats as winter cereal and corn as a summer cereal, both harvested as forage to produce silage.

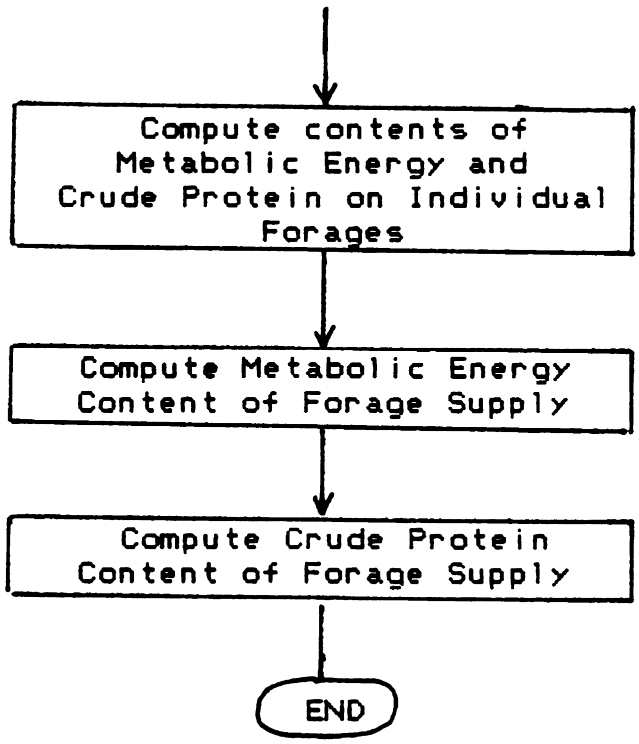
8.2. FORAGE Description.

In Figure 8-2 we see a flowchart of the subroutine and we now turn to a detailed description of the main equations within this subroutine.

Subroutine FORAGE makes at the beginning of every year a series of computations that set initial conditions for the rest of the year. These computations are then skipped, as the subroutine is called again every 1/50th period of the year, until the beginning of the following year.

Figure 8-2: FORAGE Flowchart




Compute contents of Metabolic Energy and Crude Protein on Individual Forages
Compute Metabolic Energy Content of Forage Supply
Compute Crude Protein Content of Forage Supply
END

First, and according to the progressive build-up on productivity associated with the pasture development process, updating of pasture categories takes place, with pasture developed in previous years moving up the scale. At the end of the development process, which lasts 4 years, the developed pasture reaches a level of productivity commensurate with the improved pasture plot (PASTAT) to which it is henceforth merged.

$$PASTAT = PASTAT + PASTD(4) \tag{8.1}$$

PASTAT = Improved pasture (ha)

PASTD(4) = Developed pasture 4 years old (ha)

$$PASTD(K) = PASTD(K-1) \qquad K=4 \text{ to } 2 \tag{8.2}$$

PASTD(K) = Developed pasture K years old (ha)

$$PASTD(1) = PASTBD \tag{8.3}$$

PASTD(1) = Developed pasture on 1st year of production (ha)

PASTBD = Pasture developed during the previous year (ha)

Total pasture developed at all levels of development is added up:

$$PAST = \sum_{I} PASTD(I) \qquad I=1 \text{ to } 4 \tag{8.4}$$

PAST = Total pasture in upgrading process (ha)

Total pasture of all types is now added up:

TPAST = PAST+PASTAT+PASTNI+PASTIR (8.5)

TPAST = Total pasture controlled by manager (ha)

PASTAT = Improved pasture (ha)

PASTNI = Non-irrigated natural pasture (ha)

PASTIR = Irrigated natural pasture (ha)

Total land base is now computed:

XLAND = TPAST+CRLAND (8.6)

XLAND = Total land base (ha)

CRLAND = Total cropland controlled by manager (ha)

Next, annual grass yields for the two seasons and every type of pasture is calculated. Yields for upgrading pasture are:

YIELD1(I)= GSYLD1(I) I=1 to 4 (8.7)

YIELD2(I)= GSYLD2(I) I=1 to 4 (8.8)

YIELD#(I)= Grass yield in season # of pasture in I year of development (Kg DM / ha) #=1, 2

GSYLD#(I)= Exogenous parameter fixing the annual yield (Kg DM / ha) #=1, 2

AX1(I) = YIELD1(I)/DT (8.9)

AX2(I) = YIELD2(I)/DT (8.10)

AX#(I) = Auxiliary variable used in the simulation of seasonal grass production patterns #=1, 2

DT = Interval of solution: 1/50

Yields for improved, and non irrigated pasture are computed as a function of fertilizer use.

YLDAT1 = f(FNTAT1) (8.11)

YLDAT2 = f(FNTAT2) (8.12)

YLDNI1 = f(FNTNI1) (8.13)

YLDNI1 = f(FNTNI2) (8.14)

YLDAT# = Grass yield in season # of improved pasture (Kg DM / ha) #=1, 2

FNTAT# = Fertilizer application to improved pasture in season # (Kg N / ha) #=1, 2

YLDNI# = Grass yield in season # of non-irrigated pasture (Kg DM / ha) #=1, 2

FNTNI# = Fertilizer application to non-irrigated pasture in season # (Kg N / ha) #=1, 2

The functional dependency in equations (8.11) to (8.14) is modeled with the use of table functions and linear interpolation between every two consecutive points in the table (See Manestch & Park [50]).

A set of auxiliary variables similar to those in equations (8.9) and (8.10) is computed, in an analogous way, for the dependent variables in equations (8.11) to (8.14). We will skip those simple equations.

This first part of subroutine FORAGE that, let us repeat, is computed only once at the beginning of every year, concludes by setting initial conditions to differential equations and integrators which will be computed in the following periods.

Daily grass yields are simulated with a series of distributed delay functions which spread season yields over the duration of the season. "Pseudo" unit impulse functions (based on the properties of unit impulse or Dirac functions, [50]) which met the following conditions are used in stimulating the distributed delays:

$$PUI(t-to) = \begin{cases} 0 & , \quad t \qquad (to,\ to+DT) \\ 1/DT & , \quad t \qquad (to,\ to+DT) \end{cases}$$

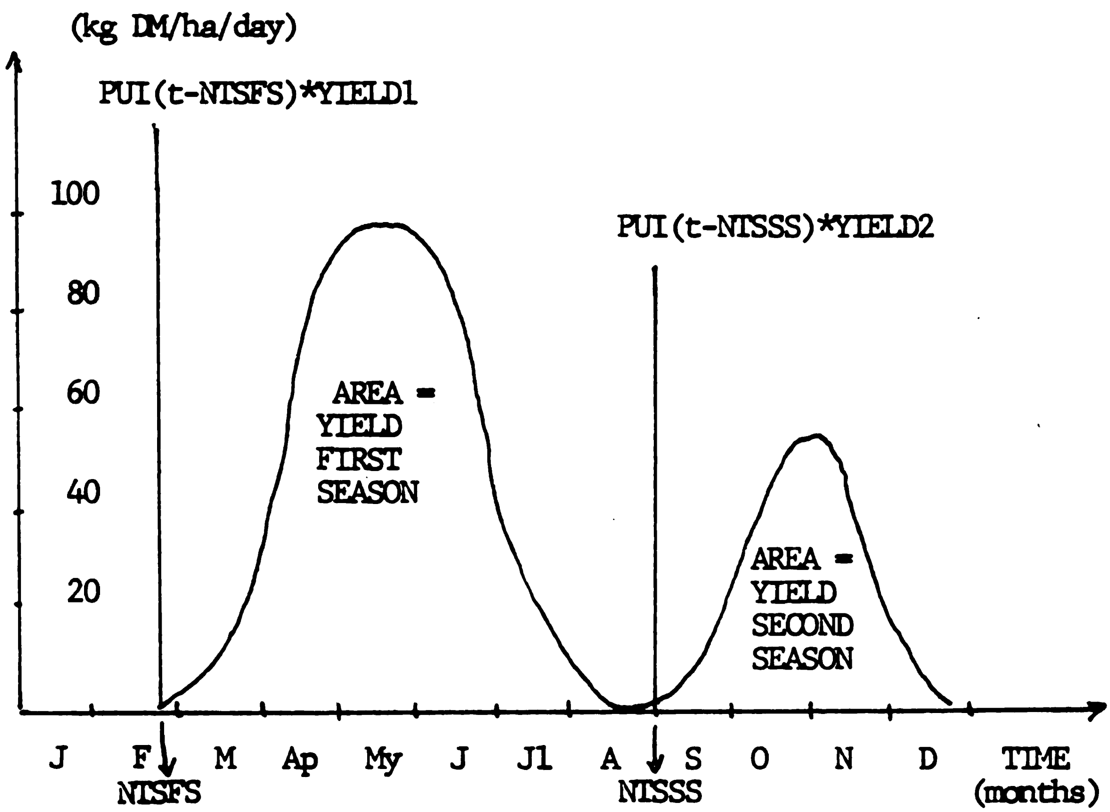
$$\int_{o}^{1} PUI\ (t-to)\ dt = 1$$

with t as time of year, $o < t < 1$, and "to" time of year to start pseudo impulse, and DT the time increment, or solution interval, used in the simulation model.

The pseudo unit impulse function is multiplied by the seasonal yield to generate timely impulses which would drive the differential equations that are simulated by the distributed delay. The output of the delay is the rate of production of grass per day throughout the season. Figure 8-3 shows the way the impulse functions and the distributed delays perform throughout the year.

The following system of differential equations generates the temporal profiles of seasonal yields.

Figure 8-3: Yield Spreading During the Year



NTSFS = Time to start first grass growth season

NTSSS = Time to start second grass growth season

$$a_k \frac{d^k}{dt^k} Y\#(I,t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} Y\#(I,t) + \dots\dots \qquad (8.15)$$

$$\dots\dots a_o Y\#(I,t) = AX\#(I) * PUI(t\text{-}NTSGS)$$

$$I=1 \text{ to } 4, \#=1, 2$$

where

a_j = coefficient of distributed delay function

$$a_j = \binom{k}{j} \left(\frac{DEL\#}{k} \right)^j, \qquad j=0,,,k$$

DEL#	=	Mean time of delay function, (years)
k	=	Order of the differential equation or delay.
Y#(I,t)	=	Grass yields in annual rate during season # on pasture I years old (Kg DM / ha / year)
AX#(I)	=	Same definition as in equations (8.9), and (8.10)
NTSGS	=	Time to start grazing season

Annual rates of grass yields are converted to daily rates by dividing by 365.

$$Y\#(I,t) = Y\#(I,t) / 365 \qquad (8.16)$$

Next, daily grass yields for both seasons are collected into a single variable.

$$GSYL(I,t) = Y1(I,t) + Y2(I,t) \qquad I=1 \text{ to } 4 \qquad (8.17)$$

GSYL(I,t)= Daily grass yield on pasture I years old (Kg DM / ha / day)

The set of equations (8.15), (8.16), (8.17) are repeated to simulate yield spreading on improved pasture and non-irrigated natural pasture. We skip these.

Grass yields spreading for irrigated pasture are generated in another way. They are simply a function of time and are simulated with a table function.

$$GSYLIR(t) = f\ (t) \qquad (8.18)$$

GSYLIR(t)= Daily grass yields on irrigated pasture (Kg DM / ha / day)

t = time, $o < t < 1$

Next, in order to compute the supply of grass available for grazing and that which will be converted into silage, we must first set the proportion of pasture that is used for grazing. This proportion is an exogenous controllable input and must be set for every close-and-cut period that the model contemplates. We show this computation only for the pasture on development, the proportions for the other pasture being set analogously.

If NTCLS# < NTIME < NTCUT#

PSTPRP(I,t) = PRPST#(I) I=1 to 4 (8.19)

Otherwise

PSTPRP(I,t) = 0 I=1 to 4 (8.20)

PSTPRP(I,t)	=	Proportion of pasture I years old reserved for silage production
PRPST#(I)	=	Proportion of pasture I years old reserved for silage on the # cutting period
NTCLS#	=	Time to close pasture for silage on cuttin period # (# =1 to 3)
NTCUT#	=	Time to cut grass reserved for silage on cutting period # (# =1 to 3)
NTIME	=	Counter clock going from 1 to 50 during the year.

PRPST#(I), as well as NTCLS# and NTCUT# are decision variables at the discretion of the manager. He can select the proportion of pasture to reserve for silage of every type of pasture that he controls and the times to withdraw pasture from grazing and to harvest the grass grown during every silage period.

Daily grass production available for grazing is now computed. Again, we only show the equations for the pasture in the process of development.

$$GSPRD(I,t) = PASTD(I)*GSYL(I,t)*(1.-PSTPRP(I,t)) \quad (8.21)$$

$$I=1 \text{ to } 4$$

GSPRS(I,t)= Daily grass production on pasture I years old (Kg DM / day)

All other variables defined as above.

Total grass production on pasture in development is calculated as:

$$GRSSPD(I,t) = \sum_{I} GSPRD(I,t) \qquad I=1 \text{ to } 4 \qquad (8.22)$$

GRSSPD(I,t)= Daily grass production on pasture in development.

Now, grass production on the other types of pasture (i.e., on the proportions of those types of pasture that have been allocated to grazing) is added to GRSSPD(I,t) to give:

$$GRASSPD(I,t) = GRASSPD(I,t)+GSPNI(I,t)+GSPAT(I,t) \quad (8.23)$$

$$+GSPAT(I,t)$$

Where GSPNI(t), GSPAT(t), and GSPIR(t) have been computed with a set of equations essentially similar to (8.21) above.

GRASSPD(t)= Total daily grass production for grazing (Kg DM / day)

GSPNI(t) = Daily grass production for grazing in non-irrigated natural pasture (Kg DM / day)

GSPAT(t) = Daily grass production for grazing in improved pasture (Kg DM / day)

GSPIR(t) = Daily grass production for grazing in irrigated pasture (Kg DM / day)

Grass available for grazing after consumption and total grass for grazing produced are computed as:

$$AVGRASS(t) = \int_{to}^{t} (GRASSPD(t) - CONSGRS(t))\, dt \qquad (8.24)$$

AVGRASS(t)= Grass available for grazing after consumption at t (Kg DM / day)

CONSGRS(t)= Daily consumption of grass grazed (Kg DM / day)

CONSGRS(t) is a variable determined in subroutine FEEDACC where we will see how it is computed.

$$TGRSSPD(t) = \int_{to}^{t} GRASSPD(t)\, dt \qquad (8.25)$$

TGRSSPD(t)= Accumulated grass production for grazing between to and t (Kg DM)

TGRSSPD(t) is a variable required in other subsystems.

Production of grass silage on the reserved pasture is computed as follows. For every silage production period in the year (there are three possible as we have already seen) and on timing decided by the manager pasture for silage is first closed. Grass is allowed to grow for the duration of the period and then is cut for silage. As we did before, the computation is shown only for pasture being developed.

If NTIME < NTCLS# or NTIME > NTCUT#

$$GSSILG\#(I,t) = 0 \qquad I=1 \text{ to } 4 \qquad (8.26)$$

NTIME = Time counter

NTCLS# = Time to close pasture in silage period #

NTCUT# = Time to cut pasture in silage period #

#=1, 2, 3

GSSILG#(I,t)= Grass silage production during silage period on pasture I years old (Kg DM)

If NTCLS# < NTIME < NTCUT#

$$GSFORSL(I,t) = \int_{to}^{t} (PASTD(I)*GSLY(I,t)*PSTPRP(I,t))dt$$

$$I=1 \text{ to } 4 \qquad (8.27)$$

GSFORSL(I,t)= Accumulated grass for silage until t on pasture I years old (Kg DM)

When the time comes to harvest

If NTIME = NTCUT#

$$GSSILG\#(I,t) = GSFORSL(I,t)*.75 \qquad I=1 \text{ to } 4 \qquad (8.28)$$

The accumulated grass production is harvested and converted into silage with losses amounting to 25% of total dry matter production.

Total grass silage production on pasture in process of development and during the three silage periods is determined by adding up:

$$GRSLG1 = \sum_{\#} \sum_{I} GRSSILG\#(I) \qquad (8.29)$$

$$\#=1,\ 2,\ 3$$

$$I=1 \text{ to } 4$$

The sequence of equations (8.26) to (8.29) is repeated in order to compute silage produced on the other types of pasture controlled by the manager.

Grass silage produced in each silage period on pasture not in development is calculated as:

$$GRSLG2\#(t) = GSLGAT\#(t)+GSLGNI\#(t)+GSLGIR\#(t) \qquad (8.30)$$

$$\#=1,\ 2,\ 3$$

GRSLG2#(t)= Total grass silage produced on pasture not in development during season # (Kg DM)

GSLGAT#(t)= Grass silage produced on improved pasture in season # (Kg DM)

GSLGNI#(t)= Grass silage produced on non-irrigated pasture in season # (Kg DM)

and total silage produced on pasture not in development throughout the year is:

$$GRSLG2(t) = \sum_{\#} GRSLG2\#(t) \qquad \#=1,\ 2,\ 3 \qquad (8.31)$$

GRSLG2(t) = Total grass silage produced, on pasture not in development, until t (Kg DM)

(Equation (8.31) may be better understood if the reader thinks of it as an integration through time with the silage produced in one season being added to the silage produced in previous seasons).

Total grass silage produced on all pasture during the year is:

$$GRASSLG(t) = GRSLG1(t)+GRSLG2(t) \qquad (8.32)$$

GRASSLG(t)= Total grass silage produced on farm until t (KgDM)

The forage production grown on the cropland is computed as the product of hectarage times yields. Yields are computed in a fertilizer response equation as a function of fertilizer application. Losses on dry matter due to the conversion of forage to silage are accounted for by applying a percentage factor.

Two consecutive crops grow on the cropland. The first a winter cereal called generically OTHSL and its silage production is computed as:

If NTIME $\neq$ NTOTHV

$$OTHSL(t) = 0 \quad (8.33)$$

iF NTIME = NTOTHV

$$OTHSL(t) = f(FTOT)*CRLAND*.75 \quad (8.34)$$

NTIME = Time counter

NTOTHV = Time to harvest the winter cereal

OTHSL(t) = Silage production of winter cereal at t (Kg DM)

FTOT = Application of N fertilizer to the winter cereal (Kg N/ha)

CRLAND = Cropland (ha)

.75 = Conversion factor of forage into silage

f(---) = A table function relating yields to fertilizer

application

The second crop is corn and its silage production is computed analogously:

If NTIME $\neq$ NTCNHV

$$CORNSL(t) = 0 \tag{8.35}$$

If NTIME = NTCNHV

$$CORNSL(t) = f(FTCRN)*CRLAND*.86 \tag{8.36}$$

NTCNHV = Time to corn harvest

CORNSL(t)= Silage production of corn at t (Kg DM)

FTCRN = Application of N fertilizer to the corn crop (Kg N/ha)

.86 = Conversion factor of forage into silage

Total cereal silage production is

$$CERSL(t) = OTHSL(t)+CORNSL(t) \tag{8.37}$$

CERSL(t) = Total accumulated cereal silage production at t (Kg DM)

Total silage production is grass silage production plus cereal silage production.

$$TSILAGE(t) = GRASSLG(t)+CERSL(t) \tag{8.38}$$

TSILAGE(t)= Total accumulated silage production at t (Kg DM)

Total silage available after consumption, at t, is computed as :

$$AVSILG(t) = \int_{to}^{t} (GRASSLG(t)+CERSL(t)-CONSSIL(t))\ dt \tag{8.39}$$

AVSILG(t) = Total silage available for consumption at t (Kg DM)

CONSSIL(t)= Consumption of silage by the herd during the period (t-DT, t), (Kg DM/DT)

CONSSIL(t) is a variable determined in subroutine FEEDACC.

Finally, the next set of equations, (8.40) to (8.45), computes the nutritional quality of forages available throughout the year. In our modelling we assume that the manager mixes the silage, coming from any source, that becomes available at any time during the year, to the silage already in storage, and the nutritional quality of the resulting mix depends upon the nutritional contents and the proportion in the mix of old and new silage.

The submodel first computes the ME and CP content of grass silage, grass for rotational grazing and cereal silage.

$$CMEGRFS(t) = \frac{\left(\sum_{\#} GRSLG2\#(t) * f_{me}(t)\right)}{GRSLG2} \qquad (8.40)$$

$$\# = 1,\ 2,\ 3$$

CMEGRFS(t)= Content of ME in grass silage at t (Mcal / Kg DM)

$f_{me}(t)$ = Table function that returns content of ME per kg DM as a function of time of year.

Only grass silage produced in the pasture not in development is used in equation (8.41) and that for two reasons. First, because of the simultaneity of events taking place on the several types of pasture, consideration of only one of them is sufficient to do the computation. Second, after year 4 in the development process there is no more pasture in development and so equation (8.41) becomes the exact relationship encompassing production from all types of pasture.

To appropriately grasp the meaning of equation (8.40) we must consider that it is computed every t during the year and that the value it returns evolves in a see-saw like trajectory. After the first silage cutting, equation (8.40) returns a ME value of grass silage that moves steadily down, due to the biological decay that the silage experiments, until the second silage cut occurs. At this time the ME value receives a boost which depends on the proportion of the new silage to the old silage in the silage mix. After the second cutting the ME value starts again to fall and for the same reasons. The CMEGRFS(t) receives another boost at the third silage cut and it starts to fall again thereafter.

The same computation is made for the CP content of grass silage:

$$CPTGRFS(t) = \frac{\left(\sum_{\#} GRSLG2\#(t) * f_{cp}(t)\right)}{GRSLG2} \qquad \#=1,\ 2,\ 3 \tag{8.41}$$

CPTGRFS(t)= Content of crude protein in grass silage at t (gr CP / Kg DM)

$f_{cp}(t)$ = Table function that returns content of CP per Kg DM as a function of time of year.

The ME and CP contents of grass for grazing and cereal silage are set to constant values throughout the year (as information concerning their evolution throughout the year is not available to model otherwise and also because frequent rotation tends to keep at a stable level those values). However, the ME and CP contents of cereal silage change during the year as follows:

$$CMECRSL(t) = \frac{(OTHSL(t)*CMEOTH+CORNSL(t)*CMECRN)}{CERSL(t)} \qquad (8.42)$$

CMECRSL(t)= Content of ME in cereal silage at t (Mcal/Kg DM)

CMEOTH = Content of ME in winter cereal silage (Mcal/Kg DM)

CMECRN = Content of ME in corn silage (Mcal/Kg DM)

$$CPTCRSL(t) = \frac{(OTHSL(t)*CPTOTH+CORNSL(t)*CPTCRN)}{CERSL(t)} \qquad (8.43)$$

CPTCRSL(t)= Content of CP in cereal silage at t (gr CP / Kg DM)

CPTOTH = Content of CP in winter cereal silage (gr CP / Kg DM)

CPTCRN = Content of CP in corn silage (gr CP / Kg DM)

Finally, the ME and CP content of the silage mix throughout the year is:

$$CMESILG(t) = \frac{(CERSL(t)*CMECRSL(t)+GRASSLG(t)*CMEGRFS(t))}{TSILAGE(t)} \qquad (8.44)$$

CMESILG(t)= Content of ME in silage at t (Mcal / Kg Dm)

$$CPTSILG(t) = \frac{(CERSL(t)*CPTCRSL(t)+GRASSLG(t)*CPTGRFS(t))}{TSILAGE(t)} \qquad (8.45)$$

CPTSILG(t)= Content of CP in silage at t (gr CP / Kg DM)

Validation of this component in discussed in Chapter 13; limitations and their eventual remedies are considered in Chapter 15.

CHAPTER 9

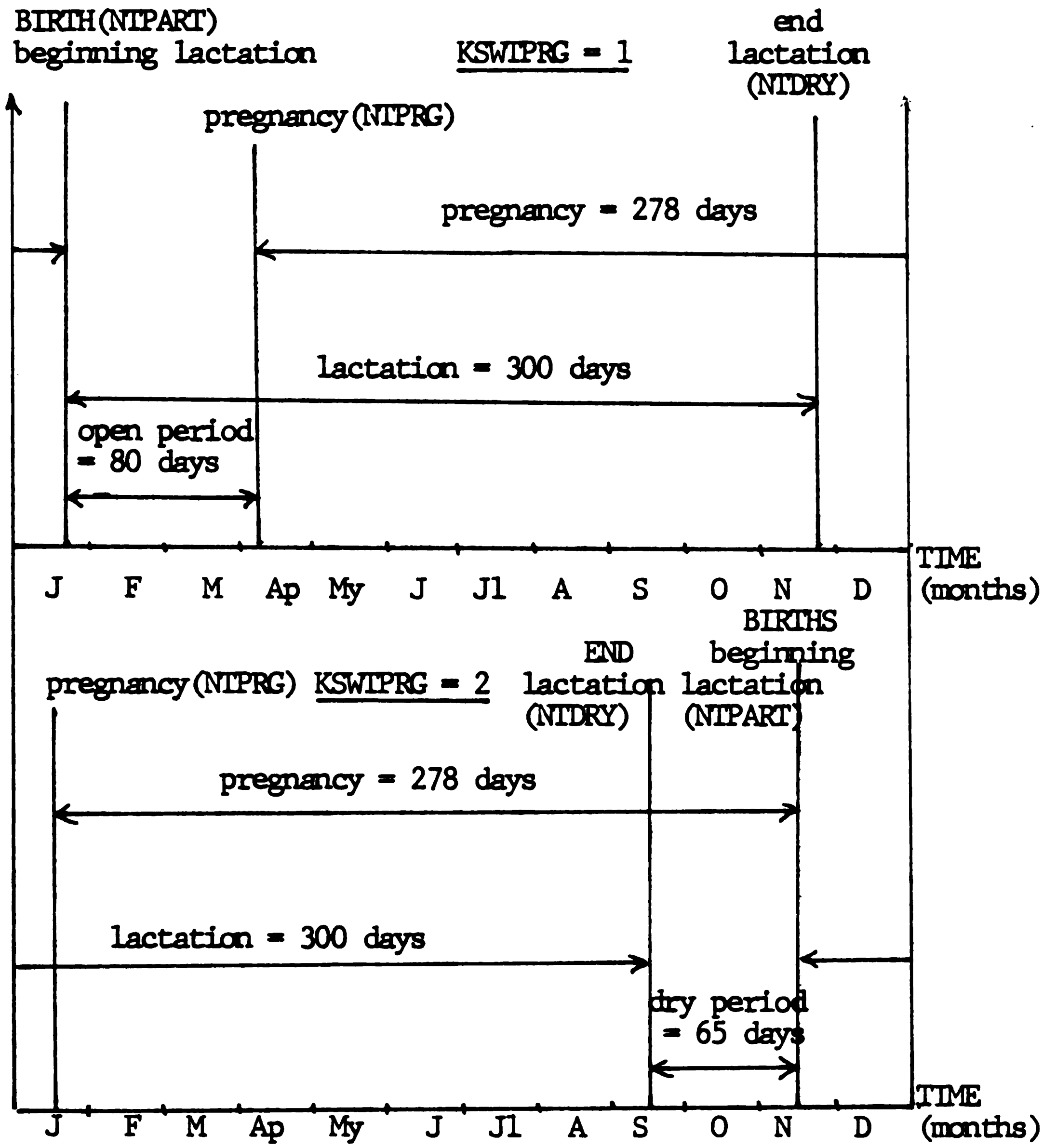
The DHERD Subsystem

The dairy herd is disaggregated into several animal and age cohorts. We assume that three types of animals are kept in the herd. They are growing calves up to 1 year of age, heifers from 1 to 2 years old and cows from 2 to 9 years of age. We assume cows are sold after the 7th lactation if they are not previously culled. The cow category is further disaggregated into seven age cohorts. The DHERD subroutine simulates the dynamics of the herd as a flow of animals leaving one age cohort and entering a higher age cohort, a shifting process which takes place once a year at parturition time. Also, animals can enter cohorts by purchases and leave them by sales and, in a probabilistically simulated fashion, by death or involuntary removals such as accident or disease which do not affect their use as meat.

In managing the feed allocation problem throughout the year, the manager may control feed supply (up to a point), as shown in Chapter 8, or change the feed needed. The manager may control feed needs by deciding when to breed cows and heifers. This automatically determines the production cycle of the cows and the timing of feed demand throughout the year.

Animal production scientists in Galicia (Ramon Gonzalez Santillana et al. [32]) consider two seasons during the year as possible alternatives for breeding the cows and heifers. These are (a) breeding in April or May with calving taking place in January or February of the following year and (b) breeding in January or February with parturitions in November or December of the same year. A switch, KSWTPRG, selects one breeding alternative or the other allowing the analyst to study the implications of choosing either of them. Figure 9.1 shows the timing of the reproduction cycle under the two breeding alternatives.

Figure 9-1: Herd Dynamics Profile



9.1 Herd Dynamics, Facts, Assumptions and Empirical Relationships.

Consider the assumptions concerning the annual production cycle of cows. As shown in Figure 9.1, two production cycles are considered with managers controlling the timing of the cycle by setting the breeding period. The calving interval is assumed to be 12 months so the cycle is repeated year after year without slippage. The lactation cycle is assumed to last 300 days with cows being dry for the next 65 days until parturition. Gestation lasts approximately 278 days and the cows remain open for about 80 days (the open period is the time between parturition and pregnancy). Replacement heifers are bred for the first time at 15 months of age which is about when they weigh 330 to 350 kg.

Lactating cows failing to get pregnant during the breeding period are kept in the herd until the end of lactation, when they are sold for meat. Heifers failing to get pregnant when due may be sold for meat or kept until the following period, depending upon the assumption in the model. A part of the female calves born are kept for replacements, while the rest of the female calves and all male calves are sold within the week following parturition.

Simulation of deaths and involuntary removals (due to accident or disease) of cows from the herd is based on information obtained by H.M. Stewart et al. [75] who analyzed disposals of 19,337 Holsteins in Canada from September 1967, to August 1968, from data coming from DHIR farms, to determine probabilities of involuntary removal, death, and survival to the next lactation. Stewart et al. reported the observed probabilities of involuntary removals and deaths are related to the age of the cow. Linear regression estimates of each probability on lactation number yielded the equations:

$$Pr\ (\text{Involuntary Removal}) = .0373 + .0170 * Li$$

$$r^2 = .98$$

$$Pr\ (\text{Death}) = .0075 + .0043 * Li$$

$$r^2 = 1.$$

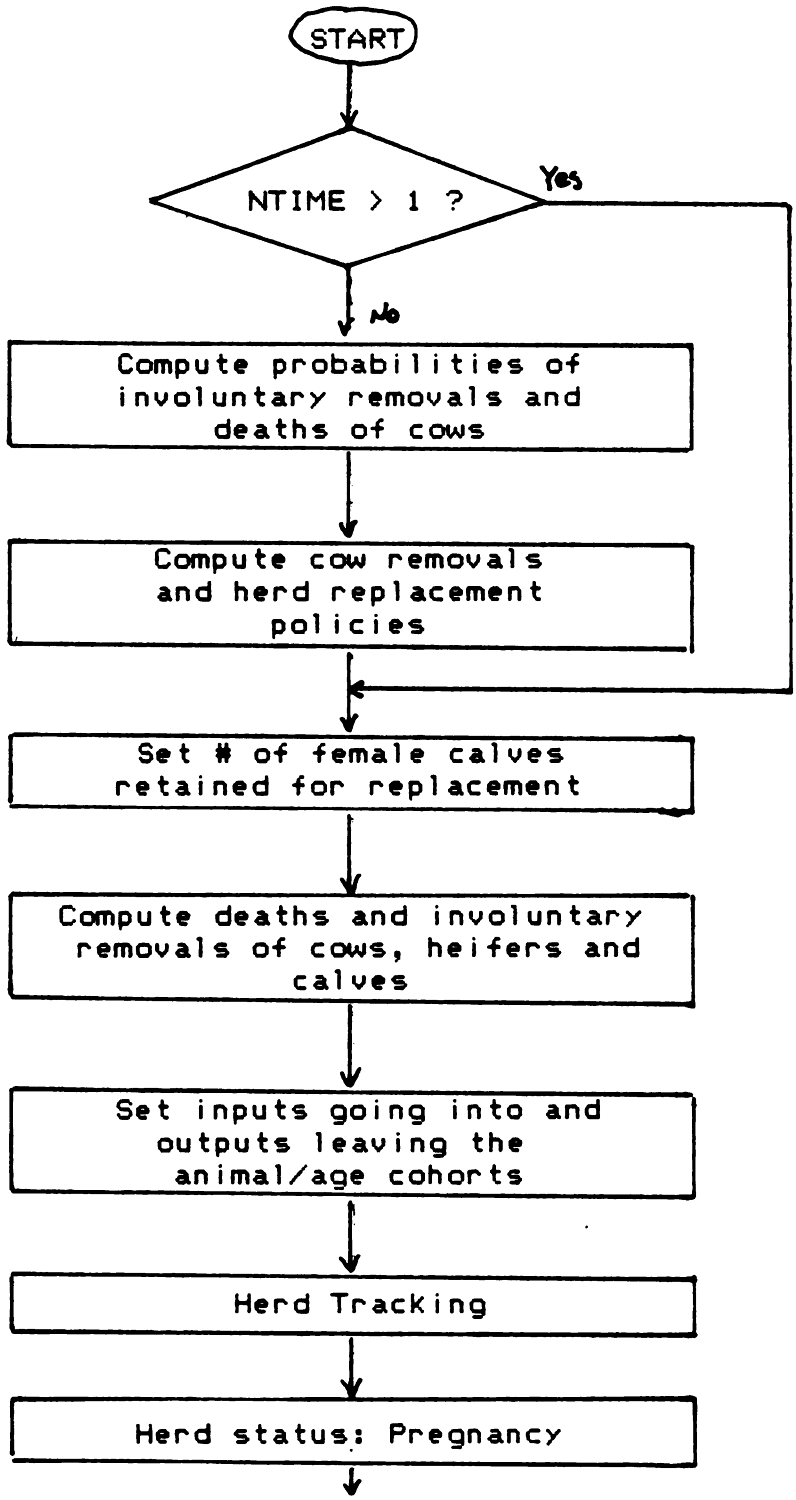
Li= Lactation number

The next section, will use the two relationships above to simulate deaths and removals of cows from the herd in a probabilistic way.

9.2 DHERD Description.

The computational flow through subroutine DHERD can be seen in Figure 9.2 and a detailed picture of DHERD structure and input-output connections are shown in Figure 9.3.

Figure 9-2: DHERD Flowchart



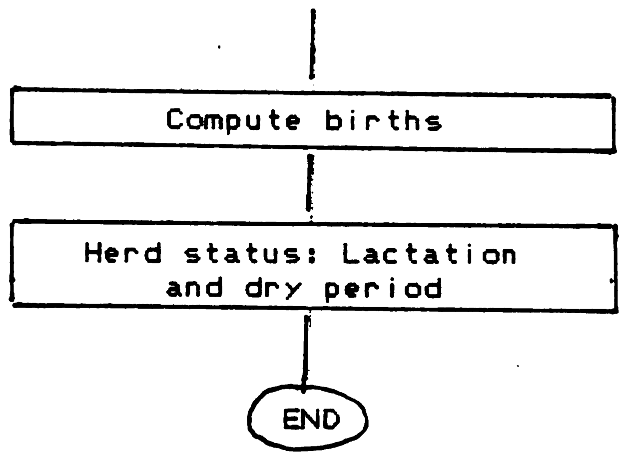
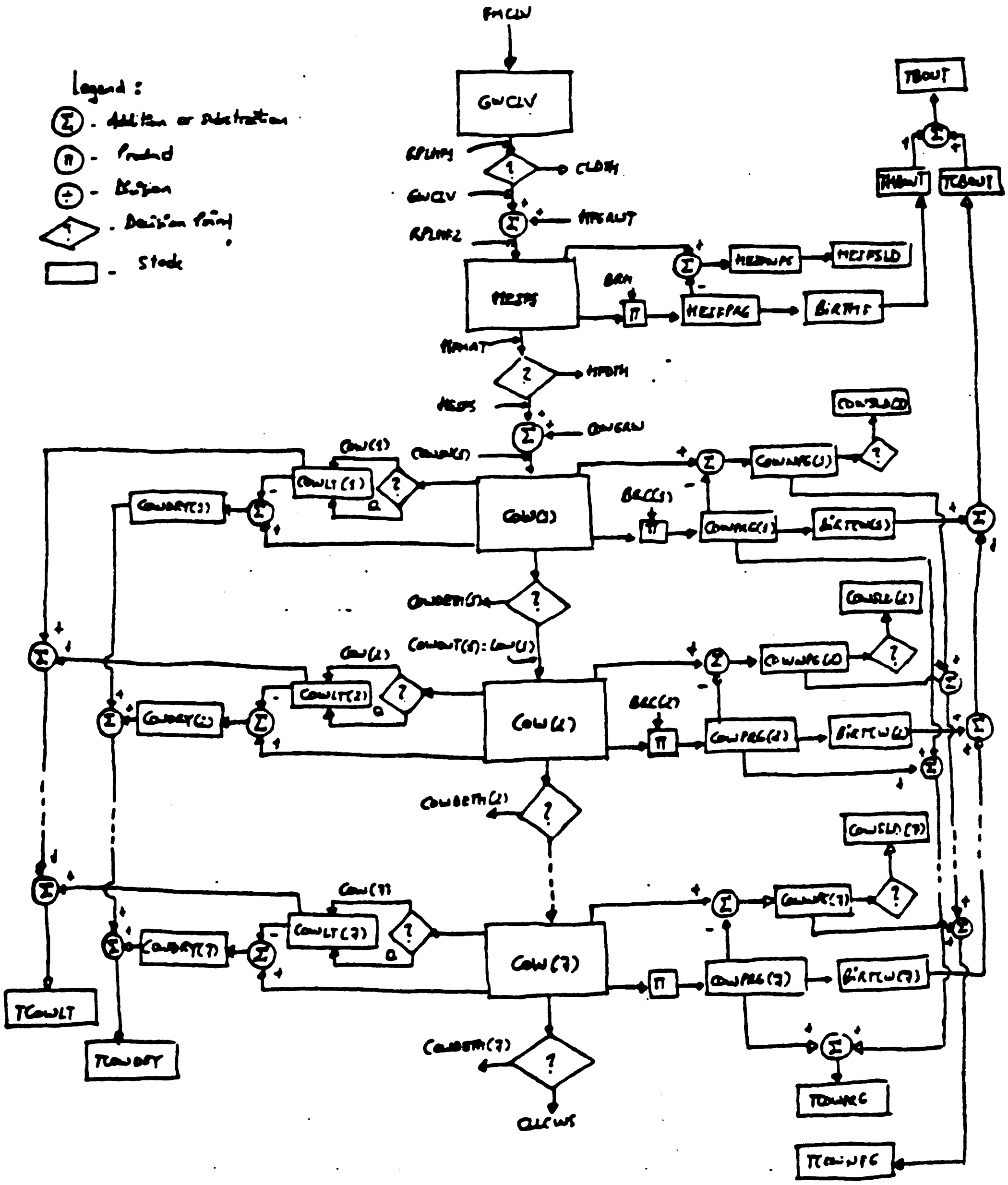

Compute births
Herd status: Lactation and dry period
END

Figure 9-3: DHERD Block Diagram



As we see in Figure 9.2 the subroutine sets at the beginning of every year the annual probabilities of involuntary removals and deaths for cows as a function of the lactation number and, then, computes cow removals and herd replacement policy. Those sets of computations are skipped for the rest of the year and are called again at the beginning of the following year.

$$\text{PRBINR(L)} = .0373+.0170*\text{L} \qquad \text{L}=1 \text{ to } 7 \tag{9.1}$$

$$\text{PRDEATH(L)} = .0075+.0043*\text{L} \qquad \text{L}=1 \text{ to } 7 \tag{9.2}$$

PRBINR(L) = Annual probability of involuntary removal of cows in lactation number L

PRDEATH(L)= Annual probability of death of cows in lactation number L

L = Lactation number, 1 to 7

Next in order to select one of the herd replacement policies, projected cow removals for the current year are calculated:

$$\text{COWRMV} = \sum_{I} \text{COW(I,t)*[PRBINR(I)+PRDEATH(I)+(1.-BRC(I))]}$$

$$\text{I}=1 \text{ to } 6 \tag{9.3}$$

COWRMV = Projected cow removals for the year (head)

COW(I,t) = Number of cows in cohort I (head), at t

BRC(I) = Birth rate of cows in cohort I

Herd size is adjusted to desired herd size by adding animals at three alternative levels according to the value selected for a switch operator: KSWT2.

If KSWT2 $<$ 1 then

$$CLVGRW = DTCOW - TCOW(t) \tag{9.4}$$

CLVGRW = Calves one week old required to adjust herd size to desired size (head)

DTCOW = Desired number of lactating cows (head)

TCOW(t) = Actual number of lactating cows (head), at t

If KSWT2 = 1 then

$$HFGRWT = DTCOW - TCOW(t) \tag{9.5}$$

HFGRWT = Heifers one year old required to adjust herd size to desired size (head)

If KSWT2 $>$ 1 then

$$COWGRW = DTCOW - (TCOW(t) + HEIFS(t) - COW(7,t)) \tag{9.6}$$

COWGRW = Heifers 2 years old and pregnant required to adjust herd size to desired value (head)

HEIFS(t) = Number of heifers on herd (head), at t

COW(7,t) = Cows in 7th lactation, which are to be culled in the current year (head), at t

The number of female calves desired for replacement purposes is determined as:

$$DFMCLV = COW(5,t) + COWRMV + HEIFS(t) * PLRH + GWCLV(t) * PLRCL$$

+CLVRW (9.7)

DFMCLV = Desired female calves for replacement (head)

COW(5,t) = Cows in fifth lactation (head), at t

PLRH = Probability of death for heifers

GWCLV(t) = Number of growing calves less than 1 year old in herd (head), at t

PLRCL = Probability of death for calves

At the time of parturition, if the number of female calves produced in the year is greater than DFMCLV, female calves actually retained are equal to DFMCLV, the remaining being sold, otherwise purchases must fill the gap.

If (TBOUT*.5) >= DFMCLV then

FMCLV(t) = DFMCLV (9.8)

FMSLS(t) = (TBOUT*.5)-FMCLV(t) (9.9)

IF (TBOUT*.5) < DFMCLV then

FMPCH(t) = DFMCLV-(TBOUT*.5) (9.10)

FMCLV(t) = (TBOUT*.5)+FMPCH (9.11)

At any other time except parturition time

FMCLV(t) = 0 (9.12)

TBOUT = Total births in current year (head)

FMCLV(t) = Female calves kept for replacement (head)

FMSLS(t) = Female calves sold (head)

FMPCH(t) = Female calves purchased (head)

Computation of deaths and involuntary removals of cows, heifers, and calves follows:

$$ACWDTH(I,t) = \int_{to}^{t} [PRDEATH(I)*COW(I,t)]\ dt \qquad (9.13)$$

I=1 to 7

If ACWDTH(I,t) >= 1 then

$$COWDETH(I,t) = 1. \qquad (9.14)$$

t = to

$$ACWDTH(I,t) = 0 \qquad (9.15)$$

If ACWDTH(I,t) < 1 then

$$COWDETH(I,t) = 0 \qquad (9.16)$$

ACWDTH(I,t) = Accumulated probability of death in cohort I, at time t

COWDETH(I,t)= Cows dead in cohort I at time t (head)

Notice the computations taking place in the system of equations (9.13) to (9.16). The probability of death for every age cohort (or lactation number) weighted by the number of cows in the cohort is accumulated throughout the entire period of study (which can be several years). When the accumulated probability reaches a value of 1, one death takes place, and the accumulated probability restarts its computation from zero.

A similar calculation is performed for involuntary removals:

$$ACPBINR(I,t) = \int_{to}^{t} [PRBINR(t)*COW(I,t)]\, dt \qquad (9.17)$$

$$I=1 \text{ to } 7$$

If ACPBINR(I,t) = 1 then

$$COWSLD(I,t) = 1 \qquad (9.18)$$

$$t = to$$

$$ACPBINR(I,t) = 0 \qquad (9.19)$$

If ACPBINR(I,t) < 1 then

$$COWSLD(I,t) = 0 \qquad (9.20)$$

ACPBINR(I,t)= Accumulated probability of involuntary removal in cohort I, at t

COWSLD(I,t) = Cows from cohort I, sold for meat by involuntary removal, at t

After finishing lactation the cows that failed to get pregnant are sold for meat.

If NTIME = NTDRY then

COWSLD(I,t) = COWNPG(I,t) (9.21)

NTIME = Time counter

NTDRY = End of lactation time

COWNPG(I,t) = Cows not pregnant in cohort I, at t time (head)

A set of computations similar to those used in determining cow deaths and involuntary removals are made for computing heifers and growing calves removals.

For heifers:

$$AHFDTH(t) = \int_{to}^{t} (PLRH*HEIFS(t))\, dt \qquad (9.22)$$

If AHFDTH(t) >= 1 then

HFDTH(t) = 1 (9.23)

t = to

AHFDTH(t) = 0 (9.24)

If AHFDTH(t) < 1 then

HFDTH(t) = 0 (9.25)

AHFDTH(t) = Accumulated probability of heifers death at t

PLRH = Annual probability of heifers death

HFDTH(t) = Heifers dead at t (head)

For growing calves:

$$ACLDTH(t) = \int_{to}^{t} (PLRCL*GCLV(t))\, dt \qquad (9.26)$$

If ACLDTH(t) >= 1 then

$$CLDTH(t) = 1 \qquad (9.27)$$

$$t = to$$

$$ACLDTH(t) = 0 \qquad (9.28)$$

If ACLDTH () < 1 then

$$CLDTH(t) = 0 \qquad (9.29)$$

ACLDTH(t) = Accumulated probability of growing calves dead at t

PLRCL = Annual probability of growing calves death

CLDTH(t) = Growing calves dead at t (head)

Next, inflows and outflows of all animal/age cohort are determined. A look at Fig 9.3 will clarify the computations made below:

At parturition, i.e, NTIME = NTPART

$$RPLHF1(t) = GWCLV(t) \qquad (9.30)$$

$$RPLHF1(t) = RPLHF1(t)+HFGRWT \qquad (9.31)$$

Otherwise, i.e, NTIME $\neq$ NTPART

RPLHF1(t) = CLDTH(t) (9.32)

RPLHF2(t) = 0 (9.33)

RPLHF1(t) = Growing calves leaving the growing calves cohort at t. At parturition time all growing calves move up to the next cohort. At any other time growing calves dead leave the cohort (head)

RPLHF2(t) = Growing calves, at least one year old, going into the next cohort at t (head)

If NTIME = NTPART

HFMAT(t) = HEIFS(t) (9.34)

COWIN(1,t) = HFMAT(t)+COWGRW (9.35)

COWOUT(1,t) = COW(1,t) (9.36)

COWIN(I,t) = COW(I-1,t) I=2 to 7 (9.37)

COWOUT(I,t) = COW(I,t) I=2 to 7 (9.38)

If NTIME ≠ NTPART

HFMAT(t) = HFDTH(t) (9.39)

COWIN(I,t) = 0 I=2 to 7 (9.40)

COWIN(I,t) = COWDETH(I,t) I=2 to 7 (9.41)

NTIME = Time counter

NTPART = Time to parturition (in # of solution intervals)

HFMAT(t) = Maturing heifers leaving the heifers cohort (head)

COWIN(I,t) = Cows entering the I cow cohort at t (head), I=1 to 7

COWOUT(1,t) = Cows leaving the I cow cohort at t (head), I=1 to 7

Cullings are computed similarly:

If NTIME = NTPART then

CLLCWS(t) = COWOUT(7,t) (9.42)

If COWGRW >= 0 that is if desired herd size is greater than the actual size, there will not be heifers in excess, and no heifers culling will occur.

CLLHEIF(t) = 0 (9.43)

If COWGRW < 0 that is if desired herd size is less than the actual size, there will be some heifers in excess, and heifers culling will occur.

CLLHEIF(t) = ABS(COWGRW) (9.44)

ABS(--) = Absolute value function

At times other that parturition equations (9.42) to (9.44) will be bypassed.

If NTIME = NTPART

CLLCWS(t) = 0 (9.45)

CLLHEIF(t) = 0 (9.46)

CLLCWS(t) = Cows culled at t (head)

CLLHEIF(t) = Heifers culled at t (head)

Next, herd tracking is done:

GWCLV(t) = GWCLV(t)+(FMCLV(t)-RPLHF1(t)) (9.47)

HEIFS(t) = HEIFS(t)+(RPLHF2(t)-HFMAT(t)) (9.48)

COW(I,t) = COW(I,t)+(COWIN(I,t)-COWOUT(I,t)
-COWSLD(I,t)) (9.49)
I=1 to 7

Herd status, starting with pregnancy is monitored below:

If NTPART =< NTIME < NTPRG

HEIFPRG(t) = 0 (9.50)

COWPRG(I,t) = 0 I=1 to 7 (9.51)

That is during the time between parturition and pregnancy again, heifers and cows are not pregnant.

At any other times we have:

If NTIME >= NTDRY and NTIME =< NTPART

HEIFPRG(t) = HEIFS () (9.52)

COWPRG(t) = COW(I,t) I=1 to 7 (9.53)

At pregnancy time the following set of computations take place.

If KSWT9 =< 1 heifers failing to get pregnant are sold for meat:

HEIFPRG(t) = HEIFS(t)*BRH (9.54)

HEIFNPG(t) = HEIFS(t)-HEIFPRG(t) (9.55)

HEIFSLD(t) = HEIFNPG(t) (9.56)

HEIFS(t) = HEIFS(t)-HEIFSLD(t) (9.57)

HEIFPRG(t) =/ HEIFS(t) (9.58)

If KSWT9 > 1 heifers failing to get pregnant are kept one more year:

HEIFPRG(t) = HEIFS(t)*BRH (9.59)

HEIFNPG(t) = HEIFS(t)-HEIFPRG(t) (9.60)

At pregnancy time the following computation is done for cows too:

COWPRG(I,t) = COW(I,t)*BRC(I) I=I to 7 (9.61)

At times other than pregnancy time we have:

If NTIME = NTPRG then

If KSWT9 =< 1

HEIFSLD(t) = 0 (9.62)

HEIFPRG(t) = HEIFS(t) (9.63)

If KSWT9 > 1

HEIFPRG(t) = HEIFS(t)*BRH (9.64)

HEIFNPG(t) = HEIFS(t)-HEIFPRG(t) (9.65)

And for cows equation (9.61) above holds together with:

COWNPG(I,t) = COW(I,t)-COWPRG(I,t) I=1 to 7 (9.66)

At the end of the lactation period the pregnant cows are sold:

COWSLD(I,t) = COWNPG(I,t) I=1 to 7 (9.67)

COWNPG(I,t) = 0 I=1 to 7 (9.68)

COWPRG(I,t) = COW(I,t) I=1 to 7 (9.69)

NTIME = Time counter

NTPART = Time to parturition

NTPRG = Time to pregnancy

NTDRY = Time to end of lactation

HEIFPRG(t) = Heifers pregnant at t (head)

COWPRG(I,t) = Cows in cohort I pregnant at t (head)

BRH = Birth rate of heifers

HEIFNPG(t) = Heifers not pregnant at t (head)

HEIFSLD(t) = Heifers sold at t (head)

BRC(I) = Birth rate of cows in cohort I

COWNPG(I,t) = Cows in cohort I not pregnant at t (head)

Births are computed now:

If NTIME = NTPART

BIRTHF(t) = HEIFPRG(t) (9.70)

BIRTCW(I,t) = COWPRG(I,t) I=1 to 7 (9.71)

Total cow births are:

$$TCBOUT(t) = \sum_{I} BIRTCW(I,t) \qquad I=1 \text{ to } 7 \qquad (9.72)$$

Total births:

TBOUT(t) = BIRTHF(t)+TCBOUT(t) (9.73)

Male births (that are sold within the week) are:

XMSLS(t) = TBOUT(t)*.5 (9.74)

At any other times of the year we have:

BIRTHF(t) = 0 (9.75)

BIRTCW(I,t) = 0 I=1 to 7 (9.76)

BIRTHF(t) = Births from heifer at t (head)

BIRTCW(I,t) = Births from cows in cohort I, at t (head)

TCBOUT(t) = Total births from cows at t (head)

TBOUT(t) = Total births at t (head)

XMSLS(t) = Total births male at t (head)

Finally, lactation status is monitored:

If NTPART =< NTIME < NTDRY then

$$COWLT(I,t) = COW(I,t) \qquad I=1 \text{ to } 7 \qquad (9.77)$$

$$COWDRY(I,t) = 0 \qquad I=1 \text{ to } 7 \qquad (9.78)$$

If NTDRY =< NTIME < NTPART then

$$COWLT(I) = 0 \qquad I=1 \text{ to } 7 \qquad (9.79)$$

$$COWDRY(I) = COW(I,t) \qquad I=1 \text{ to } 7 \qquad (9.80)$$

COWLT(I,t) = Cows in cohort I lactating, at t (head)

COWDRY(I,t) = Cows in cohort i dry, at t (head)

The subroutine concludes with computation of the following summations:

$$TCOW(t) = \sum_I COW(I,t) \qquad I=1 \text{ to } 7 \qquad (9.81)$$

$$TCOWTG(t) = \sum_I COWPRG(I,t) \qquad I=1 \text{ to } 7 \qquad (9.82)$$

$$TCOWNPG(t) = \sum_I COWNPG(I\ \ ,) \qquad I=1 \text{ to } 7 \qquad (9.83)$$

$$TCOWSLD(t) = \sum_I COWSLD(I,t) \qquad I=1 \text{ to } 7 \qquad (9.84)$$

$$TCOWLT(t) = \sum_I COWLT(I,t) \qquad I=1 \text{ to } 7 \qquad (9.85)$$

$$TCOWDRY(t) = \sum_I COWDRY(I,t) \quad I=1 \text{ to } 7 \tag{9.86}$$

TCOW(t) = Total number of cows at t (head)

TCOWPG(t) = Total number of cows pregnant at t (head)

TCOWNPG(t) = Total number of cows not pregnant at t (head)

TCOWSLD(t) = Total number of cows sold at t (head)

TCOWLT(t) = Total number of cows lactating at t (head)

TCOWDRY(t) = Total number of cows dry at t (head)

CHAPTER 10

The NUTIMP Subsystem

The NUTIMP component is concerned with the biological processes by which heifers and growing calves convert feed into body weight gains and the similar, although more complex, biological process by which cows convert feed into milk, body weight and products of conception.

A complex maze of relationships appears, to the inexperienced eye at least, to characterize those biological process. Dry matter intake, body weight, milk yield, ME content of the ration, net energy requirements for different purposes, efficiencies in ME utilization, weight gains or losses, all those variables seem to cause and be dependent upon each other making it difficult to sort out a consistent hierarchical causation among the variables.

In our model we stress the energy and protein requirements of the dairy animals during their productive and reproductive cycles and we assume that other requirements (minerals, crude fiber in diet, etc) are always met.

A short survey of the literature in dairy science showed that a complete theory of the biological processes mentioned above is, despite the considerable amount of knowledge accumulated, not yet definitive and complete. Problems remain unsolved, one of the most crucial being the seeming ability of high yielding cows to utilize energy from body stores, i.e., by losing weight, to maintain a high level of milk production in early lactation. Mobilization of net energy from body stores allows the cow to bridge a energy deficit situation, since dry matter intake increases slowly after parturition, at a much lower rate than milk production, and consequently energy supply lags behind energy demand for milk production. In late lactation, as milk yield decreases while dry matter intake remains relatively high the energy balance situation is reversed with an energy surplus emerging. This energy surplus is used by the cow to restore the body weight loss in early lactation. A production cycle equilibrium is apparent here, with energy deficits in early lactation compensated, through body weight mobilization, with energy surplus in late lactation, that allows the high yielding cow to produce milk up to her potential.

This pattern of body stores mobilization has been demonstrated for high yielding cows (Broster & Alderman [8]) although the internal mechanism allowing the cow to mobilize body weight .is still unclear. For instance, although the conversion of ME in body weight into net energy for milk production, i.e., the technical coefficient kg weight/lt milk,has been quantified, little is known about the level of daily weight loss at which the biological priority of milk production vs weight maintenance is reversed, hence causing a depression in milk yield.

It is also unclear whether average yielding cows have the same abilities of body stores mobilization as high yielding cows, or the biological priority in those cows is always weight maintenance, with actual milk yield falling whenever an energy deficit situation arises (for whatever reason, for instance, conscious underfeeding or feeding of low energy rations)

In the design of this component we have taken advantage of the considerable amount of technical information contained in the National Research Council # 3 document on Nutrient Requirements of Dairy Cattle (fifth revised edition, 1978), [55]. This document containts a quantified, dynamic, model of the biological processes of dairy cows, heifers and growing calves which are of interest for us. Together with data from the relevant literature in dairy science, the NRC document provides the foundation for the NUTIMP submodel.

The next section discusses the data, assumptions, and technical relationships used in this submodel as well as the sources of this information. In the second and last section we describe in detail the NUTIMP mathematical model.

10.1. NUTIMP Data, Assumptions and Technical Relationship.

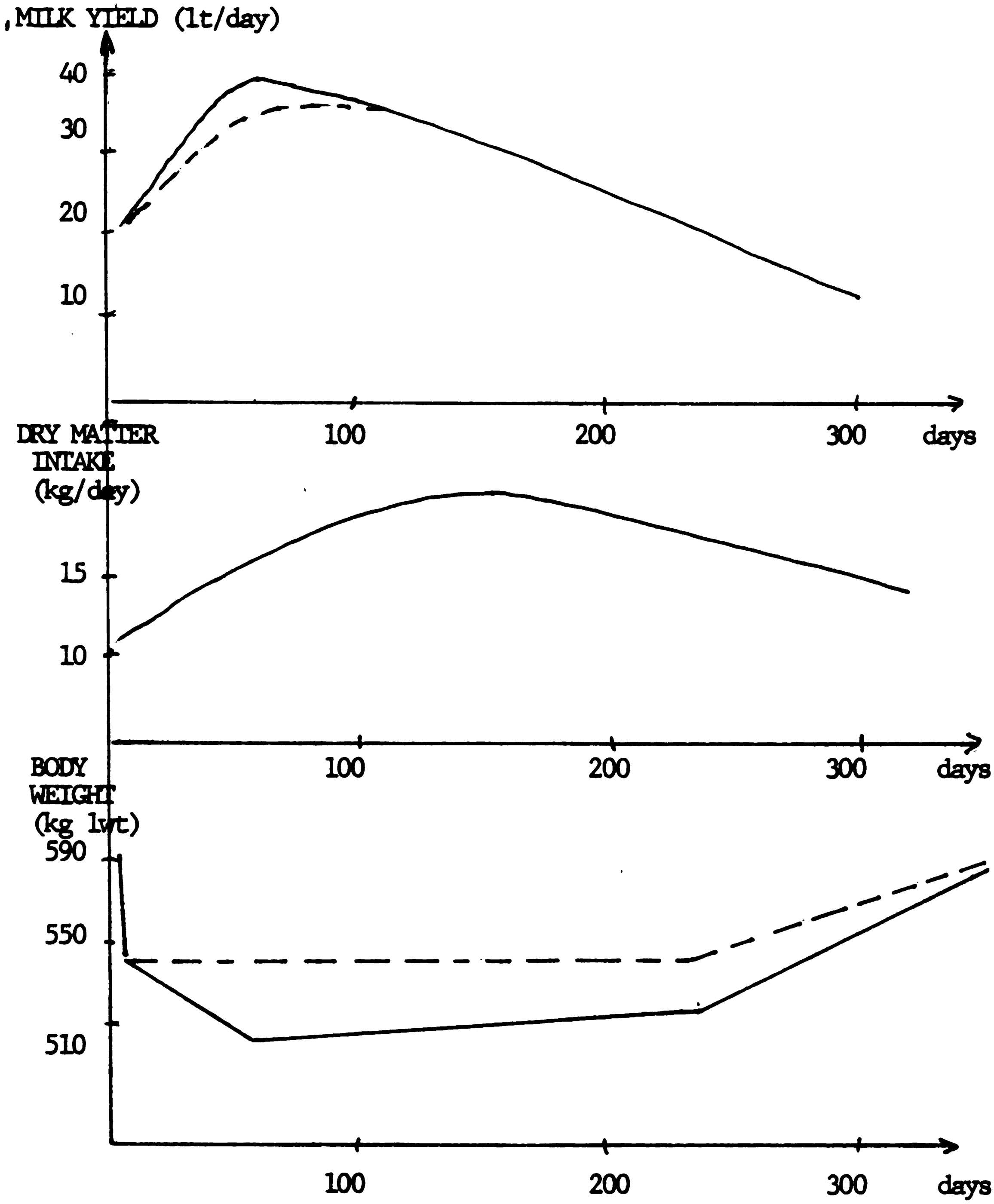
10.1.1. Lactating Cows.

Cows convert feed into milk and body weight following a defined time pattern from the time of parturition to the beginning of the dry period. The prediction of daily voluntary dry matter intake and daily milk yield as well as the daily evolution of body weight is a principal concern of this subroutine.

Daily milk yield, daily voluntary dry matter intake, and body weight evolve throughout the year following patterns similar to those shown in Figure 10-1. As shown there, daily milk yield rises sharply after parturition, reaching a peak at between 4 to 8 weeks into lactation, and decreasing later progressively until the dry period starts. The fall in daily milk yield in late lactation is associated with the energy demands of pregnancy and this means that cows with longer calving periods, have higher milk yields in late lactation.

Voluntary dry matter intake rises slowly, (at a lower rate than milk yield in any case), peaking 2 to 6 weeks after milk yield does and then decreasing steadily, also at a lower rate than milk yield, until the end of the production cycle.

Figure 10-1: Annual Profiles of Daily Milk Yield, Dry Matter Intake and Body Weight



(Source: BROSTER & ALDERMAN [8])

The net energy demands for milk production rises early in lactation following the rise in daily milk yields potential that we show in the upper diagram in Figure 10.1. For the milk yield potential to become actual yield, energy fed to the cow has to balance energy demand. For average yielding cows the manager can match energy supply to energy demand by increasing the energy concentration of the diet during early lactation. However, for high yielding cows even diets with high concentrate to forage ratios can not supply enough energy to meet the energy requirements of the cow during early lactation. The high yielding cow overcomes this energy imbalance by mobilizing energy deposited in body stores.

The lower diagram in Figure 10.1 shows the evolution of body weight during the calving period. At parturition the cow loses about 60 to 70 kgs in fetal products (baby calf, placenta). Then in early lactation, if we consider a high yielding cow, body weight decreases steadily as the cow mobilizes body stores in order to keep her high milk yield. During mid and late lactation the cow is able to restore body weight as the energy imbalance changes sign. If we consider an average yielding cow, however, after the drop in weight following parturition, weight remains stable until late lactation when increases in weight due to pregnancy occur. Under this hypothesis the biological priority of the cow is weight maintenance and the energy imbalances during the lactation cycle show up in actual milk yields lower than potential. The dashed lines in the upper and lower diagram of Figure 10-1 illustrate this case.

Figure 10-2 and Figure 10-3 show the causal relationships among critical state variables for the two cases of high yielding and average yielding cows respectively. Both diagrams should be helpful when going through the relevant equations in the next section. We now review the causality flow for the average yielding cows (Figure 10-3).

Figure 10-2: High Yielding Cow Causal Block Diagram

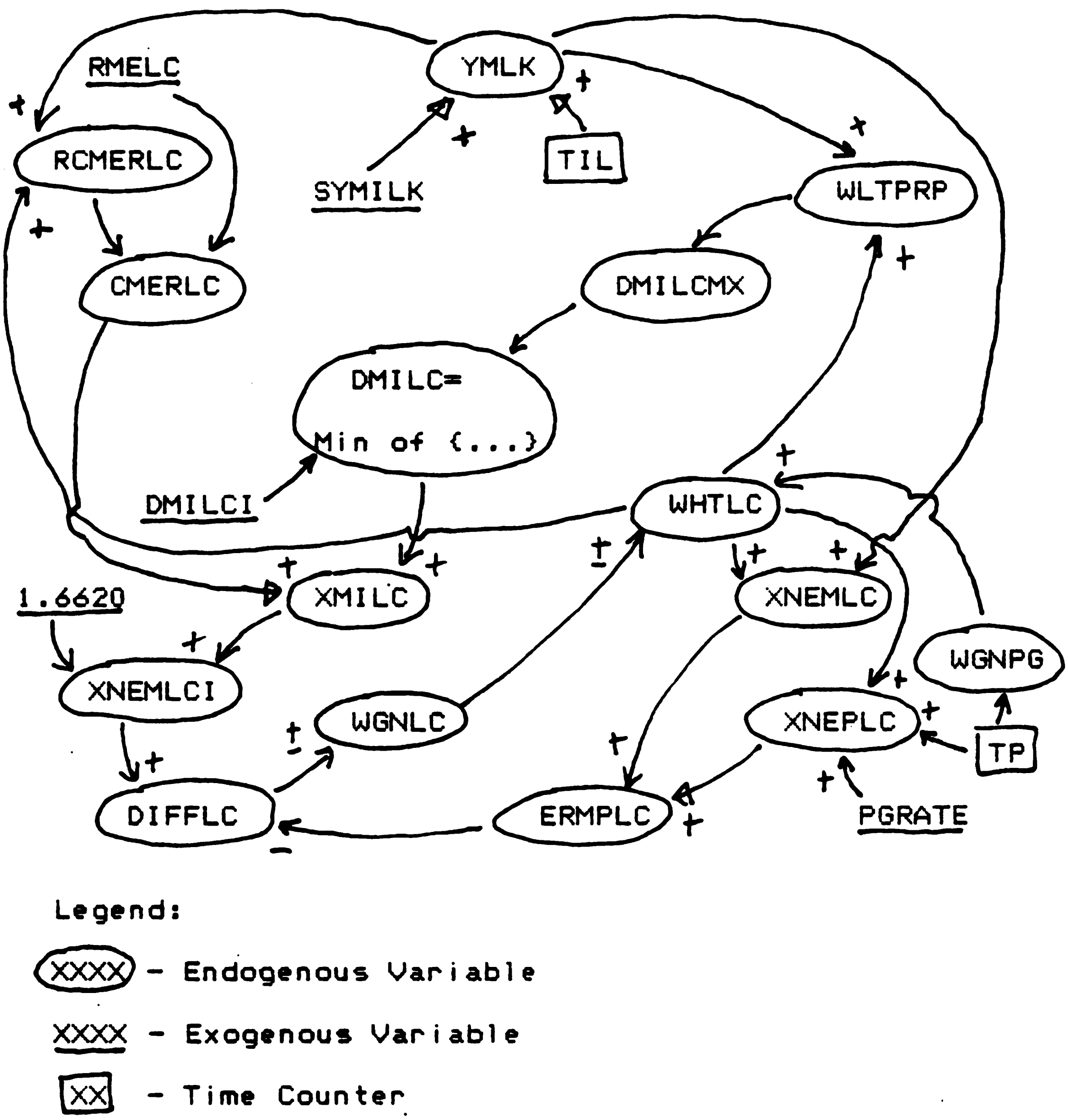
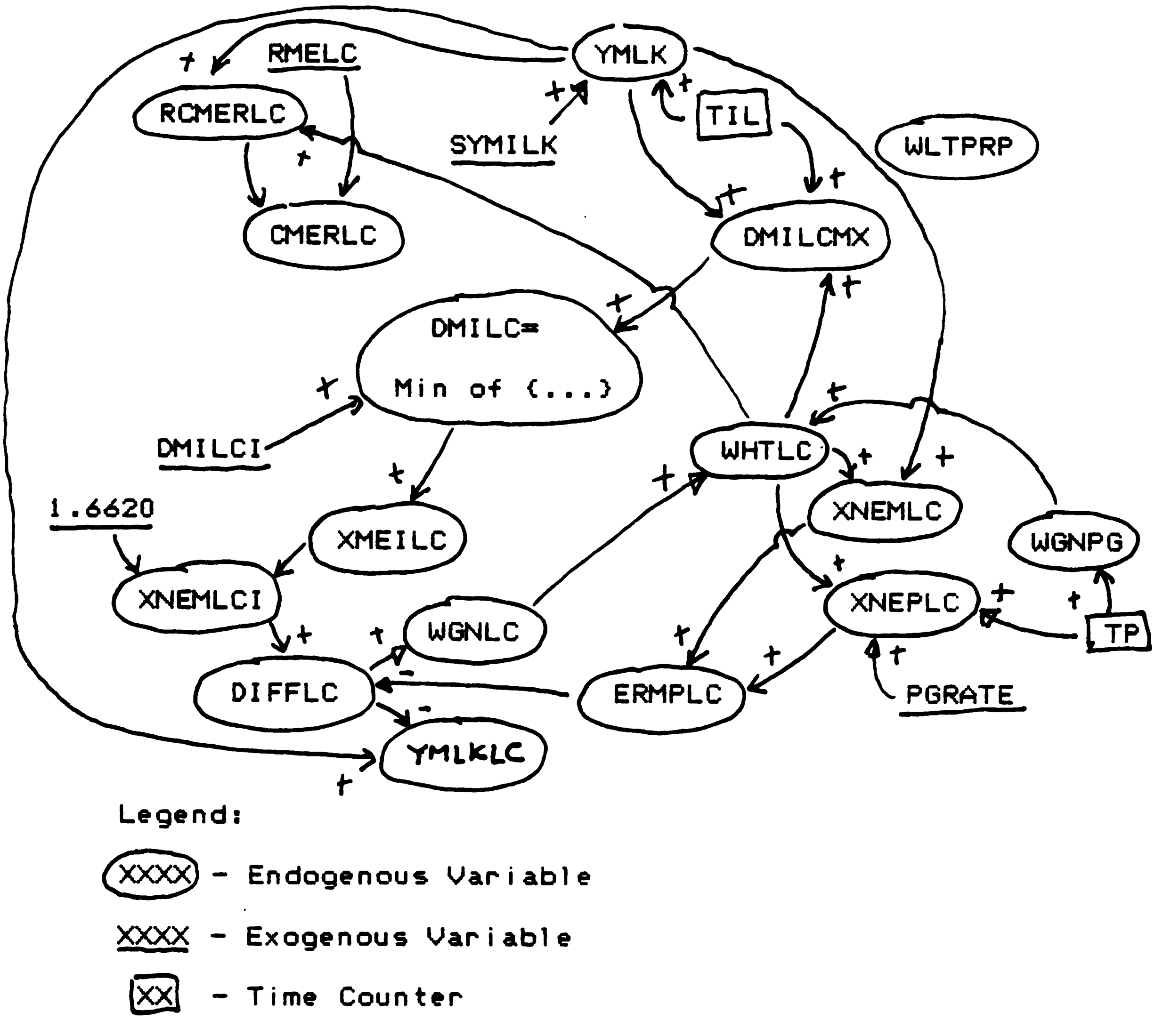


Figure 10-3: Average Yielding Cow Causal Block Diagram



Daily milk yield potential (YMLK) is a function of annual milk yield potential (SYMILK) and days into lactation (TIL). The concentration of ME in the ration (CMERLC) may be determined in two ways: i) As recommended in the NRC tables (RCMERLC): Function of milk yield (YMLK) and body weight (WHTLC); ii) As exogenous input from other subroutine in the model (RMELC). Voluntary dry matter intake (DMILCMX) is a function of milk yield (YMLK), body weight (WHTLC) and days into lactation (TIL). Actual dry matter intake (DMILC) is the minimum of voluntary dry matter intake (DMILCMX) and dry matter intake fed (DMILCI), which is an exogenous controllable input. The ME ingested (XMEILC) is the product of actual dry matter intake (DMILC) times the concentration of ME in ration (CMERLC). Net energy supply (XNEMLCI) is equal to ME intake (XMEILC) divided by an efficiency factor (1.6620). Net energy requirements for maintenance and lactation (XNEMLC) is a function of body weight (WHTLC) and milk yield potential (YMLK). Net energy requirements for pregnancy (XNEPLC) is a function of body weight (WHTLC) and days into pregnancy (TP). Total net energy requirements (ERMPLC) is the sum of net energy requirements for maintenance, lactation and pregnancy. i.e., (XNEMLC) plus (XNEPLC). Net energy requirements are now substracted from net energy supply. The difference, surplus or deficit, is (DIFFLC). If there is an energy surplus, (i.e; DIFFLC > 0) it will be converted in body weight gain (WGNLC). If there is an energy deficit, (i.e., DIFFLC < 0) milk yield potential will be adjusted downwards (YMLKLC). There will be, especially during the last two months of lactation, substantial body weight gains (WGNPG) due to pregnancy, i.e., as a function of days into pregnancy (TP) and the rate of growth of products of conception (PGRATE). Finally, body weight (WHTLC) will by adjusted every day by weight gains or losses, i.e., (WGNLC) plus (WGNPG).

We now revise the functional forms used for the lactation curve and the voluntary dry matter intake.

For the lactation curve we adopted the estimations provided by Kellog, Scott Urquhart and Ortega [43]. They analyzed milk production records of healthy Holstein cows which were fed rations providing at least 5% more nutrients than required. They adjusted, by nonlinear regression methods, the following gamma curve:

$$Y_i = B_1 * t_i^{B_2} * e^{-B_3 * t_i} + \varepsilon_i$$

where:

Y_i = Milk production in kilograms at t_i

t_i = Time in months

The results for the first 4 lactations are summarized in Table

10-1 below:

Table 10-1

Lactation Curve Parameters

Lactation	B_1	B_2	B_3	R^2
1	23.365	.154	-.074	.9878
2	34.716	.245	-.162	.9968
3	37.503	.286	-.177	.9976
4	37.838	.297	-.181	.9949

(Source: Table 1, Kellog, Scott Urquhart & Ortega [43], page 1309)

The coefficients affect the curves in the following way:

i) B_1 changes the height of the curve across all times (it should by affected by feeding policy), but it has no impact on shape of the curve.

ii) The peaks occur at B_2/B_3 , which lies between 1.5 and 2.0 months for all lactation.

iii) B_2 shapes the rising portion of the curve.

iv) B_3 dominates how fast the curve drops off from its maximum.

In our research we disregard the values obtained for the scaling parameter B_1 , which are calculated in the model as functions of the annual milk yield potentials for different lactations (AYMLK(L)). We call the scaling parameter α(L) (L=lactation number) and it is computed as follows:

$$\alpha(L) = \frac{AYMLK(L)}{\int_{t_{bl}}^{t_{el}} (t^{B_2} * e^{-B_3 * t}) \, dt}$$

t_{bl} = Beginning of lactation

t_{el} = End of lactation

The parameters of the lactation curves for lactation numbers 5 to 7 are made equal, in our model, to those for the 4th lactation.

Annual milk production ability increases with age, up to the 6th lactation when it reaches a maximum. It then falls slighthy in the 7th lactation. Annual milk yields for every lactation are computed by applying a proportion factor to annual milk yield for the 6th lactation (SYMILK) which is the maximum. The proportional factors represent the ratio of annual milk yield for the L lactation (L=1 to 7) over annual milk yield for the 6th lactation (i.e., the proportional factor for the 6th lactation is 1.0).

AYMLK(L) = SYMILK*RTMK(L) I=1 to 7

SYMILK = Annual milk yield for the 6th lactation (kg milk yield/year)

AYMLK(L) = Annual milk yield for the L lactation (kg milk/year)

RTMK(L) = Ratio of annual milk yield for the L lactation over annual milk yield for the 6th lactation

The values for the proportional factors (RTMK(L)) are taken from Stewart, Burnside, Wilton & Pfeiffer [75], who analyzed in their study a large amount of Canadian dairy production records. We reproduce below a part of Table 8 taken from their article:

Table 10-2

Lactation Number Coefficients

Lactation number(L)	Ratios (RTMK(L))
1	.734
2	.862
3	.933
4	.975
5	.994
6	1.000
7	.994

(Source: H.M. Stewart, E.B. Burnside, J.W. Wilton & W.C. Pfeiffer (1976). A Dynamic Programming Approach to Culling Decision in Commercial Dairy Herds. Journal of Dairy Science Vol. 60, No.4).

The increasing ability of a dairy cow to produce milk as she grows older will affect, when we consider also the changing composition of the dairy herd from year to year, the rolling milk yield average from year to year and consequently the economic performance of the dairy business.

The prediction of voluntary dry matter intake is simulated according to the research of Brown, Chandler & Holter [9].

They attempted to develop prediction equations for milk yield and dry matter intake. A total of 4,135 Holstein and 704 Jersey, 28- day records were analyzed with linear regression methods. We are interested here mainly in the dry matter equation the authors found, since milk yield is generated, in our model, in a different way. Table 10.2 shows the results obtained by the authors that we use in subroutine NUTIMP. The dependent variable is the natural logarithm of dry matter intake (kg DM/day).

Table 10•3

Dry Matter Intake Equation Coefficients

Variables	Regresion coefficients b
Intercept	.519776
Location coefficient	--
Season coefficient:	
Fall-winter	.041770
Spring	-.004122
Summer	-.037648
Days (in lactation)	-.000827
Ln days	.148073
Ln milk (kg/day)	.339220
Fat (kg/day)	.99266
Body weight (kg)	.000675
Crude fiber(% of DM)	.018001
Crude fiber square	-.000557
R^2	.741

(Source: Brown, Chandler & Holter [9] Table 3, page 1745).

All regression coefficients are significant at .05 level.

In our version of this equation we omit the intercept, location and season coefficients and we apply a scaling factor, (TN1), that allow us to move up or down the dry matter equation in order to have it behave in accord with other parts of the model.

From the daily milk yield equation derived by Brown et al., we retain one coefficient, the elasticity of daily milk yield to daily dry matter intake. We use this elasticity value to adjust downwards, if actual dry matter intake is below voluntary dry matter intake, daily milk yields. Equations (10.76) and (10.77) in the next section, show how the adjustment is performed for pregnant and nonpregnant cows respectively.

We now offer some comments on the different types of energy considered in the model. A quotation taken from the NRC document [55] will hopefully clarify the matter:

> "Digestible or metabolizable energy is used with different efficiencies for maintenance and body gain in nonlactating animals, but is used with similar efficiencies for maintenance and milk production in lactating animals. For this reason, three net energy values have been used. The net energy value for maintenance (NEm) is the net energy value of feeds for the maintenance of nonlactating animals. The net energy value for gain (NEg) is the net energy value of feeds for the deposition of body tissue in nonlactating animals........ Since energy is used with similar degrees of efficiency for maintenance and milk production in lactating animals, a single net energy value of feeds (NE) is adequate to calculate rations for both maintenance and milk production." (NRC, #3, page 2).

Accordingly, four types of energy are accounted for in our model: i) ME, ii) Net energy for maintenance of nonlactating animals (NEm)., iii) Net energy for gain of nonlactating animals (NEg)., and iv) Net energy for maintenance and lactation of lactating animals (NE). ME is converted into the three other types of energy by application of the relevant energy efficiency factors.

Net energy requirements for pregnancy and the growth of the fetus and related tissue have been shown, according to NRC (page 4), to follow an exponential growth. We use the following functional forms in our model:

$$\text{NEp (Mcal/day)} = A * \text{Weight}^{.75} * e^{g*tp}$$

$$\text{Daily weight gain (kg/day)} = B * e^{g*tp}$$

NEp = Net energy requirement for pregnancy (Mcal NE/day)

g = Growth rate of products of conception

tp = Days into pregnancy

A and B are scaling factors which have been found by trial and error.

Finally we generate CP requirements following two methods, both based on data found in the NRC document. The analyst can choose either of the two methods when running the model. In the first mode, we use the factorial method described in pages 5 to 7, with total CP requirements defined as:

$$TCP = \frac{U + F + S + G + C}{Ep} + \frac{L}{Ep}$$

TCP = Total CP requirements (gr CP/day)

U = Net protein lost in urine (gr P/day)

F = Net protein lost in feces (gr P/day)

S = Net protein lost in skin secretions, scurf, and hair (gr P/day)

G = Net protein deposited in body weight gains (gr P/day)

C = Net protein deposited in products of conception (gr P/day)

L = Net protein required for milk synthesis (Kg P/day)

Ep = Factors, depending on body weight, that convert net protein into CP requirements.

The values of U, F, S, G, C, L and Ep depend upon other variables and we will show how they are computed in the next section (10.36) to (10.55), and (10.93) to (10.103).

In the second method we use the values for CP requirements offered on Table 2 of the NRC document to create table functions that will return total CP requirements as a function of weight, daily milk production and daily body weight gain.

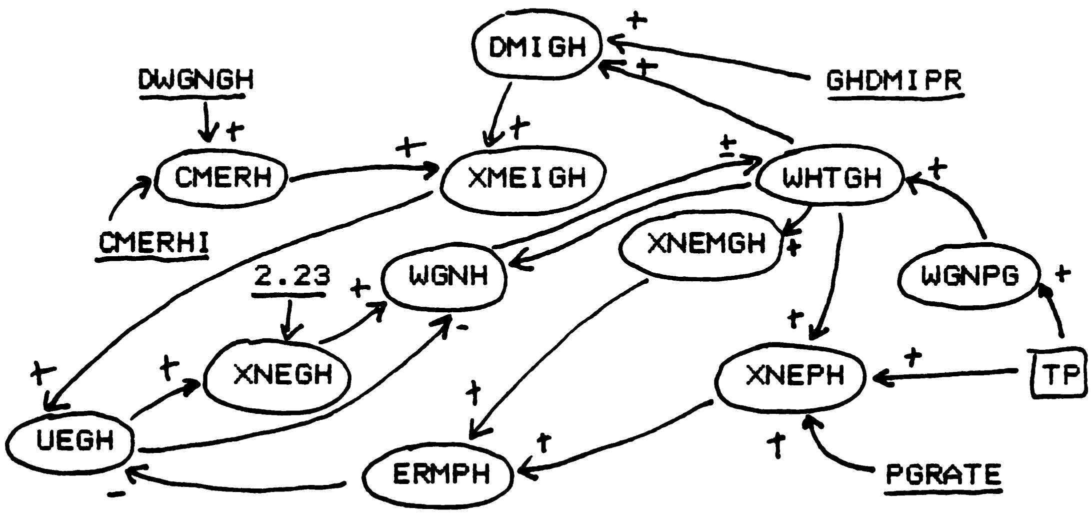
Equations (10.36) to (10.55) and (10.93) to (10.103) in the next section show in detail how the computation for the two methods is performed.

10.1.2. Heifers.

The biological processes of heifers, mainly growth and pregnancy, are simulated following the lines shown in Figure 10-4.

Daily dry matter intake (DMIGH) is a user-set proportion (GHDMIPR) of body weight (WHTGH). The concentration of metabolic energy in the ration (CMERH) is either set exogenously by the analyst (CMERHI) or a function of desired daily body weight gain (DWGNGH) also set exogenously. Daily dry matter intake (DMIGH) times concentration of ME in the ration gives the daily ME intake (XMEIGH). Daily net energy requirements for maintenance (XNEMGH) is a function of body weight (WHTGH). Daily net energy for pregnancy is a function of weight (WHTGH), days into pregnancy (TP) and the growth rate of products of conception (PGRATE). Total daily net energy requirements for maintenance and pregnancy (ERMPH) is the sum of net energy requirements for maintenance (XNEMGH) and pregnancy (XNEPH). Utilizable ME for weight gain (UEGH) is a function of ME intake (XMEIGH) and total net energy requirements (ERMPH). If there is a surplus of ME after maintenance and pregnancy requirements have been accounted for (i.e., UEGH > 0) then an amount of net energy for body weight gains appears (XNEGH) and body weight gains (WGNH > 0) occur. If there is a deficit (UEGH < 0) there will be weight losses (WGNH < 0). Body weight (WHTGH) evolves according to the daily weight gains (WGNH if positive, plus WGNPG) or daily weigh losses (WGNH if negative) computed as above.

Figure 10-4: Heifers Causal Block Diagram



Legend:

XXXX - Endogenous Variable

XXXX - Exogenous Variable

XX - Time Counter

The data to quantify the implicit relationships of Figure 10-4 have been taken from the NRC report. Energy requirements for maintenance, pregnancy and CP requirements are computed in ways similar to those shown earlier for lactating cows. However, only the factorial method is considered in the computation of CP requirements.

Two functional relationships stand out as different from the parallel relationships for lactating cows. These are the functions determining the net energy available for body weight gain and the conversion of this energy available into body weight gains.

Given the data in Table 1, pages 32-33,(NRC document), we fit a linear regression to the values of the variables net energy requirements for maintenance (NEm), net energy requirements for weight gain (NEg) and ME fed to young heifers at several weight and daily weight gain rates. The fit gave the following equation:

$$ME = -.25 + 2.23 * NEg + 1.88 * NEm \qquad (a)$$

We now define UE as ME available for weight gain:

$$UE = 2.23 * NEg \qquad (b)$$

and rewrite equation (a) above as:

$$UE = ME + .25 - 1.88\ NEm \qquad (c)$$

If UE > 0 then

NEg = UE / 2.23 from (b) above and daily weight gain is defined by the following equation:

$$\text{(Daily weight gain)} = \frac{NEg}{(1.501+.3*NEg+.0045\ Weight)} \qquad (d)$$

If UE < 0 then

(Daily weight loss) = UE / 4.78 (e)

Equations (d) and (e) come from A. Gonzalez de Chaves Fernandez [30], who reported data taken from MAFF 1975 (Energy allowances and feeding systems for ruminants. Technical Bulletin 33.MAFF), and according to the validation runs reported in Chapter 13, both equations perform with enough accuracy for the purposes of our study.

10.1.3. Growing Calves.

The biological process of growing calves are simulated in ways similar to those for young heifers except for weights below 100 kg. For weights between birth weight and 100 Kg, values for daily dry matter intake, ME and weight gain are set according to guidelines in the NRC document and as functions of desired daily weight gain. CP requirements are computed, as was the case with young heifers, by the factorial method.

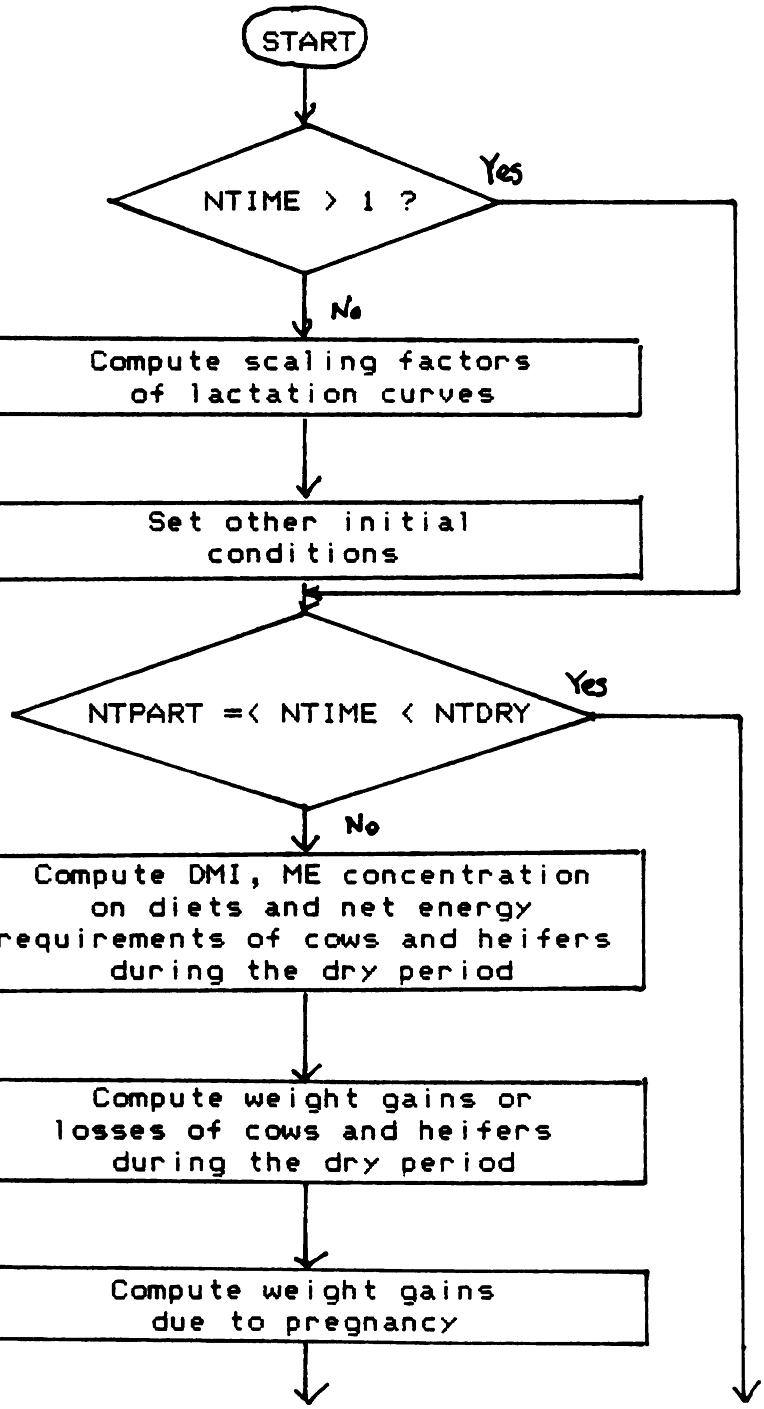
Equations (10.106) to (10.132) below simulate the biological processes inherent in the growth of calves.

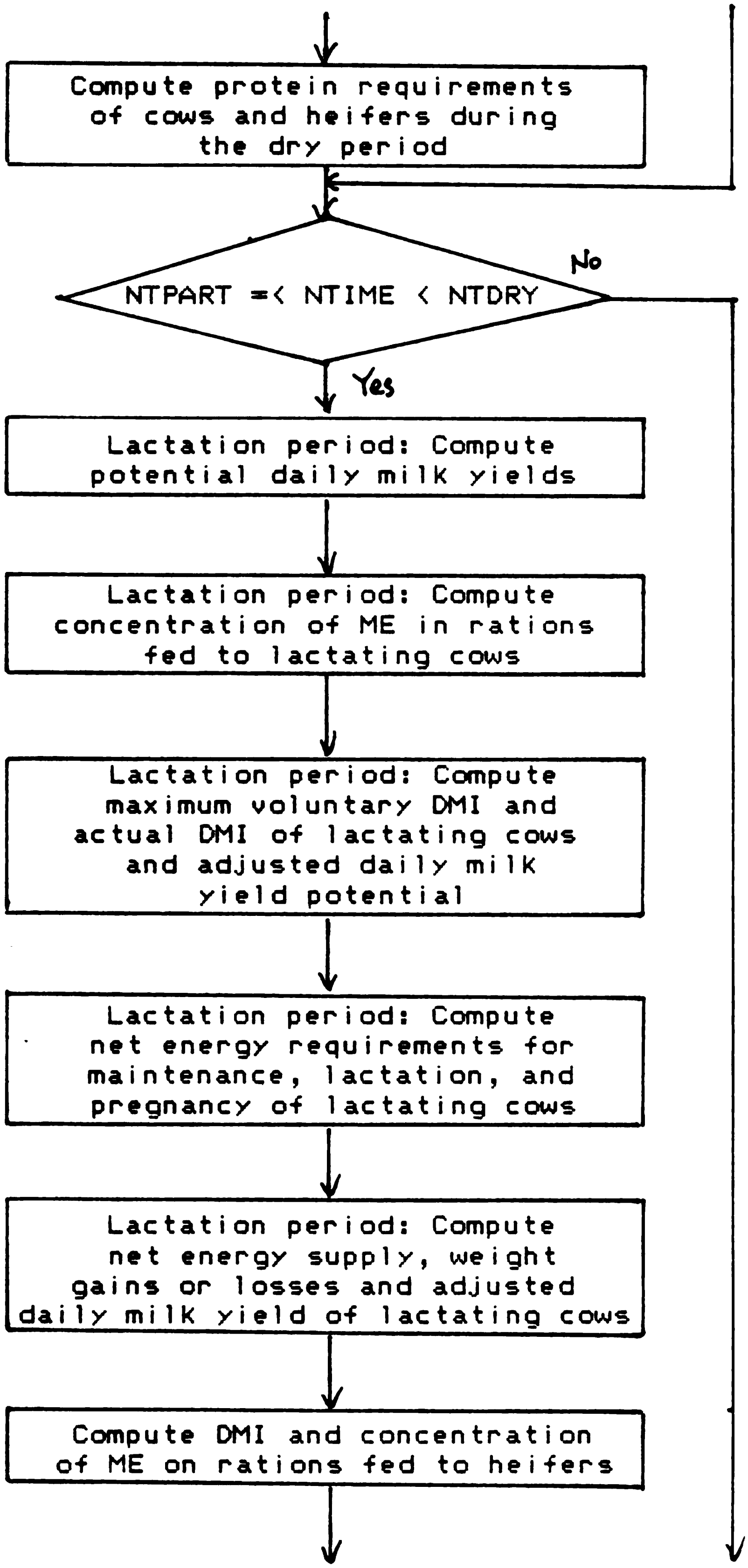
10.2. NUTIMP Description.

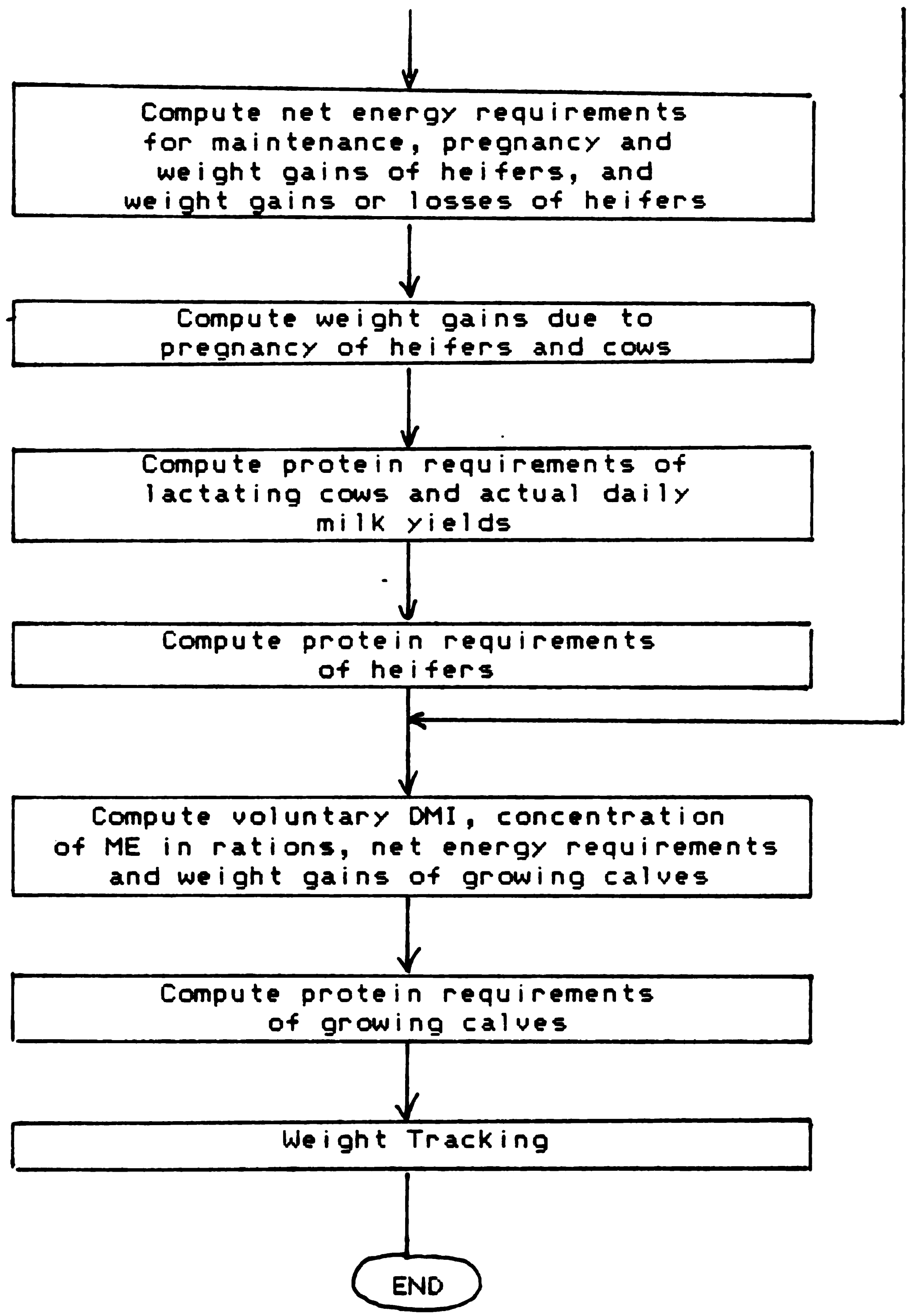
In this section we proceed to offer a lengthy description of the main equations in subroutine NUTIMP. The computational flow throughout the subroutine can be seen in

Figure 10-5.

Figure 10-5:NUTIMP Flowchart




Compute protein requirements of cows and heifers during the dry period
NTPART =< NTIME < NTDRY
No
Yes
Lactation period: Compute potential daily milk yields
Lactation period: Compute concentration of ME in rations fed to lactating cows
Lactation period: Compute maximum voluntary DMI and actual DMI of lactating cows and adjusted daily milk yield potential
Lactation period: Compute net energy requirements for maintenance, lactation, and pregnancy of lactating cows
Lactation period: Compute net energy supply, weight gains or losses and adjusted daily milk yield of lactating cows
Compute DMI and concentration of ME on rations fed to heifers


Compute net energy requirements for maintenance, pregnancy and weight gains of heifers, and weight gains or losses of heifers
Compute weight gains due to pregnancy of heifers and cows
Compute protein requirements of lactating cows and actual daily milk yields
Compute protein requirements of heifers
Compute voluntary DMI, concentration of ME in rations, net energy requirements and weight gains of growing calves
Compute protein requirements of growing calves
Weight Tracking
END

The first thing that the subroutine does, which then skips until the beginning of the following year, is to determine the annual milk yield potential of cows in different age cohorts (or lactation number) and the scaling factor of the lactation curve and to set the initial conditions.

$$ATMLK(L) = SYMILK*f(L) \qquad L=1 \text{ to } 7 \qquad (10.1)$$

AYMLK(L) = Annual milk yield potential of cows cohort L (lt/year)

SYMILK = Annual milk yield potential of cows in cohort 6 (lt/year)

f(L) = Function table that returns a number representing the ratio of milk yield potential of cows in cohort L to cows in cohort 6 (i.e; for cows in cohort 6 f(L)=1)

The scaling factor of the lactation curve is calculated as follows:

$$\alpha(L) = \frac{ATMLK(L)}{\int_0^{NLACT} (t^{B1(L)} * e^{B2(L)*t})dt} \qquad (10.2)$$

L=1 to 7

$\alpha(L)$ = Scaling factor of lactation curve of cows in cohort L

NLACT = Lenght of lactation cycle

t = Time

B1(L) = Coefficient fixing the shape of the lactation curve of cows on cohort L

B2(L) = Same as above

Next, initial conditions - which we omit to show here since they have more to do with the computer model than with the mathematical model - are set.

As we said above, equations (10.1), (10.2) and initial conditions are computed only once at the beginning of every year. We enter now into the dry period computations for cows and heifers. First, concentration of ME (ME from now on) on ration, dry matter intake (DMI from now on) and ME energy on ration for cows are computed. The same computations for heifers follow afterwards.

A switch, KSWT3, controls the flow of computation when fixing the concentration of ME, allowing the analyst to set that concentration to the recommended NRC value or to a value coming from subroutine FEEDACC:

If KSWT3 =< 1 then

CMERLC(I,t) = 2.23 I=1 to 7 (10.3)

If KSWT3 > 1 then

CMERLC(I,t) = RMELC(I,t) I=1 to 7 (10.4)

CMERLC(I,t) = Concentration of ME on rations fed to cows in cohort I, at t (Mcal ME/kg DM)

RMELC(I,t) = Same definition as above. This value is computed in subroutine FEEDACC

Another switch, KSWTDRY, allows the analyst to set the dry matter fed to cows during the dry period either as a proportion of cows weight or as a given quantity:

If KSWTDRY =< 1 then

DMILC(I,t) = PRPDRY*WHTLC(I,t) I=1 to 7 (10.5)

If KSWTDRY > 1 then

DMILC(I,t) = DMIDRY(I,t) I=1 to 7 (10.6)

DMINP(I,t) = 0 I=1 to 7 (10.7)

DMILC(I,t) = Daily dry matter intake of pregnant cows on cohort I, at t (kg DM/day)

PRPDRY = Proportion of dry matter intake to cow weight. Exogenous input.

DMIDRY(I,t) = Daily dry matter fed to pregnant cows in cohort I, at t (kg DM/day). Exogenous input

DMINP(I,t) = Daily dry matter intake of not pregnant cows i cohort I, at t (kg DM/day). The value is set to zero since there are no nonpregnant cows in the herd during the dry period

The intake of ME by cows is:

XMEILC(I,t) = DMILC(I,t)*CMERLC(I,t) (10.8)

I=1 to 7

XMEILC(I,t) = Daily intake of ME by cows in I cohort at t (Mcal ME/day)

A similar computation is done for heifers. First, a switch, KSWT7, allows the selection of the concentration of ME in rations fed to heifer as recommended by the NRC tables or as inputted as an exogenous variable.

If KSWT7 =< 1 then

CMERH(t) = f(WHTGH(t),DWGNGH(t)) (10.9)

If KSWT7 > 1 then

CMERH(t) = CMERHI(t) (10.10)

CMERH(t) = Concentration of ME in rations fed to heifers at t (Mcal ME/kg DM)

WHTGH(t) = Weight of heifers at t (kg)

DWGNGH(t) = Exogenous controllable input. Desired daily weight gain of heifers (kg/day)

Dry matter and ME intake of heifers is computed next:

DMIGH(t) = GHDMIPR(t)*WHTGH(t) (10.11)

DMINPH(t) = GHDMIPR(t)*WHTNPH(t) (10.12)

DMIGH(t) = Daily dry matter intake of pregnant heifers at t (kg DM/day)

GHDMIPR(t) = Proportion of dry matter intake to pregnant heifers weight. Exogenous controllable input

WHTGH(t) = Pregnant heifers weight at t (kg)

DMINPH(t) = Daily dry matter intake of nonpregnant heifers at t (kg DM/day)

WHTNPH(t) = Nonpregnant heifers weight at t (kg)

$$XMEINPH(t) = DMIGH(t)*CMERH(t) \tag{10.13}$$

$$XMEINPH(t) = DMINPH(t)*CMERH(t) \tag{10.14}$$

XMEIGH(t) = Daily intake of ME of pregnant heifers at t (Mcal ME/day)

XMEINPH(t) = Daily intake of ME of nonpregnant heifers at t (Mcal ME/day)

Next, net energy requirement for maintenance and pregnancy, and total net energy requirements for cows during the dry period are determined:

$$XNEMLC(I,t) = .08*WHTLC(I,t)^{.75}*(1+GZAL) \quad I=1 \text{ to } 7 \tag{10.15}$$

$$XNEPLC(I,t) = .0023*WHTLC(I,t)^{.75}*Exp(PGRATE*tp) \quad I=1 \text{ to } 7 \tag{10.16}$$

$$ERMPLC(t) = XNEMLC(I,t)+XNEPLC(I,t) \quad I=1 \text{ to } 7 \tag{10.17}$$

XNEMLC(I,t) = Daily net energy requirements for maintenance of cows in cohort I at t (Mcal NEm/day)

GZAL = Grazing allowance. Exogenous. Increase in maintenance requirements for grazing cows.

Set in the model at .20

Exp(---) = Exponential function

XNEPLC(I,t) = Daily net energy requirements for pregnancy (due to weight increases) of cows in cohort I (Mcal NEp/day)

PGRATE = Rate of growth of fetal weight

tp = Days into lactation

ERMPLC(I,t) = Total daily net energy requiremants of cows in cohort I (Mcal NE/day)

Daily net energy supply to the cow and the difference between energy supply and energy requirements is calculated below:

$$\text{XNEMLCI(I,t)} = \frac{\text{XMEILC(I,t)}}{1.6620} \qquad \text{I=1 to 7} \qquad (10.18)$$

$$\text{DIFFLC(I,t)} = \text{XNEMLCI(I,t)} - \text{ERMPLC(I,t)} \qquad (10.19)$$

I=1 to 7

XNEMLCI(I,t)= Daily net energy supply to cows in I cohort , at t (Mcal NE/day)

1.6620 = Efficiency factor converting ME into net energy for maintenance and lactation. Average value obtained from NRC tables

DIFFLC(I,t) = Daily deficit or surplus of net cows in cohort I, at t (Mcal NE/day)

A similar set of computations as (10.15) to (10.19) applies to heifers.

$$\text{XNEMGH(t)} = .0765*\text{WHTGH(t)}^{.75}*(1+\text{GZAL}) \qquad (10.20)$$

$$XNEMNPH(t) = .0765*WHTNPH(t)^{.75}*(1+GAZL) \quad (10.21)$$

$$XNEPH(t) = .0023*WHTGH(t)^{.75}*Exp(PGRATE*tp) \quad (10.22)$$

$$ERMPH(t) = XNEMGH(t)+XNEPH(t) \quad (10.23)$$

$$ERMNPH(t) = XNEMNPH(t) \quad (10.24)$$

$$UEGH(t) = XMEIGH(t)+.25-1.88*ERMPH(t) \quad (10.25)$$

$$UENPH(t) = XMEINPH(t)+.25-1.88*ERMNPH(t) \quad (10.26)$$

XNEMGH(t) = Daily net energy requirements for maintenance of pregnant heifers at t (Mcal NEm/day)

XNEMNPH(t) = Same for nonpregnant heifers

XNEPH(t) = Daily net energy requirements for pregnancy of heifers at t (Mcal NEp/day)

ERMPH(t) = Total daily net energy requirements of pregnant heifers at t (Mcal NE/day)

ERMNPH(t) = Same for nonpregnant heifers

UEGH(t) = Daily utilizable net energy (surplus or deficit) for weight gains of pregnant heifers at t (Mcal ME/day)

UENPH(t) = Same for nonpregnant heifers

Now, weight gains or losses for cows and heifers are computed.

For cows:

If DIFFLC(I,t) >= 0 then

$$WGNLC(I,t) = \frac{DIFFLC(I,t)}{5.12} \qquad I=1 \text{ to } 7 \qquad (10.27)$$

If DIFFLC(I,t) < 0 then

$$WGNLC(I,t) = \frac{DIFFLC(I,t)}{4.92} \qquad I=1 \text{ to } 7 \qquad (10.28)$$

WGNLC(I,t) = Daily weight gains or losses of cows in cohort I, at t (kg)

5.12 = Conversion factor of net energy surplus into body weight gain i.e.; number of Mcal of NEg required to increase body weight by 1 kg (NRC Table 2, page 35)

4.92 = Conversion factor of net energy deficit into body weight loss, i.e., number of NEg liberated as body weight decreases by 1 kg (NRC Table 2, page 35)

For heifers:

If UEGH(t) >= 0 and UENPH >= 0 then

$$XNEGH(t) = UEGH(t)/2.63 \qquad (10.29)$$

$$XNENPH(t) = UENPH(t)/2.63 \qquad (10.30)$$

$$WGNH(t) = \frac{XNEGH(t)}{(1.501+.3*XNEGH(t)+.0045*WHTGH(t)} \qquad (10.31)$$

$$WGNPH(t) = \frac{XNENPH(t)}{(1.501+.3*XNENPH(t)+.0045*WHTNPH(t)} \qquad (10.32)$$

If UEGH(t) < 0 and UENPH < 0 then

$$WGNH(t) = \frac{UEGH(t)}{4.78} \qquad (10.33)$$

$$WGNPH(t) = \frac{UENPH(t)}{4.78} \qquad (10.34)$$

XNEGH(t) = Daily net energy available for body weight gain of pregnant heifers at t (Mcal NEg/day)

XNENPH(t) = Same for nonpregnant heifers

2.63 = Conversion factor of ME into net energy for gain

WGNH(t) = Daily body gain or loss of pregnant heifers at t (kg)

WGNPH(t) = Same of nonpregnant heifers

Weight gains due to pregnancy are:

$$WGNPG(t) = .0322*Exp(PGRATE*tp) \qquad (10.35)$$

WGNPG(t) = Daily weight gain due to pregnancy at t (kg)

Protein requirements for cows and heifers during the dry period are computed next. For cows, two computing methods, both based on NRC information, may be used depending on the value taken by a switch, KSWT6. The first method is the factorial method used in the NRC document to obtain the values shown in the tables for CP requirements. If KSWT6 =< 1 we reproduce the equations used to calculate those table values. The second computational method takes advantage of the table values to generate a table function which returns

CP requirements as a function of weight (see NRC, pages 4-7, for reference).

If KSWT6 =< 1 then

$$PTULC(I,t) = 2.75*WHTLC(I,t)^{.5} \qquad I=1 \text{ to } 7 \qquad (10.36)$$

$$PTUNP(I,t) = 2.75*WHTNPC(I,t)^{.5} \qquad I=1 \text{ to } 7 \qquad (10.37)$$

$$PTF11(I,t) = .03*DMILC(I,t)*1000 \qquad I=1 \text{ to } 7 \qquad (10.38)$$

$$PTF12(I,t) = .03*DMINP(I,t)*1000 \qquad I=1 \text{ to } 7 \qquad (10.39)$$

$$PTSLC(I,t) = .2*WHTLC(I,t)^{.6} \qquad I=1 \text{ to } 7 \qquad (10.40)$$

$$PTSNPC(I,t) = .2*WHTNPC(I,t)^{.6} \qquad I=1 \text{ to } 7 \qquad (10.41)$$

$$BGPTPC1(I,t) = f(WHTLC(I,t)) \qquad I=1 \text{ to } 7 \qquad (10.42)$$

$$BGPTPC2(I,t) = f(WHTNPC(I,t)) \qquad I=1 \text{ to } 7 \qquad (10.43)$$

If UELC(I,t) and UENPLC(I,t) >= 0 then ,,

$$PTGLC(I,t) = BGPTPC1(I,t)*WGNLG(I,t)*1000 \quad ,, \qquad (10.44)$$

$$PTGNPC(I,t) = BGPTPC2(I,t)*WGNNPC(I,t)*1000 \quad ,, \qquad (10.45)$$

If UELC(I,t) and UENPLC(I,t) < 0 then

$$PTGLC(I,t) = 0 \qquad I=1 \text{ to } 7 \qquad (10.46)$$

$$PTGNPC(I,t) = 0 \qquad I=1 \text{ to } 7 \qquad (10.47)$$

$$PTPC(I,t) = 1.136*WHTLC(I)^{.7} \qquad I=1 \text{ to } 7 \qquad (10.48)$$

$$TCPLC(I,t) = \frac{(PTULC(I,t)+PTF11(I,t)+PTSLC(I,t)}{.45}$$

$$\frac{PTGLC(I,t)+PTPC(I,t)}{.45} \qquad I=1 \text{ to } 7 \qquad (10.49)$$

For nonpregnant cows since none are kept during the dry period:

$$TCPNPC(I,t) = 0 \qquad (10.50)$$

For the lactation period that we will later see

$$TCPNPC(I,t) = \frac{(PTUNP(I,t)+PTF12(I,t)+PTSNPC(I,t)+}{.45}$$

$$\frac{+PTGNPC(I,t)}{.45} \qquad I=1 \text{ to } 7 \qquad (10.51)$$

PTULC(I,t) = Daily protein loss in urine of pregnant cows in cohort I, at t (gr P/day)

PTUNP(I,t) = Same as above for nonpregnant cows

PTF11(I,t) = Daily protein loss in feces of pregnant cows in cohort I, at t (gr P/day)

PTF12(I,t) = Same as above for nonpregnant cows

PTSLC(I,t) = Daily protein loss in skin secretions, scurf, and hair of cows in cohort I, at t (gr P/day)

PTSNPC(I,t) = Same as above for nonpregnant cows

BGPTPC1(I,t)= Percentage of protein in body weight gain of pregnant cows in cohort I, at t

BGPTPC2(I,t)= Same as above for nonpregnant cows

PTGLC(I,t) = Protein deposited with the increase in body weight of pregnant cows in cohort I, at t (gr P/day)

PTGNPC(I,t) = Same as above for nonpregnant cows

PTPC(I,t) = Daily protein deposited in products of conception: fetus, placenta, fetal fluids, and uterus, of pregnant cows in cohort I, at t (gr P/day)

.45 = Factor that converts the sums of the net protein requirements to CP requirements

TCPLC(I,t) = Daily total CP requirements of pregnant cows in cohort I, at t (gr CP/day)

TCPNPC(I,t) = Same as above for nonpregnant cows

If KSWT6 > 1 then

PTGDRY(I,t) = f(WHTLC(I,t))   I=1 to 7   (10.52)

If UELC(I,t) >= 0 then

PTWG(I,t) = WGNLC(I,t)*500   I=1 to 7   (10.53)

If UELC(I,t) < 0 then

PTWG(I,t) = WGNLC(I,t)*320   I=1 to 7   (10.54)

TCPLC(I,t) = PTGDRY(I,t)+PTWG(I,t)   I=1 to 7   (10.55)

PTGDRY(I,t) = Daily CP requirements for maintenance and pregnancy of pregnant cows in cohort I ,at t, during the dry period (gr CP/day)

PTWG(I,t) = Daily CP deposited with body gains or liberated with body losses of pregnant cows in cohort I, at t, during the dry period (gr CP/day)

500 = Grams of CP required to deposit 1 kg of body gain (gr CP) (NRC Table 2, page 35)

320 = Grams of CP liberated with 1 kg of body loss (gr CP) (NRC Table 2, page 35)

The factorial method, equations (10.36) to (10.51), is repeated in the computation of CP requirements of pregnant and no pregnant heifers. We omit here these equations.

Equations (10.3) to (10.55) are computed only during the dry period. During the lactation period a similar, although not identical, set of equations is activated. The lactation period is the time between parturition and end of lactation (or beginning of dry period).

If NTPART =< NTIME < NTDRY then

First dairy milk yield potential of cows in different cohorts is computed:

$$YMLK(I,t) = \alpha(I)*til^{B1(I)}*e^{B2(I)*til} \qquad (10.56)$$

$$I=1 \text{ to } 7$$

YMLK(I,t) = Daily milk yield potential of cows in cohort I, at t (lt/day)

til = Time into lactation

$\alpha(I)$ = Scaling factor that fixes the lactation curve for cows in cohort I

B1(I),B2(I) = Parameter affecting the shape of the lactation curve for cows in cohort I

Next, two parameters that will be used in the calculation of daily dry matter intake are computed:

$$B52 = Exp(.099266*FATMT) \qquad (10.57)$$

$$B62 = Exp(.018001*CFPC-.000557*(CFPC)^{2}) \qquad (10.58)$$

B52,B62 = Auxiliary variable

FATMT = Fat (kg/day)

CFPC = Percent of crude fiber in dry matter intake

Concentration of ME in rations fed to lactating cows is computed according to either of two methods. A switch, KSWT3, controls the flow of computation as in equations (10.3), (10.4) above.

If KSWT3 =< 1 then

$$CMERLC(I,t) = f(YMLK(I,t),WHTLC(,I)) \quad I=1 \text{ to } 7 \qquad (10.59)$$

If KSWT3 > 1 then

$$CMERLC(I,t) = RMELC(I,t) \quad I=1 \text{ to } 7 \qquad (10.60)$$

All variables in equations (9.59) and (9.60) have already been defined. The function f(----) in equation (9.59) is a table function with independent variables derived from the NRC document (Table 3, page 36). It returns the recommended concentration of ME in rations fed to cows of certain weight yielding a given amount of daily milk.

Daily voluntary dry matter intake and actual dry matter intake are computed in two ways according to the value selected for a switch, KSWT8. The first method is based on data provided by NRC which is summarized in a table function. The second method is based on equations derived by Brown and Chandler that had already been surveyed in the previous section.

If KSWT8 =< 1 then

FCM(I,t) = (.4+15.*FM)*YMLK(I,t) I=1 to 7 (10.61)

FCM(I,t) = 4% fat corrected daily milk yield of cows in cohort I, at t (lt/day)

FM = Percent of fat in milk

WLTPRP(I,t) = f(FCM(I,t),WHTLC(I,t) I=1 to 7 (10.62)

WNPPRP(I,t) = f(FCM(I,t),WHTNPC(I,t)) I=1 to 7 (10.63)

DMILCMX(I,t)= WLTPRP(I,t)*WHTLC(I,t) I=1 to 7 (10.64)

DMINPMX(I,t)= WNPPRP(I,t)*WHTNPC(I,t) I=1 to 7 (10.65)

WLTPRP(I,t) = Ratio of daily voluntary dry matter intake to body weight of pregnant cows in cohort I, at t

WNPPRP(I,t) = Same as above for nonpregnant cows

DMILCMX(I,t)= Daily voluntary (maximum) dry matter intake of pregnant cows in cohort I, at t (kg DM)

DMINPMX(I,t)= Same as above for nonpregnant cows

Actual daily dry matter intake under this option (i.e., KSWT8 =< 1) can be computed in two alternative ways, again according to the value selected for a switch, KSWT4.

If KSWT4 =< 1 then actual DMI is function of body weight

$$DMILC(I,t) = Min(DMILCMX(I,t);WRLT(I,t)*WHTLC(I,t)) \quad I=1 \text{ to } 7 \qquad (10.66)$$

$$DMINP(I,t) = Min(DMINPMX(I,t);WRNPC(I,t)*WHTNPC(I,t)) \quad I=1 \text{ to } 7 \qquad (10.67)$$

If KSWT4 > 1 then actual DMI is an exogenous input

$$DMILC(I,t) = Min(DMILCMX(I,t);DMILCI(I,t)) \qquad (10.68)$$
$$I=1 \text{ to } 7$$

$$DMINP(I,t) = Min(DMINPMX(I,t);DMINPI(I,t) \qquad (10.69)$$
$$I=1 \text{ to } 7$$

DMILC(I,t) = Actual daily dry matter intake of pregnant cows in cohort I, at t (kg DM)

DMINP(I,t) = Same as above for nonpregnant heifers

WRLT(I,t) = Exogenous input. Ratio of actual DMI to body weight of pregnant cows in cohort I, at t

WRNPC(I,t) = Same as above for nonpregnant cows

DMILCI(I,t) = Exogenous input. Actual daily dry matter intake of pregnant cows in cohort I, at t (kg DM/day)

DMINPI(I,t) = Same as above for nonpregnant cows

If KSWT8 > 1 then

$$DMILCMX(I,t) = TN1*B52*B62*Exp(.519776)*til^{.148073}$$

$$*Exp(-.000823*til)*YMLK(I,t)^{.339220}$$

$$*Exp(.000675*WHTLC(I,t)) \qquad (10.70)$$

I=1 to 7

$$DMINPMX(I,t) = TN1*B52*B62*Exp(.519776)*til^{.148073}$$

$$*Exp(-.000823*til)*YMLK(I,t)^{.339220}$$

$$*Exp(.000675*WHTNC(I,t)) \qquad (10.71)$$

I=1 to 7

DMILCI(I,t) = DMILCMX(I,t)-TN2 I=1 to 7 (10.72)

DMINPI(I,t) = DMINPMX(I,t)-TN2 I=1 to 7 (10.73)

DMILC(I,t) = Min(DMILCMX(I,t);DMILCI(I,t)) (10.74)

I=1 to 7

DMINP(I,t) = Min(DMINPMX(I,t);DMINPI(I,t)) (10.75)

I=1 to 7

FDMLC(I,t) =

$$= \quad [1.+.784748*(\mathrm{Min}(0.;(\frac{DMILC(I,t)-DMILCMX(I,t)}{DMILC(I,t)}))]$$

I=1 to 7 (10.76)

FDMNP(I,t) =

$$= \quad [1.+.784748*(\mathrm{Min}(0.;(\frac{DMINP(I,t)-DMINPMX(I,t)}{DMINP(I,t)}))]$$

I=1 to 7 (10.77)

Daily milk yield potentials are now adjusted downward according to the dry matter intake elasticities provided by equations (10.76) and (10.77) (these elasticities were also obtained from Brown and Chandler data).

YMLKLC(I,t) = YMLK(I,t)*FDMLC(I,t) I=1 to 7 (10.78)

YMLKNP(I,t) = YMLK(I,t)*FDMNC(I,t) I=1 to 7 (10.79)

TN1 = Scaling factor used to move up or down the daily voluntary DMI curve

til = Days into lactation

FDMLC(I,t) = Elasticity parameter that returns the ratio of adjusted daily milk yield potential to daily milk yield potential. The adjustment is always downwards and is a function of actual DMI as compared to potential DMI. Applicable to pregnantcows in cohort I, at t

FDMNP(I,t) = Same as above for nonpregnant cows

YMLKLC(I,t) = Adjusted daily milk yield potential of pregnant cows in cohort I, at t

YMLKNP(I,t) = Same as above for nonpregnant cows

Daily net energy requirements for maintenance, milk production and pregnancy of lactating cows is computed next:

$$XNEMLC(I,t) = .08*WHTLC(I,t)^{.75}*(1.+GZAL)+ \quad (10.80)$$
$$+YMLKLC(I,t)*f(FM) \qquad I=1 \text{ to } 7$$

$$XNEMNPC(I,t)= .08*WHTNPC(I,t)^{.75}*(1.+GZAL)+ \quad (10.81)$$
$$+YMLKNP(I,t)*f(FM) \qquad I=1 \text{ to } 7$$

$$XNEPLC(I,t) = .0023*WHTLC(I,t)^{.75}*Exp(PGRATE*tp \quad (10.82)$$

$$ERMPLC(I,t) = XNEMLC(I,t)+XNEPLC(I,t) \quad I=1 \text{ to } 7 \quad (10.83)$$

$$ERMNPLC(I,t)= XNEMNPC(I,t) \qquad I=1 \text{ to } 7 \quad (10.84)$$

XNEMLC(I,t) = Daily net energy requirements for maintenance and lactation of pregnant cows in cohort I, at t (Mcal NE/day)

f(FM) = Table function based on NRC data (Table 2, page 35) that returns net energy requirement per kg of milk of different fat percentages (Mcal NE/Kg milk)

FM = Fat percentage of milk

XNEMNPC(I,t)= Same definition as XNEMLC(I,t) for nonpregnant cows

XNEPLC(,I) = Daily net energy requirements for pregnancy of cows in cohort I, at t (Mcal NE/day)

PGRATE = Growth rate of products of conception: fetus, placenta, fetal fluids, and uterus

tp = Days into pregnancy

ERMPLC(I,t) = Total daily net requirements of pregnant lactating cows in cohort I, at t

(Mcal NE/day)

ERMNPLC(I,t)= Same as above for nonpregnant cows

Actual net energy supply to lactating cows, weight gains or losses and actual daily milk of lactating cows is computed below.

$$XNEMLCI(I,t)= XMEILC(I,t)/1.6620 \qquad I=1 \text{ to } 7 \qquad (10.85)$$

$$XNEMNPI(I,t)= XMEINP(I,t)/1.6620 \qquad I=1 \text{ to } 7 \qquad (10.86)$$

$$DIFFLC(I,t) = XNEMLCI(I,t)-ERMPLC(I,t) \quad I=1 \text{ to } 7 \ (10.87)$$

$$DIFFNPC(I,t)= XNEMNPI(I,t)-ERMNPLC(I,t) \ I=1 \text{ to } 7 \ (10.88)$$

XNEMLCI(I,t)= Daily net energy supply to pregnant cows in cohort I, at t (Mcal NE/day)

WNEMNPI(I,t)= Same as above for nonpregnant cows

DIFFLC(I,t) = Daily net energy surplus or deficit in rations fed to pregnant cows in cohort I, at t (Mcal NE/day)

DIFFNPC(I,t)= Same as above for nonpregnant cows

Weight gains or losses and actual milk yield production are computed in two ways which reflect the theoretical indeterminacy that we mentioned earlier in this chapter.

First, if cows are fed ad libitum (free to choose and eat all they want) and the ration fed has the recommended concentration of ME in it (if KSWT3 =< 1) then actual milk yield is equal to potential milk yield and there will be weight gains or losses according to whether net energy supply exceeds or is short of net energy requirements. What this means is that milk production is a biological priority and that cows are able, for a given period, to lose weight in order to liberate net energy nutrients required to sustain a high level of daily milk production. This biological compensation is most likely to occur during the period between parturition and milk yield peak as the net energy requirements increase sharply while voluntary dry matter increases at a much slower rate. A net energy deficit develops that is filled by the cow losing weight and hence liberating the needed net energy nutrients required.

If DMILC(I,t) = DMILCMX(I,t) and KSWT3 =< 1 then

If DIFFLC(I,t) >= 0 then

$$WGNLC(I,t) = \frac{DIFFLC(I,t)}{5.12} \qquad I=1 \text{ to } 7 \qquad (10.89)$$

If DIFFLC(I,t) < 0 then

$$WGNLC(I,t) = \frac{DIFFLC(I,t)}{4.92} \qquad I=1 \text{ to } 7 \qquad (10.90)$$

WGNLC(I,t) = Daily body weight gain or loss by pregnant cows in cohort I, at t (Kg/day)

5.12 = Number of megacalories of net energy required to increase weight by 1 kg (NRC, Table 2, page 35)

4.92 = Number of megacalories of net energy mobilized as body weight decreases by 1 kg (NRC, Table 2, page 35)

Alternatively, if cows are fed less than voluntary dry matter intake, and with whatever ME concentration in ration selected, weight maintenance is assumed to be the biological priority with milk production adjusting downwards if a net energy deficit arises.

If DMILC(I,t) < DMILCMX(I,t) and KSWT3 > 1 then

If DIFFLC(I,t) >= 0 then

$$WGNLC(I,t) = \frac{DIFFLC(I,t)}{5.12} \qquad I=1 \text{ to } 7 \qquad (10.91)$$

If DIFFLC(I,t) < 0 then

$$YMLKLC(I) = YMCKLC(I,t) + \frac{DIFFLC(I,t)}{f(MF)} \qquad I=1 \text{ to } 7 \qquad (10.92)$$

All the variables and functions in equations (10.91) and (10.92) have been defined.

The set of equations (10.89) to (10.92) is repeated for nonpregnant cows; we omit them here.

Equations (10.9) to (10.12), (10.20) to (10.26), and (10.29) to (10.34) are recomputed during the lactation period.

Protein requirements for lactating cows and heifers are computed, with some additions, as they were during the dry period. Equations (10.36) to (10.48) are repeated for lactating pregnant and nonpregnant cows. Protein requirements for milk production are now added:

If KSWT6 =< 1 then

$$PTPCMK(I,t) = \frac{1.9+.4*FM*100}{100} \qquad (10.93)$$

$$PTLC(I,t) = (PTPCMK(I,t)*YMLK(I,t)+.03*DMILC(I,t))*1000. \qquad I=1 \text{ to } 7 \qquad (10.94)$$

$$PTNPLC(I,t) = (PTPCMK(I,t)*YMLK(I,t)+.03*DMINP(I,t))*1000. \qquad I=1 \text{ to } 7 \qquad (10.95)$$

PTPCMK(I,t) = Milk protein percentage

PTLC(I,t) = Daily CP required for synthesis of milk production of pregnant cows in cohort I, at t (gr P/day)

PTNPLC(I,t) = Same as above for nonpregnant cows

$$TCPLC(I,t) = \frac{PTULC(I,t)+PTF11(I,t)+PTSLC(I,t)}{.45} + \frac{PTGLC(I,t)+PTPC(I,t)}{.45} + \frac{PTLC(I,t)}{.52} \qquad (10.96)$$

$$I=1 \text{ to } 7$$

$$TCPNPC(I,t) = \frac{PTUNP(I,t)+PTF12(I,t)+PTSNPC(I,t)+PTGNPC(I,t)}{.45} + \frac{PTNPLC(I,t)}{.52} \qquad I=1 \text{ to } 7 \qquad (10.97)$$

.52 = Factor converting net requirements in terms of CP requirement (NRC, pages 3 to 7)

All other variables have already been defined.

If KSWT6 > 1 then

$$CPFAT = f(FM) \qquad (10.98)$$

$$PTMLC(I,t) = f(WHTLC(I,t)) \qquad I=1 \text{ to } 7 \qquad (10.99)$$

$$PTMNPC(I,t) = f(WHTNPC(I,t)) \qquad I=1 \text{ to } 7 \qquad (10.100)$$

$$PTMILK(I,t) = YMLK(I,t)*CPFAT \qquad I=1 \text{ to } 7 \qquad (10.101)$$

Equations (10.53) and (10.54) are computed again during the lactation period.

Total CP requirements under this alternative computational method are now:

$$TCPLC(I,t) = PTMLC(I,t)+PTMILK(I,t)+PTWG(I,t) \qquad (10.102)$$

I=1 to 7

$$TCPNPC(I,t) = PTMNPC(I,t)+PTMILK(I,t)+PTWG(I,t) \qquad (10.103)$$

I=1 to 7

CPFAT = CP in 1 kg of milk of different fat percentages (gr CP/kg milk)

PTMLC(I,t) = Daily CP requirements for maintenance and pregnancy of lactating pregnant cows in cohort I, at t (gr CP/day)

DTMNPC(I,t) = Same as above for nonpregnant cows

DTMILK(I,t) = Daily CP requirement for milk synthesis of cows in cohort I, at t (gr CP/day)

TCPLC(I,t) = Total daily requirements of CP of pregnant cows in cohort I, at t (gr CP/day)

TCPNPC(I,t) = Same as above for nonpregnant cows

Actual daily milk yield is also constrained by the available supply of CP received by cows per day. A downward adjustment of daily milk yields takes place if the total daily supply of CP is less than total daily requirement of CP. This adjustment is modelled as follows.

First the difference between requirements and supply is computed:

DIFCPLC(I,t)= TCPLC(I,t)-TSCPLC(I,t) I=1 to7 (10.104)

If this difference is negative, i.e., supply is greater than requirements, no adjustment takes place and actual milk yield keeps its current value. However, if the difference is positive the adjustment occurs:

if DIFCPLC(I,t) > 0 then

$$YMLKLC(I,t) = YMLKLC(I,t) - \frac{DIFCPLC(I,t)}{f_{cp}(FM)} \qquad (10.105)$$

DIFCPLC(I,t)= Difference between daily requirements of CP and daily supply of CP for lactating pregnant cows in cohort I at t (gr CP/ head/day)

TSCPLC(I,t) = Daily supply of CP in ration fed to lactating pregnant cows in cohort I, at t (gr CP/head/day). value from FEEDACC.

FM = Fat matter in milk

f_{cp}(-----) = Table function that returns the number of grams of CP per kilogram of milk of different fat matter percentages. (Values taken from NRC document, Table 2, p 35)

The same adjustment is made to the daily milk yield of lactating nonpregnant cows.

As we said earlier, the factorial method is used for the computation of CP requirements for heifers. The equations, with the exception of CP requirements for milk synthesis, are essentially the same as those for lactating cows. We again omit to show them.

Following the flow of computation in the subroutine, calculations for growing calves are done next. Equations (10.106) to (10.130) which determine voluntary dry matter intake, ME intake, net energy requirements and weight gains of growing calves, are computed all throughout the year. The computation method varies for growing calves in different weight brackets:

If $WHTGCL(t) < 50.$ then

$$DMIGCL(t) = .63 \tag{10.106}$$

$$XMEIGCL = 2.98 \tag{10.107}$$

$$WGNGCL(t) = .5 \tag{10.108}$$

If $50. =< WHTGCL(t) < 75.$ then

$$DMIGCL(t) = f_1(DWGNGCL(t)) \tag{10.109}$$

$$XMEIGCL(t) = f_2(DWGNGCL(t)) \tag{10.110}$$

$$WGNGCL(t) = DWGNGCL(t) \tag{10.111}$$

If $75. =< WHTGCL(t) < 100$ then

$$DMIGCL(t) = 2.10 \tag{10.112}$$

$$XMEIGCL(t) = f_3(DWGNGCL(t)) \tag{10.113}$$

$$CMERGCL(t) = \frac{XMEIGCL(t)}{DMIGCL(t)} \tag{10.114}$$

$$WGNGCL(t) = DWGNGCL(t) \tag{10.115}$$

If $WHTGCL(t) >= 100.$ then

$$PROP(t) = f_4(WHTGCL(t)) \tag{10.116}$$

$$DMIGCL(t) = PROP(t)*WHTGCL(t) \tag{10.117}$$

$$CMERGCL(t) = f_5(WHTGCL(t)*CMERGCL(t)) \tag{10.118}$$

$$XMEIGCL(t) = DMIGCL(t)*CMERGCL(t) \tag{10.119}$$

Daily net energy requirements are:

$$XNEMGCL(t) = .0765*WHTGCL(t)^{.75}*(1+GZAL) \tag{10.120}$$

Usable ME for weight gain is:

$$UEGCL(t) = XMEIGCL(t)+.25-1.88*XNEMGCL(t) \tag{10.121}$$

and weight gains or losses are as follows:

If UEGCL(t) >= 0 then

$$XNEGCL(t) = \frac{UEGCL(t)}{2.63} \tag{10.122}$$

$$WGNGCL(t) = \frac{XNEGCL(t)}{1.501+.3*XNEGCL(t)+.0045*WHTGCL(t)} \tag{10.123}$$

If UEGCL(t) < 0 then

$$WGNGCL(t) = \frac{UEGCL(t)}{4.78} \tag{10.124}$$

WHTGCL(t) = Body weight of growing calves at t (kg)

DMIGCL(t) = Daily dry matter intake of growing calves at t (kg DM/day)

XMEIGCL(t) = Daily ME intake of growing calves at t (Mcal ME/day)

WGNGCL(t) = Daily weight gain or loss of growing calves at t (kg)

DWGNGCL(t) = Exogenous input. Desired weight gain of growing calves at t (kg)

CMERGCL(t) = Concentration of ME in rations fed to growing calves at t (Mcal ME/kg DM)

PROP(t) = Ratio of daily dry matter intake to weight of growing calves at t

XNEMGCL(t) = Daily net energy requirement of growing calves at t (Mcal NE/day)

UEGCL(t) = Usable ME for weight gain of growing calves at t (Mcal ME/day)

XNEGCL(t) = Daily net energy available for weight gain of growing calves at t (Mcal NE/day)

f_1, f_2, f_3, f_4, and f_5 are function tables obtained from NRC data (Table 1, page 32).

Daily CP requirements for growing calves are computed essentially in a similar way as for cows and heifers:

$$\mathrm{PTUGCL}(t) = 2.75*\mathrm{WHTGCL}(t)^{.5} \tag{10.125}$$

$$\mathrm{PTFGCL}(t) = .03*\mathrm{DMIGCL}(t)*1000 \tag{10.126}$$

$$\mathrm{PTSGCL}(t) = .2*\mathrm{WHTGCL}(t)^{.6} \tag{10.127}$$

$$\mathrm{BGPTPCL}(t) = f(\mathrm{WHTGCL}(t)) \tag{10.128}$$

If UEGCL(t) >= 0 then

$$PTGCL(t) = BGPTPCL(t)*WGNGCL(t)*1000 \; . \qquad (10.129)$$

If $UEGCL(t) < 0$ then

$$PTGCL(t) = 0 \qquad (10.130)$$

$$EPGCL(t) = f(WHTGCL(t)) \qquad (10.131)$$

Total CP requirements per day are then:

$$TCPGCL(t) = \frac{PTUGCL(t)+PTFGCL(t)+PTSGCL(t)+PTGCL(t)}{EPGCL(t)} \qquad (10.132)$$

PTUGCL(t) = Daily protein loss in urine of growing calves at t (gr P/day)

PTFGCL(t) = Daily protein loss in feces of growing calves at t (gr P/day)

PTSGCL(t) = Daily protein loss in skin secretions, scurf, and hair of growing calves at t (gr P/day)

BGPTPCL(t) = Percentage of protein in body weight gain of growing calves at t

PTGCL(t) = Daily protein deposited with increases in body weight of growing calves at t (gr P/day)

EPGCL(t) = Factors converting net protein requirements into CP requirements

TCPGCL(t) = Total daily CP requirements of growing calves at t (gr CP/day)

Finally, weight of cows, heifers and growing calves plus weight updating from one cohort to another is computed. First the weight of products of conception (fetus, placenta, fetal fluids, and uterus) is determined.

$$PGWHT(t) = PGWHT(t-DT) + \int_{t-DT}^{t} WGNPG(t)\,dt \qquad (10.133)$$

PGWHT(t) = Weight of products of conception at t (kg)

During the dry period we have (see Fig 10-1).

If NTIME < NTPART then

$$TWGPLC(I,t) = WGNLC(I,t)+WGNPG(t) \qquad I=1 \text{ to } 7 \qquad (10.134)$$

$$TWGNPC(I,t) = 0 \qquad I=1 \text{ to } 7 \qquad (10.135)$$

$$TWGH(t) = WGNH(t) \qquad (10.136)$$

$$TWGNPH(t) = WGNPH(t) \qquad (10.137)$$

TWGPLC(I,t) = Total weight gain or loss between t-DT and t of pregnant cows in cohort I, at t (kg)

TWGNPC(I,t) = Same as above for nonpregnant cows

TWGH(t) = Total weight gain or loss between t-DT and t of pregnant heifers at t (kg)

TWGNPH(t) = Same as above for nonpregnant heifers

If NTIME >= NTDRY then

$$TWGPLC(I,t) = WGNLC(I,t)+WGNPG(t) \qquad I=1 \text{ to } 7 \qquad (10.138)$$

$$TWGNPC(I,t) = 0 \qquad (10.139)$$

$$TWGH(t) = WGNH(t)+WGNPG(t) \qquad (10.140)$$

$$TWGNPH(t) = WGNPH(t) \qquad (10.141)$$

Weight tracking is done as follows:

$$WHTLC(I,t) = WHTLC(I,t-DT)+\int_{t-DT}^{t} TWGPLC(I,t)\ dt \qquad I=1 \text{ to } 7 \qquad (10.142)$$

$$WHTNPC(I,t) = 0 \qquad I=1 \text{ to } 7 \qquad (10.143)$$

For heifers:

$$WHTGH(t) = WHTGH(t-DT)+\int_{t-DT}^{t} TWGH(t)\ dt \qquad (10.144)$$

$$WHTNPH(t) = WHTNPH(t-DT) + \int_{t-DT}^{t} TWGNPH(t)\, dt \quad (10.145)$$

For growing calves:

$$WHTGCL(t) = WHTGCL(t-DT) + \int_{t-DT}^{t} WGNGCL(t)\, dt \quad (10.146)$$

During the lactation period we have the following sequence of events:

If NTPART =< NTIME < NTDRY then

At parturition time the weight of pregnant cows decreases by an amount equal to the weight of the products of conception.

If NTIME = NTPART then

$$WHTLC(I,t) = WHTLC(I,t)-PGWHT(t) \quad (10.147)$$

Growing calves receive their starting weight:

$$WHTGCL(t) = 42. \quad (10.148)$$

Pregnant heifers see their weight decrease for the same reason pregnant cows do:

$$WHTGH(t) = WHTGH(t)-PGWHT(t) \quad (10.149)$$

For the time between parturition and pregnancy weight updating (see Figure 10-1 for a reminder of the reproduction cycle of the cow; remenber that we are showing the computational flow of the subroutine under the assumption that KSWTPRG =< 1 > is determined as follows:

If NTPART < NTIME < NTPRG then

$$\mathrm{TWGPLC}(I,t) = \mathrm{WGNLC}(I,t) \qquad I=1 \text{ to } 7 \qquad (10.150)$$

$$\mathrm{WHTLC}(I,t) = \mathrm{WHTLC}(I,t-DT) + \int_{t-DT}^{t} \mathrm{TWGPLC}(I,t)\,dt$$

$$I=1 \text{ to } 7 \qquad (10.151)$$

TWGPLC(I,t) = Total weight gain or loss between t-DT and t of cows in cohort I, at t (Kg)

Similar computation is made for heifers:

$$\mathrm{WHTGH}(t) = \mathrm{WHTGH}(t-DT) + \int_{t-DT}^{t} \mathrm{TWGH}(t)\,dt \qquad (10.152)$$

$$\mathrm{WHTNPH}(t) = 0 \qquad (10.153)$$

and for growing calves we repeat equation (10.146) again.

If NTPRG =< NTIME < NTDRY , i.e., between pregnancy and the end of lactation we have:

$$\mathrm{TWGPLC}(I,t) = \mathrm{WGNLC}(I,t) + \mathrm{WGNPG}(t) \qquad I=1 \text{ to } 7 \qquad (10.154)$$

$$\mathrm{TWGNPC}(I,t) = \mathrm{WGNNPC}(I,t) \qquad I=1 \text{ to } 7 \qquad (10.155)$$

At NTIME = NTPRG we have for nonpregnant cows

$$\mathrm{WHTNPC}(I,t) = \mathrm{WHTLC}(I,t-DT) + \int_{t-DT}^{t} \mathrm{TWGNPC}(I,t)\,dt$$

$$I=1 \text{ to } 7 \qquad (10.156)$$

and after that, that is NTIME > NTPRG we have:

$$WHTNPC(I,t) = WHTNPC(I,t-DT) + \int_{t-DT}^{t} TWGNPC(I,t-DT)\,dt$$

$$I=1 \text{ to } 7 \qquad (10.157)$$

For pregnant cows, equation (10.150) still holds.

A similar computation (i.e., equations (10.154), (10.155) and (10.156) is made for nonpregnant heifers. Computations for pregnant heifers and growing calves are the same as we showed for the dry period.

Shifting of weights between cohorts occurs at parturition time:

If NTIME = NTPART then

$$WHTLC(K,t) = WHTLC(K-1,t) \qquad K=2 \text{ to } 7 \qquad (10.158)$$

$$WHTLC(1,t) = WHTGH(t) \qquad (10.159)$$

$$WHTGH(t) = WHTGCL(t) \qquad (10.160)$$

Validation of this component will be discussed in Chapter 13.

CHAPTER 11

The FEEDACC Subsystem

The FEEDACC subsystem performs the interfacing function of the dairy/forage model, especially the all important task of matching total feed demand to total feed supply throughout the year. The other subcomponents (see Figure 6-1 for a reference) interact with each other mainly through FEEDACC.

As we will see in more detail below, FEEDACC allows the model user to match supply to demand in several alternative ways. It allows one to change the ratio of concentrate to forage in the ration at different time periods and also to fix the length of the period during which a particular feeding regime is to be sustained. By setting these two types of parameters, ratio of concentrate to forage and length of feeding regime period one will be able to find the most profitable use of concentrate during the year.

11.1. Feed Accounting Facts and Assumptions.

FEEDACC contemplates four forage feeding seasons and four concentrate feeding seasons, in what we call a forage season. FEEDACC sets the ratio of grass to silage in the forage ration fed to animals, independently of the total amount of forage fed. In the concentrate feeding seasons FEEDACC sets the amount of concentrate fed to the animals per day and, given the daily dry matter intake fixed in other part of the model, it also sets the total forage consumption per animal per day.

The forage seasons depend upon the growth of grass and other forage crops and upon the relative availability of grass for grazing and silage accumulated throughout the year, that is they depend on the biological pattern of grass production that we saw in Chapter 8 (see Figure 8-1). The manager typically allows the cows to graze from early spring, when daily grass growth is high, until beginning of summer when daily grass growth declines. During that period, that may coincide with the higher net energy demands of the cows, the forage ration consists only of grass. During the summer the manager limits grazing so as not to exceed daily grass growth which is very low. The rest of the forage ration is made up of silage. During the fall and early winter we have another period, quite shorter however, of grass regrowth and again animals are permitted to graze their entire forage ration. Finally, during the winter and until early spring the animals are given only silage in their forage ration.

According to the forage mix pattern mentioned above the concentration of ME and CP in the forage fed to animals will vary throughout the year. FEEDACC keeps track of those critical state variables.

The concentrate feeding seasons depend on the productive and reproductive status of the animals, that is on the temporal pattern of net energy and CP requirements of the animals. The first concentrate season starts at parturition. From that moment, and because of the high net energy requirements for milk production and lagging voluntary dry matter intake, a ration high on concentrates is needed. This first season lasts usually two to three months, well after the milk yield peak has occurred, until about pregnancy time. This is the period in which dairy cows utilize more efficiently the concentrate in milk production; the amount of concentrate fed per day and the length of the season impacts heavily on the profitability of the farm. The second period goes from a few weeks after pregnancy to several weeks prior to the dry period. We are here in the descent segment of the lactation curve. Net energy requirements are declining and voluntary dry matter intake is relatively high so the ratio of concentrate to forage is set much lower than in the previous season. The third period includes the last part of the lactation curve and most of the dry period. No concentrate is given during this period, the forage ration being able to supply all nutrients needed by the animals. The two to three weeks prior to parturition make up the fourth period, the cows receiving one to two kilograms of concentrate in preparation to parturition.

The concentrate feeding seasons are only valid for dairy cows. The heifers and growing calves receive concentrate and forage in proportions required to enable them to sustain an adequate rate of growth.

As we said in Chapter 10 and earlier, there are two ways in which the model user can set the use of concentrate per day and per cow. In method (a), given the recommended concentration of ME in the ration , the concentration of ME in forage and in concentrates fed and the dry matter intake, the concentrate and forage input levels are obtained. In method (b) the use of concentrate is inputted exogenously by the model user and the computation of forage use and the concentration of ME in the ration follows. The computations in method (b) are straightforward and don't need further clarification to the simple statement of the equations which is done in the next section.

Two identities are used in method (a)

CNCLC(I,t)*CNCMEC3+FORLC(I,t)*CMEFCW(t) =

= DMILC(I,t)*CMERLC(I,t) (i)

DMILC(I,t) = CNCLC(I,t)+FORLC(I,t) I=1 to 7 (ii)

CNCLC(I,t) = Daily concentrate consumption by pregnant cows in cohort I, at t (Kg DM/head/day)

FORLC(I,t) = Daily forage consumption by pregnant cows in cohort I at t (kg DM/head/day)

DMILC(I,t) = Daily dry matter intake by pregnant cows in cohort I at t (kg DM/head/day)

CNCMEC3 = Concentration of ME in concentrates fed to cows (Mcal ME/Kg DM)

CMEFCW(t) = Concentration of ME in forage fed to cows (Mcal ME/kg DM)

CMERLC(I,t) = Recommended concentration of ME in ration fed to pregnant cows in cohort I at t (Mcal ME/Kg DM)

The unknows on the simple two equation system above are CNCLC(I,t) and FORLC(I,t). To solve the system we first obtain FORLC(I,t) as a function of DMILC(I,t) and CNCLC(I,t) in (ii)

FORLC(I,t) = DMILC(I,t)-CNCLC(I,t) (iii)

We now substitute (iii) into (i) and we obtain after some manipulation CNCLC(I,t) as a function of all other parameters:

$$\mathrm{CNCLC(I,t)} = \left\{\frac{\mathrm{(CMERLC(I,t)-CMEFCW(t))}}{\mathrm{(CNCMEC3-CMEFCW(t))}}\right\}*\mathrm{DMILC(I,t)} \quad \text{(iv)}$$

Equations (iv) and (iii) are respectively equations (11.47) and (11.48) in the submodel description offered in next section.

Method (a) is also used in the calculations for growing calves and heifers.

The total supply of CP in the ration fed to lactating cows sets, as we saw in Chapter 10, an important constraint on daily milk yield. Given the concentration of crude protein in concentrates and in forage fed to the cows, the total daily supply of CP is the sum of the concentrate and forage intakes per day weighted by the respective CP contents.

For the dry period we are only interested in monitoring the required concentration of CP in concentrates which is computed in equation (v) below:

$$CNCPTLC(I,t)= \frac{(TCPLC(I,t)-FORLC(I,t)*CPTFCW(t))}{CNCLC(I,t)} \qquad (v)$$

$$I=1 \text{ to } 7$$

CNCPTLC(I,t)= Required concentration of CP in concentrates fed to pregnant cows in cohort I, at t (gr of CP/kg DM)

TCPLC(I,t) = Daily required consumption of CP by pregnant cows in cohort I, at t (gr CP/head/day). Value comes from NUTIMP

FORLC(I,t) & CNCLC(I,t) have already been defined

CPTFCW(t) = Concentration of CP in forage fed to animals at t (gr of CP/kg DM)

Equations similar to (v) hold for nonpregnant cows, pregnant and nonpregnant heifers and growing calves.

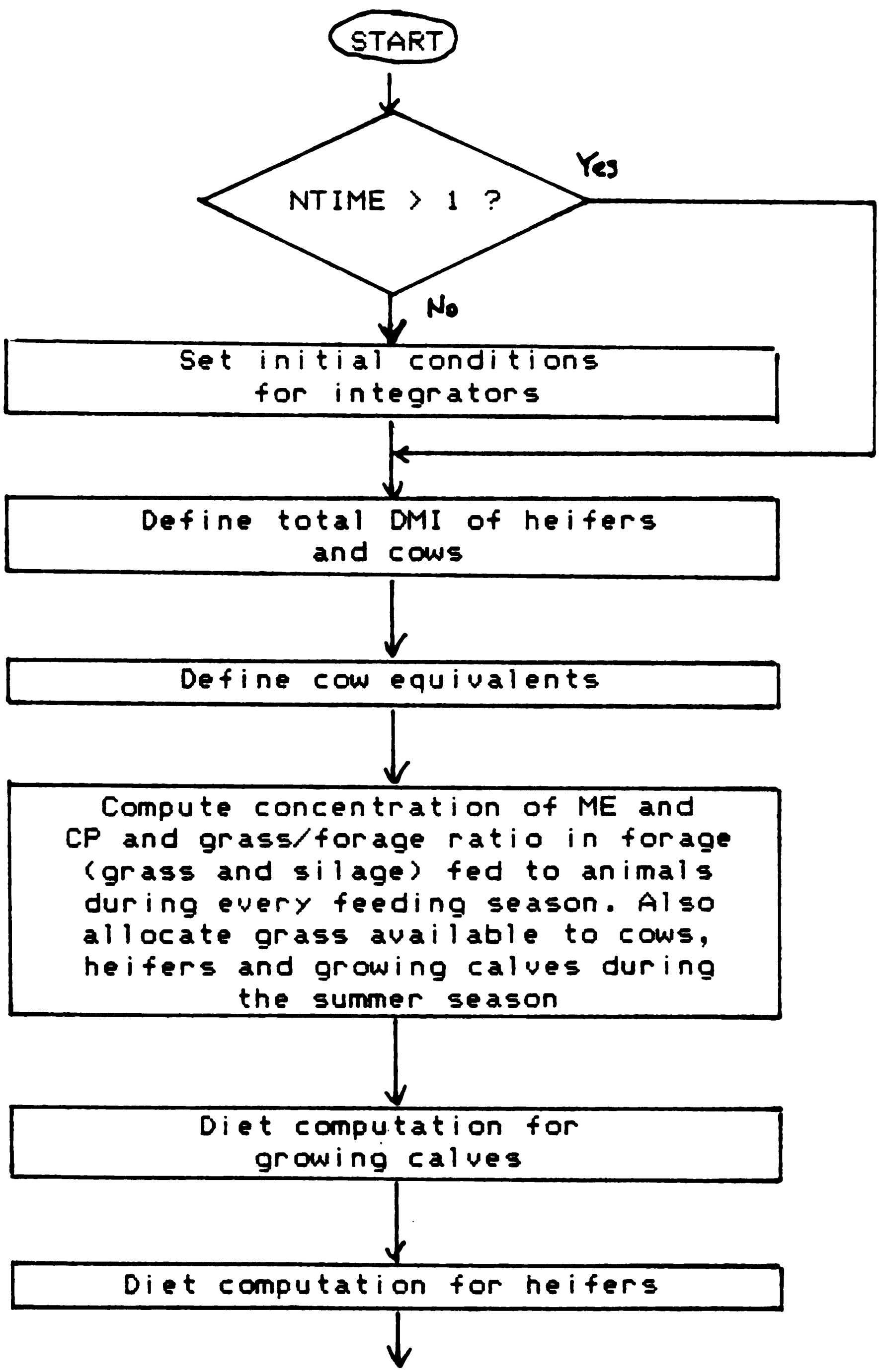
There may arise some moments throughout the year that the demand for grass or silage, as fixed by the mechanisms that we just mentioned, exceeds supply. Those are very transitory periods. However, a mechanism is built into the FEEDACC subroutine that allocates feeds of different types to animals according to a given priority.

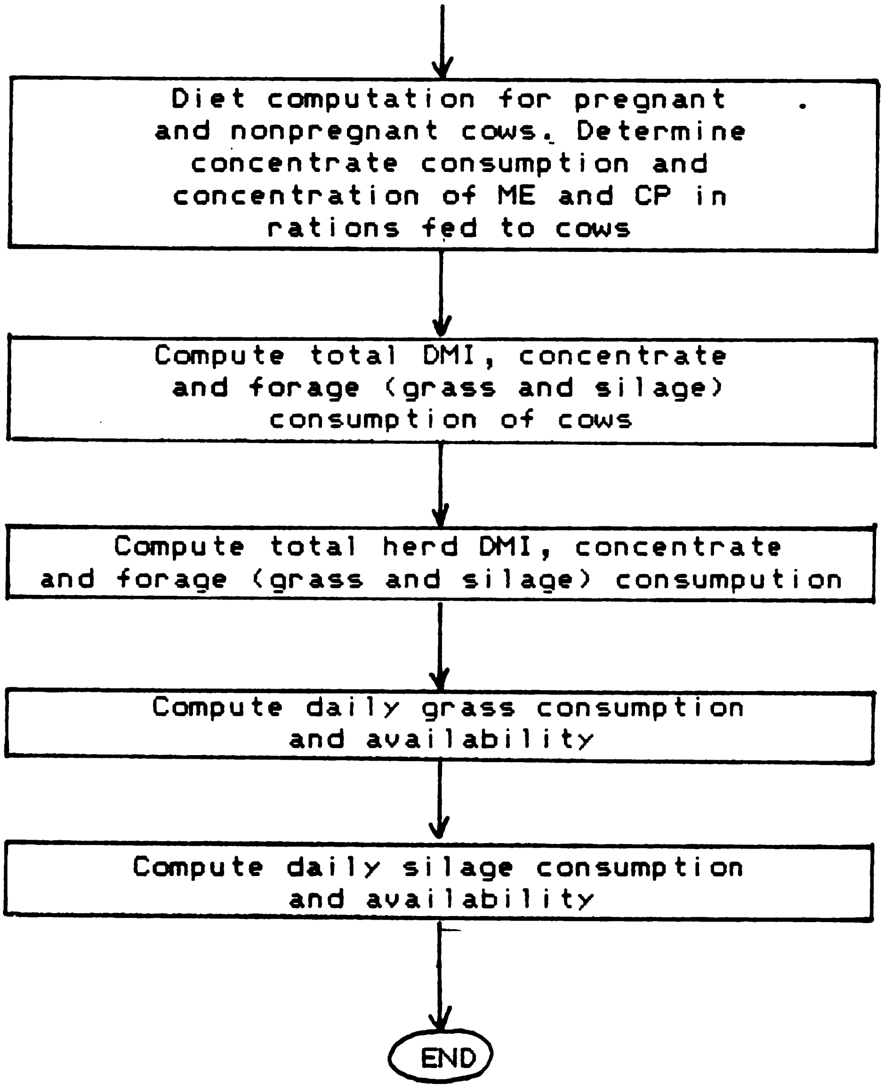
If grass demand is greater than grass availability at any moment, grass consumption is limited to grass available and the deficit is taken up by silage, hence increasing total silage consumption over what it was designed. If no silage is available, concentrate consumption is increased with the total ration being made up, in this case, exclusively by concentrate. Equations (11.70) to (11.79) in next section operationalize this consumption priority mechanism.

11.2. FEEDACC Description

The computational flow of subroutine FEEDACC can be seen in Figure 11-1. We now proceed to offer an equation by equation description of this submodel that, as we said earlier, ties the other submodels together.

Figure 11-1: FEEDACC Flowchart




Diet computation for pregnant and nonpregnant cows. Determine concentrate consumption and concentration of ME and CP in rations fed to cows
Compute total DMI, concentrate and forage (grass and silage) consumption of cows
Compute total herd DMI, concentrate and forage (grass and silage) consumpution
Compute daily grass consumption and availability
Compute daily silage consumption and availability
END

As we see in the flowchart this subroutine first fixes, at the beginning of every year, the initial conditions for the integrations that will be performed later throughout the year. This initial condition setting is then skipped for the rest of the year.

Next, using data from subroutines NUTIMP and DHERD it computes total dry matter intake of cows and heifers and aggregates all animals on the herd into a single figure by weighting their numbers by their dry matter intake relative to the dry matter intake of cows. That aggregate, which will be later used in the allocation of grass available to each type of animal during the summer season, will be called "equivalent cows" (EQCOWS).

First, total daily dry matter intake of heifers is computed:

$$DMIHEF(t) = DMIGH(t)*HEIFPRG(t)+DMINPH(t)*HEIFNPG(t) \qquad (11.1)$$

DMIHEF(t) = Total daily dry matter intake of heifers at t (kg DM/day)

DMIGH(t) = Daily DMI of individual pregnant heifers at t (kg DM/day). Determined in NUTIMP

HEIFPRG(t) = Heifers pregnant at t (head). Value from DHERD

DMINPH(t) = Daily DMI of individual nonpregnant heifers at t (kg DM/day). Determined in NUTIMP

HEIFNPG(t) = Heifers nonpregnant at t (head). Value from DHERD

Total dry matter intake of cows per day is:

$$DMILCW(I,t) = DMILC(I,t)*COWPRG(I,t) \quad I=1 \text{ to } 7 \quad (11.2)$$

$$DMINPC(I,t) = DMINP(I,t)*COWNPG(I,t) \quad I=1 \text{ to } 7 \quad (11.3)$$

$$DMICW(I,t) = DMILCW(I,t)+DMINPC(I,t) \quad I=1 \text{ to } 7 \quad (11.4)$$

$$TDMICW(t) = \sum_{I} DMICW(I,t) \quad I=1 \text{ to } 7 \quad (11.5)$$

DMILCW(I,t) = Total daily DMI of pregnant cows in cohort I at t (kg DM/day)

DMINPC(I,t) = Same as above for nonpregnant cows

DMILC(I,t) = Daily DMI of a pregnant cow in cohort I at t (kg DM/day). Determined in NUTIMP

DMINP(I,t) = Same as above for a nonpregnant cow

COWPRG(I,t) = Cows pregnant in cohort I at t (head). Value from DHERD

COWNPG(I,t) = Cows nonpregnant in cohort I at t (head). Value from DHERD

DMICW(I,t) = Total daily DMI of pregnant and nonpregnant cows in cohort I at t (kg DM/day)

TDMICW(t) = Total daily DMI of cows at t (Kg DM/day)

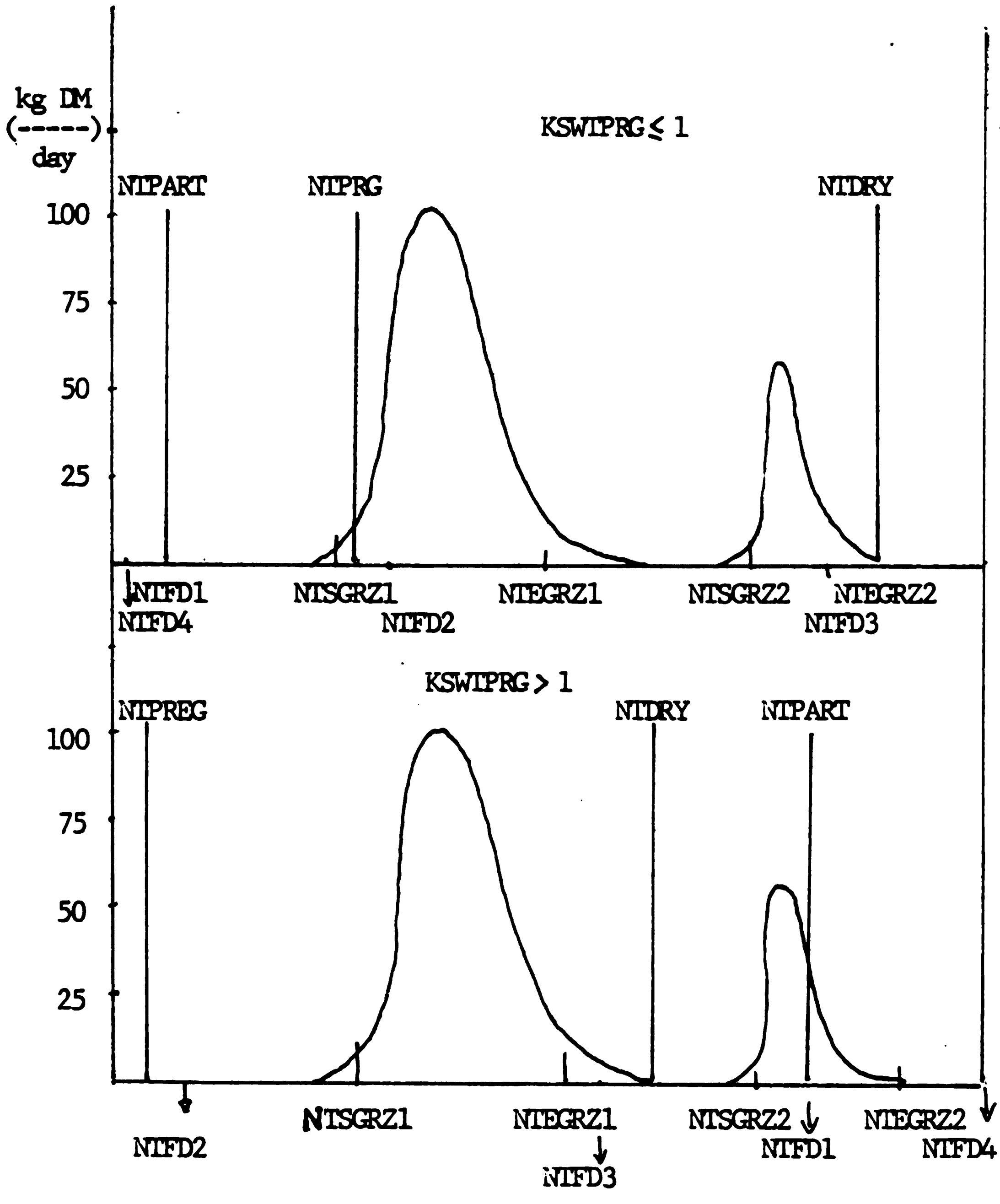
Equivalent cows are now defined:

$$EQCOWS(t) = TCOW(t)+HEIFS(t)*\left(\frac{(DMIHEF(t)/HEIFS(t))}{(TDMICW(t)/TCOW(t))}\right)+ GWCLV(t)*\left(\frac{DMIGCL(t)}{(TDMICW(t)/TCOW(t))}\right) \quad (11.6)$$

EQCOWS(t)	=	Cow equivalents at t (head)
TCOW(t)	=	Total cows in herd at t (head). From DHERD
HEIFS(t)	=	Total heifers in herd at t (head). From DHERD
GWCLV(t)	=	Total growing calves in herd at t (head). From DHERD
DMIGCL(t)	=	Daily DMI of growing calves at t (kg DM/day). From NUTIMP

Now, the concentration of ME and CP in forage, grass or silage or a mixture of both, and the ratio of grass to forage fed to animals is computed for the different forage feeding seasons defined in the model. As we said in the previous section there are four forage feeding seasons defined with the analyst being able to determine the length of any of them and their timing along the year.(A look at Figure 11-2, will help clarify the issue).

Figure 11-2: Forage Feeding Seasons Diagram



During the winter season the forage fed to animals consists entirely of silage:

If NTIME < NTSGRZ1 or NTIME >= NTEGRZ2 then

CMEFGCL(t)	=	CMESILG(t)	(11.7)
CMEFGH(t)	=	CMESILG(t)	(11.8)
CMEFNPH(t)	=	CMESILG(t)	(11.9)
CMEFCW(t)	=	CMESILG(t)	(11.10)
CPTFGCL(t)	=	CPTSILG(t)	(11.11)
CPTFGH(t)	=	CPTSILG(t)	(11.12)
CPTFNPH(t)	=	CPTSILG(t)	(11.13)
CPTFCW(t)	=	CPTSILG(t)	(11.14)
GRPGCL(t)	=	0	(11.15)
GRPHF(t)	=	0	(11.16)
GRPNPH(t)	=	0	(11.17)
GRPCW(t)	=	0	(11.18)

NTIME = Time counter

NTSGRZ1 = Time to start first grazing season

NTEGRZ2 = Time to end second grazing season

CMEFGCL(t) = Concentration of ME in forage fed to growing calves at t (Mcal ME/Kg DM)

CMEFGH(t) = Same as above for pregnant heifers

CMEFNPH(t) = Same as above for nonpregnant heifers

CMEFCW(t) = Same as above for cows

CMESILG(t) = Concentrarion of ME in silage available at t (Mcal ME/kg DM). From FORAGE

CPTFGCL(t) = Concentration of CP in forage fed to growing calves at t (gr CP/Kg DM)

CPTFGH(t) = Same as above for pregnant heifers

CPTFNPH(t) = Same as above for nonpregnant heifers

CPTFCW(t) = Same as above for cows

CPTSILG(t) = Concentration of CP in silage available at t (gr CP/kg DM)

GRPGCL(t) = Ratio of grass to forage in forage fed to growing calves at t

GRPHF(t) = Same as above for pregnant heifers

GRPNPH(t) = Same as above for nonpregnant heifers

GRPCW(t) = Same as above for cows

During the two grazing seasons (i.e., Spring and fall seasons)

If NTSGRZ# =< NTIME < NTEGRZ# then (#=1, 2)

CMEFGCL(t), CMEFGH(t), CMEFNPH(t) and CMEFCW(t) are equal to CMEGRSS(t) (which comes from FORAGE).

CMEGRSS(t) = Concentration of ME in grass available for grazing at t (Mcal ME/kg DM)

CPTFGCL(t), CPTFGH(t), CPTFNPH(t) and CPTFCW(t) are equal to CPTGRSS (t) (which comes from FORAGE).

CPTGRSS(t) = Concentration of CP in grass available for grazing at t (gr CP/kg DM)

GRPGCL(t), GRPHF(t), GRPNPH(t) and GRPCW(t) are all equal to 1.

The last season to consider is the period between the two grazing seasons, i.e., the summer. During this period grass growth is very slow and grass consumption by animals is limited to daily grass production with the rest of forage consumption taken up by silage. The limited grass available is allocated to every type of animals as an equal proportion of their total dry matter intake.

If NTEGRZ1 =< NTIME < NTSGRZ2 then

$$AUX1(t) = \frac{GRASSPD(t)}{EQCOWS(t)} \qquad (11.19)$$

AUX1(t) = Daily grass available per equivalent cow at t (kg DM/head/day)

GRASSPD(t) = Daily grass production at t (kg DM). From FORAGE

$$AUXGCL1(t) = AUX1(t)*\left(\frac{DMIGCL(t)}{(TDMICW(t)/TCOW(t))}\right) \qquad (11.20)$$

AUXGCL1(t) = Daily grass available for consumption by growing calves at t (kg DM/head/day)

$$AUXGH1(t) = AUX1(t)*\left\{\frac{DMIGH(t)}{(TDMICW(t)/TCOW(t))}\right\} \quad (11.21)$$

AUXGH1(t) = Daily grass available for consumption by pregnant heifers at t (kg DM/head/day)

$$AUXNPH1(t) = AUX1(t)*\left\{\frac{DMINPH(t)}{(TDMICW(t)/TCOW(t))}\right\} \quad (11.22)$$

AUXNPH1(t) = Daily grass available for consumption by nonpregnant heifers at t (kg DM/head/day)

$$GRPGCL(t) = \frac{AUXGCL1(t)}{FORGCL(t)} \quad (11.23)$$

$$GRPHF(t) = \frac{AUXGH1(t)}{FORHF(t)} \quad (11.24)$$

$$GRPNPH(t) = \frac{AUXNPH1(t)}{FORNPH(t)} \quad (11.25)$$

$$GRPCW(t) = \frac{AUX1(t)}{(TFORCW(t)/TCOW(t))} \quad (11.26)$$

FORGCL(t) = Daily forage consumption of growing calves at t (kg DM/head/day). Determined later in this same subroutine

FORHF(t) = Same as above for pregnant heifers

FORNPH(t) = Same as above for nonpregnant heifers

TFORCW(t) = Total daily forage consumption by cows at t (kg DM/day)

$$CMEFGCL(t) = GRPGCL(t)*CMEGRSS(t)+(1-GRPGCL(t))*CMESILG(t)$$

(11.27)

$$\mathrm{CMEFGH(t) = GRPHF(t)*CMEGRSS(t)+(1-GRPHF(t))*CMESILG(t)} \tag{11.28}$$

$$\mathrm{CMEFNPH(t) = GRPNPH(t)*CMEGRSS(t)+(1-GRPNPH(t))*CMESILG(t)} \tag{11.29}$$

$$\mathrm{CMEFCW(t) = GRPCW(t)*CMEGRSS(t)+(1-GRPCW(t))*CMESILG(t)} \tag{11.30}$$

A computation similar to equations (11.27) to (11.30) is made to determine CPTFGCL(t), CPTFGH(t), CPTFNPH(t) and CPTFCW(t), during the summer season. This is done by substituting CMEGRSS(t) and CMESILG(t), by CPTGRSS(t) and CPTSILG(t) respectively in equations (11.27) to (11.30).

The computation of daily diets for growing calves is next. The amount of concentrate fed to growing calves is a function of the recommended concentration of ME in ration, the concentration of ME in forage fed, the concentration of ME in concentrate fed and dry matter intake.

$$\mathrm{CNCGCL(t) = \left\{\frac{(CMERGCL(t)-CMEFGCL(t))}{(CNCMEC1-CMEFGCL(t))}\right\}*DMIGCL(t)} \tag{11.31}$$

CNCGCL(t) = Daily concentrate consumption by growing calves at t (Kg DM/head/day)

CMERGCL(t) = Concentration of ME in ration fed to growing calves at t. Value from NUTIMP

(Mcal ME/kg DM)

CNCMEC1 = Concentration of ME in concentrates fed to growing calves (Mcal ME/kg DM). Exogenous controllable input.

Forage consumption is dry matter intake less concentrate consumption:

$$FORGCL(t) = DMIGCL(t)-CNCGCL(t) \quad (11.32)$$

The required concentration of CP in concentrates fed to growing calves is computed as:

$$CNCPTGC(t) = \frac{(TCPGCL(t)-FORGCL(t)*CPTFGL(t))}{CNCGCL(t)} \quad (11.33)$$

CNCPTGC(t) = Concentration of CP in concentrates fed to growing calves at t (gr CP/kg DM)

TCPGCL(t) = Total CP requirements per day of growing calves at t (gr CP/head/day)

Total forage and concentrate consumption by growing calves is:

$$RFORGCL(t) = FORGCL(t)*GWCLV(t) \quad (11.34)$$

$$CONCGCL(t) = CNCGCL(t)*GWCLV(t) \quad (11.35)$$

RFORGCL(t) = Total daily forage consumption by growing calves at t (kg DM/day)

CONCGCL(t) = Total daily concentrate consumption by growing calves at t (kg DM/day)

Forage consumption is split between grass and silage consumption:

RGSGCL(t) = GRPGCL(t)*RFORGCL(t) (11.36)

RSLGCL(t) = (1.-GRPGCL(t))*RFORGCL(t) (11.37)

RGSGCL(t) = Total daily grass consumption by growing calves at t (Kg DM/day)

RSLGCL(t) = Total daily silage consumption by growing calves at t (Kg DM/day)

Diet computation for heifers is next. Concentrate consumption is computed similarly to the growing calves computation:

$$CNCGH(t) = \left(\frac{CMERH(t)-CMEFGH(t)}{CNCMEC2-CMEFGH(t)}\right)*DMIGH(t) \quad (11.38)$$

CNCGH(t) = Daily concentrate consumption by pregnant heifers at t (kg DM/head/day)

CMERH(t) = Concentration of ME in ration fed to pregnant heifers at t. Value from NUTIMP (Mcal ME/Kg DM)

CNCMEC2 = Concentration of ME in concentrates fed to pregnant heifers (Mcal ME/Kg DM)

Forage consumption by pregnant heifers is:

FORHF(t) = DMIGH(t)-CNCGH(t) (11.39)

FORHF(t) = Daily forage consumption by pregnant heifers at t (Kg DM/head/day)

The concentration of CP in concentrates fed to pregnant heifers must be:

$$CNCPTHF(t) = \frac{(TCPHF(t)-FORHF(t)*CPTFGH(t))}{CNCGH(t)} \qquad (11.40)$$

CNCPTHF(t) = Concentration of CP in concentrates fed to pregnant heifers at t (gr CP/kg DM)

Total forage and concentrate consumption by pregnant heifers is:

$$RFORHFP(t) = FORHF(t)*HEIFPRG(t) \qquad (11.41)$$

$$RCNCHFP(t) = CNCGH(t)*HEIFPRG(t) \qquad (11.42)$$

RFORHFP(t) = Total forage consumption per day by pregnant heifers at t (kg DM/day)

RCNCHFP(t) = Total concentrate consumption per day by pregnant heifers at t (Kg DM/day)

Equations (11.38) to (11.42) are repeated for nonpregnant heifers. We omit those equations here:

$$FORHEIF(t) = RFORHFP(t)+RFORNPH(t) \qquad (11.43)$$

$$CONCHF(t) = RCNCHFP(t)+RCNCNPH(t) \qquad (11.44)$$

FORHEIF(t) = Total forage consumption per day by heifers at t (kg DM/day)

CONCHF(t) = Total concentrate consumption per day by heifers at t (kg DM/day)

Forage consumption is split between grass and silage consumption:

$$RGSGH(t) = RFORHFP(t)*GRPHF(t) \tag{11.45}$$

$$RSLGH(t) = RFORHFP(t)*(1.-GRPHF(t)) \tag{11.46}$$

RGSGH(t) = Total daily grass consumption by pregnant heifers at t (Kg DM/day)

RSLGH(t) = Total daily silage consumption by pregnant heifers at t (Kg DM/day)

Two equations identical to (11.43) and (11.44) hold for nonpregnant heifers.

The computation of diets for cows is performed by two methods, the analyst being able to select either of them. In method (a), the computation is very much like the ones we showed above for growing calves and heifers. The consumption of concentrate is determined by the concentration of ME in forage and concentrates and by daily dry matter intake. In this method the concentration of ME in the ration is a given and the daily consumption of concentrates results from the computation. In method (b) the model user selects the amount of concentrate that he wants to fed (two alternatives exist in the way the level of concentrates to be fed are fixed) and the final concentration of ME in the ration is calculated.

Consider first method (a).

If KSWT3 =< 1 then

```
                    (CMERLC(I,t)-CMEFCW(t))
CNCLC(I,t)   =   (-------------------------)*DMILC(I,t)
                    (CNCMEC3-CMEFCW(t))

                                    I=1  to 7          (11.47)
```

CNCLC(I,t) = Daily concentrate consumption by pregnant cows in cohort I, at t (kg DM/head/day)

CMERLC(I,t) = Concentration of ME in ration fed to pregnant cows in cohort I, at t (Mcal ME/Kg DM). From NUTIMP

CNCMEC3 = Concentration of ME in ration fed to cows in cohort I, at t(Mcal ME/kg DM). Exogenous controllable input

Forage consumption is:

```
FORLC(I,t)   =   DMILC(I,t)-CNCLC(I,t)   I=1 to 7     (11.48)
```

FORLC(I,t) = Daily forage consumption by pregnant cows in cohort I, at t (kg DM/head/day)

The total supply of CP in concentrates fed to lactating pregnant cows is computed as follows:

```
CNCPTLC(I,t)=  GCPKCN                    I=1  to 7     (11.49)

TSCPLC(I,t) =  CNCLC(I,t)*CNCPTLC(I,t)+FORLC(I,t)*CPTFCW(t)

                                         I=1 to 7      (11.50)
```

CNCPTLC(I,t)= Concentration of CP in concentrates fed to lactating pregnant cows in cohort I, at t (gr CP/Kg)

GCPKCN = Concentration of CP in concentrates (gr CP/kg). Exogenous controllable input.

TSCPLC(I,t) = Total daily supply of CP in ration fed to lactating pregnant cows (gr CP/kg)

Forage consumption is split between grass and silage consumption:

CGSLCL(I,t) = FORLC(I,t)*GRPCW (11.51)

CSLLC(I,t) = FORCL(I,t)*(1.-GRPCW(t)) (11.52)

CGSLC(I,t) = Daily consumption of grass by pregnant cows in cohort I, at t (kg DM/head/day)

CSLLC(I,t) = Daily consumption of silage by pregnant cows in cohort I, at t (Kg DM/head/day)

Now, method (b).

If KSWT3 > 1 then another switch is set.

As we said earlier, the concentrate fed to cows may be set as a fixed quantity or a given proportion of dry matter intake. A switch operator, KSWT12, allows the model user to select either of the two alternatives.

If KSWT12 =< 1 then

CNCLC(I,t) = CINPLC#(I,t) I=1 to 7 (11.53)
#=1, 2, 3, 4

CINPLC#(I,t)= Concentrates fed to pregnant cows in cohort I, at t, during concentrate feeding season # (Kg DM/head/day)

= Concentrate feeding season

If KSWT12 > 1 then

CONCPCL(I,t)= CPCINL#(t) (11.54)

CONCPCL(I,t)= Percentage of concentrate in ration fed to pregnant cows in cohort I, at t (%)

CPCINL#(t) = Exogenous controllable input. Same definition as above

Concentrate consumption will be in this last case:

CNCLC(I,t) = DMILC(I,t)*CONCFCL(I,t)/100 (11.55)

In both cases, forage consumption, required concentration of CP in concentrates, grass and silage consumption are computed as in method (a) and we again omit to repeat those equations.

Equations (11.47) to (11.55) are repeated for nonpregnant cows.

Next, total consumption of concentrate and forage, this latter disaggregated into grass and silage consumption, by pregnant and nonpregnant cows is computed.

FORCW(I,t) = FORLC(I,t)*COWPRG(I,t)+FORNP(I,t)*COWNPG(I,t) (11.56)

CONCCW(I,t) = CNCLC(I,t)*COWPRG(I,t)+CNCNP(I,t)*COWNPG(I,t) (11.57)

GSCW(I,t) = CGSLC(I,t)*COWPRG(I,t)+CGSNP(I,t)*COWNPG(I,t) (11.58)

$$SLCW(I,t) = CSLLC(I,t)*COWPRG(I,t)+CSLNP(I,t)*COWNPG(I,t) \quad I=1 \text{ to } 7 \qquad (11.59)$$

FORCW(I,t) = Total daily forage consumption by cows in cohort I, at t (kg DM/day)

CONCCW(I,t) = Total daily concentrate consumption by cows in cohort I, at t (kg DM/day)

GSCW(I,t) = Total daily grass consumption by cows in cohort I, at t (kg DM/day)

SLCW(I,t) = Total daily silage consumption by cows in cohort I, at t (kg DM/day)

$$TFORCW(t) = \sum_I FORCW(I,t) \qquad I=1 \text{ to } 7 \qquad (11.60)$$

$$TCONCW(t) = \sum_I CONCCW(I,t) \qquad I=1 \text{ to } 7 \qquad (11.61)$$

$$TGSCW(t) = \sum_I GSCW(t) \qquad I=1 \text{ to } 7 \qquad (11.62)$$

$$TSLCW(t) = \sum_I SLCW(I,t) \qquad I=1 \text{ to } 7 \qquad (11.63)$$

TFORCW(t) = Total daily forage consumption by cows at t (kg DM/day)

TCONCW(t) = Total daily concentrate consumption by cows at t (kg DM/day)

TGSCW(t) = Total daily grass consumption by cows at t (kg DM/day)

TSLCW(t) = Total daily silage consumption by cows at t (kg DM/day)

Now, total dry matter intake and total concentrate, forage, grass and silage consumption per day by the herd is computed:

TRFOR(t) = RFORGCL(t)+FORHEIF(t)+TFORCW(t (11.64)

CONCPR(t) = CONCGCL(t)+CONCHF(t)+TCONCW(t) (11.65)

TDMI(t) = TRFOR(t)+CONCPR(t) (11.66)

CONCPR(t) = CONCPR(t)/.84 (11.67)

TGS(t) = RGSGCL(t)+RGSGH(t)+RGSNPH(t)+TGSCW(t) (11.68)

TSL(t = RSLGCL(t)+RSLGH(t)+RSLNPH(t)+TSLCW(t) (11.69)

TRFOR(t) = Total dairy forage consumption at t (kg DM/day)

CONCPR = Total daily concentrate consumption at t . In equation (11.65) it is measured in kg DM. In equation (11.67) it is measured in kg

TDMI(t) = Total daily dry matter intake at t (kg DM/day)

TGS(t) = Total daily grass consumption at t (kg DM/day)

TSL(t) = Total daily silage consumption at t (kg DM/day)

The values for grass and silage consumption computed above are desired values. They will be realized if availability of grass and silage allows it. In computing actual grass and silage consumption a priority mechanism is at work. If desired grass consumption is greater than grass availability, silage will take up the difference. If desired silage consumption is greater than silage availability, concentretes will take up the difference.

First, actual grass consumption is:

If TGS(t) =< AVGRASS(t) then

$$CONSGRS(t) = TGS(t) \tag{11.70}$$

$$GRSSURP(t) = AVGRASS(t)-CONSGRS(t) \tag{11.71}$$

If TGS(t) > AVGRASS(t) then

$$CONGRS(t) = AVGRASS(t) \tag{11.72}$$

$$TSL(t) = TGS(t)-AVGRASS(t) \tag{11.73}$$

GRSSURP(t) = 0 (11.74)

AVGRASS(t) = Grass available for grazing at t (kg DM). Value from FORAGE

CONSGRS(t) = Actual daily consumption of grass at t (kg DM/day)

GRSSURP(t) = Grass surplus after consumption at t (kg DM)

Second, silage consumption is:

If TSL(t) =< AVSILG(t) then

CONSSIL(t) = TSL(t) (11.75)

SILGSUR(t) = AVSILG(t)-CONSSIL(t) (11.76)

If TSL(t) > AVSILG(t) then

CONSSIL(t) = AVSILG(t) (11.77)

SILGSUR(t) = 0 (11.78)

CONCPR(t) = CONCPR(t)+(TSL(t)-AVSILG(t)) (11.79)

Equation (11.79) means that the value of CONCPR(t) defined in (11.67) is adjusted to account for an unexpected and undesired silage deficit.

AVSILG(t) = Silage available at t (kg DM). Value comes from FORAGE

CONSSIL(t) = Actual daily consumption of silage at t (kg DM/day)

SILGSUR(t) = Silage surplus after consumption at t (kg DM)

Finally, in order to compute several performance factors at the end of every year, accumulated dry matter intake, and concentrate, forage, grass and silage, consumption are computed:

$$TTRFOR(t) = \int_{to}^{t} TRFOR(t)\ dt \tag{11.80}$$

$$TCONCPR(t) = \int_{to}^{t} CONCPR(t)\ dt \tag{11.81}$$

$$TTDMI(t) = TTRFOR(t)+TCONCPR(t) \tag{11.82}$$

$$TTGS(t) = \int_{to}^{t} TGS(t)\ dt \tag{11.83}$$

$$TTSL(t) = \int_{to}^{t} TSL(t)\ dt \tag{11.84}$$

TTRFOR(t) = Accumulated forage consumption at t (kg DM)

TCONCPR(t) = Accumulated concentrate consumption at t (kg DM)

TTDMI(t) = Accumulated dry matter intake at t (kg DM)

TTGS(t) = Accumulated grass consumption at t (kg DM)

TTSL(t) = Accumulated silage consumption at t (kg DM)

CHAPTER 12

The FINACC Subsystem

The FINACC subsystem is concerned with the financial accounting of the farm business and the elaboration of a host of performance indicators useful in the analysis of the farm business. FINACC produces an important part of the information required for the control of the farm business. In these computations FINACC, as we see in Figure 6-1 (Chapter 6, page 6.3), collects information coming from all other subsystems.

12.1. Financial Accounting Facts and Assumptions.

The FINACC subroutine follows quite closely the accounting conventions and principles stated in Harsh, Connor & Schwab [33]. According to these authors there are three accounting records needed for business analysis purposes: (1) the net worth statement; (2) the income statement; (3) the cash flow or sources and uses of funds statement.

The net worth statement is a summary of the assets, liabilities and equity at a given point in time; in our case, at the end of the year. It indicates the financial solvency of the business, that is, a business is considered solvent if equity is greater than zero. The income statement, which is a summary of both cash and noncash financial transactions during the year, measures the profitability of the business, that is, its ability to provide a return to the owner's capital and management. The cash flow or sources and uses of funds statement is concerned with the ability of the business to meet its financial obligations. In particular, it examines the amount of cash available to the farm family and how that cash is utilized for various purposes during the accounting period.

The elaboration of the net worth statement follows the lines of Figure 12-1 (itself inspired in Table 5.1, page 81 of Harsh, Connor & Schwab's book). The net income statement follows Figure 12-2 (which is a simplification of Table 5.3, page 88, of Harsh, Connor & Schwab's book). The cash flow statement is shown in Figure 12-3 (which follows Table 5.5, page 92, of Harsh, Connor & Schwab's book). When going through the equations in the next section a look back at these figures may help in following the causal flow of computation.

Figure 12-1:

NET WORTH STATEMENT

	ASSETS	Variable name
	Current Assets	
1.	Checking Account Balance	CHACCB
2.	Accounts Receivable	ACCREC
3.	Livestock Raised for Sale	LIVRFSL
4.	Crops and Supplies	CRPASUP
5.	TOTAL CURRENT ASSETS (1+2+3+4)	TCASSTS
	Intermediate Assets	
6.	Breeding Stock	BRDSTK
7.	Equipment (Cost - Accumulated Depreciation)	EQUIPMT
8.	TOTAL INTERMEDIATE ASSETS (6+7)	TIASSTS
	Long-term Assets	
9.	Improvements (Cost - Accumulated Depreciation)	ASSIMPR
9a.	Buildings and Others Structures (Cost-Accumulated Depreciation)	BLDAOTH
10.	Farmland	FARMLD
11.	TOTAL LONG-TERM ASSETS (9+9a+10)	TLASSTS
12.	TOTAL ASSETS (5+8+11)	TASSETS

LIABILITIES AND NET WORTH

	Current Liabilities	
13.	Accounts Payable	ACCPYB
14.	Forthcoming Principal Due on Intermediate and Long-term Liabilities	PRPDUE_
16.	TOTAL CURRENT LIABILITIES (13+14)	TCLIAB
	Intermediate Liabilities	
17.	Balance Intermediate Credit Line	BICREDT

18.	TOTAL INTERMEDIATE LIABILITIES (17)	TILIAB
	Long-term Liabilities	
19.	Real Estate Mortgage	RESTMTG
20.	Balance Long-term Credit Line	BLCREDT
21.	TOTAL LONG-TERM LIABILITIES (19+20)	TLLIAB
22.	TOTAL LIABILITIES (16+18+21)	TLIAB
23.	NET WORTH OR EQUITY (12-22)	EQUITY

Figure 12-2:

INCOME STATEMENT

	INCOME	Variable name
	Cash Receipts	
1.	Milk Sales	TSLSMLK
2.	Calves Sales	CLVSLS
3.	Other Cash Sales	OTHSLS
4.	TOTAL CASH RECEIPTS (1+2+3)	CSHRCP
	Net Capital Gains Income	
5.	Breeding Cow Sales	COWSLS
6.	Other Capital Sales	CKSLS
7.	TOTAL NET CAPITAL GAINS INCOME (5+6)	CKNGI
	Change in Inventory Value	
8.	Change in Crops in Inventory	CHCRPI
9.	Change in Livestock in Inventory	CHLVI
10.	Change in Other in Inventory	CHOTI
11.	TOTAL CHANGE IN INVENTORY VALUE (8+9+10)	CHINV
	Less Major Purchase Adjustments	
12.	Purchased Feed	FEEDPR
13.	TOTAL MAJOR PURCHASES (12)	TPRCH
14.	GROSS FARM INCOME (4+7+11-13)	FIGROSS

	EXPENSES	
	Operating Expenses	
15.	Hired Labor	HLABOR
16.	Machinery, Fuel, Repairs, etc	EXPMACH
17.	Fertilizer	FERTEX

18.	Other Crop Expenses (seed, spray, etc)	OTCREX
19.	Livestock,-veterinary, marketing, etc-, expenses	EXPLIV
20.	Land rent	RENTLND
21.	Utilities and Other Miscellaneous	EXPMISC
22.	TOTAL OPERATING EXPENSES(15+16+17+18+19+20+21)	TOPEXP
	Fixed Expenses	
23.	Property Taxes	TXLAND
24.	Improvements repairs, insurance, etc	RMIEXP
25.	Interest on Intermediate and Long-term Debt	DLILOAN
26.	Equipment Depreciation	DEPREQM
27.	Improvements Depreciation	DEPRIMP
28.	Breeding Stock Depreciation	DEPRHRD
29.	TOTAL FIXED EXPENSES (23+24+25+26+27+28)	TFIXEXP
30.	TOTAL EXPENSES (22+29)	TEXPD
31.	NET FARM INCOME (14-30)	FINET

Figure 12-3:

ANNUAL SOURCES AND USES OF FUNDS STATEMENT

	Variable name
Sources of Funds	
1. Beginning Cash Balance	CHACCB(-1)
2. Cash Farm Receipts	CSHRCP
3. Capital Sales	CKNGI
4. Cash Nonfarm Income	CSNFINC
5. New Annual Loan	ANLOAN
6. New Intermediate Loan	XNILOAN
7. Depletion of Nonfarm Investment and Savings	DEPLSAV
8. TOTAL CASH INFLOW (1+2+3+4+5+6+7)	TCASHIN
Uses of Funds	
9. Cash Farm Expenses	CSHFEXP
10. Capital Expenditures:	
Initial Investment	TINVEST
Breeding Stock Investment	ACCBSTP
11. Cash Nonfarm Business Expenses	CSNFEXP
12. Family Living Expenses and Savings	FFEXPSV
13. Taxes Paid	TAXEXFM
14. Debt Repayment	RPYLOAN
15. Ending Cash Balance	CHACCB
16. TOTAL CASH OUTFLOW (9+10+11+12+13+14+15)	TCSHOUT
17. CASH-FLOW BALANCE (8-16)	

We now discuss the assumptions made in the elaboration of the net worth statement. In the valuation of the breeding stock, cows in lactations 1 and 2 are valued at market prices for these two categories of animals. Cows in later lactations are valued according to their market value for meat. Heifers are valued according to their value for milking purposes. Calves are valued according to their value for meat. Intermediate and long-term assets are accounted for following the book value concept, that is, cost minus accumulated depreciation. Depreciation of assets is computed following the straight-line depreciation method which is customary in Spain.

Concerning the computation of the net farm income in the income statement, we should look at the meaning of that concept as it is calculated in the next section. First, the operator labor which is an important input in the operation of a small-scale farm is absent from the expenditures tables in Figure 12-2. No charge for operator and family labor is accounted for there. Second, no charge is made either for the owner's capital (i.e., farmland, breeding stock, and equipment and facilities). Third, and again, no charge is made for management. In summary, then, we can say that the net farm income, at which we arrive in equation (12.81) below, represents the return to the operator's labor, capital and management committed to the farm business as well as to the investment made at the beginning of the period of study. Were we interested in finding, for instance, the rate of return on owner's capital and management we would have to make an assumption concerning how much to charge the operator and family labor. In that case a complete set of problems would arise, since there is no completely satisfactory way to price operator and family labor. Some type of shadow wage imputation would have to be made and, since there is no rigourous set of principles to follow in doing the imputation, a good deal of arbitrariness would be involved. (Hottel & Gardner [38] consider, however, the concept emerging from equation (12.81), (net farm income) a good enough indicator of the profitability of the farm business.

The problems with the net farm income concept just mentioned carry into the computation of the net present worth of investment after financing which allows the decision maker to judge on the desirability of making or not the investment. The net present worth is the difference between the present worths of the benefits and costs of a project (M.L. Brown [10]). The discounting rate is an assumed opportunity cost of capital. An investment is worth undertaking if the net present worth is greater than zero. Equations (12.89) and (12.90) below show how it is computed. The problems arise because the net farm income used in equation (12.90) represents, as we said, the return to the farm family labor, capital and management committed to the farm business. The net present worth figure applies then to the whole farm resource base (including unpaid family labor) and does not allow us to judge on the desirability of the incremental investment.

One way to adjust the net present worth after financing, so that it can become a better indicator upon which to judge the investment, is by substracting from the net farm income figure an amount that would represent the net farm income without the investment (M.L. Brown [10]). Doing that we make an allowance for the family labor, capital and management commited to the farm, and the resulting adjusted net farm income can be fully attributed to the new investment. With this procedure, however, we would be introducing again in the computation the arbitrariness that we wanted to avoid earlier when calculating the net farm income.

In order to limit the extent of this arbitrarianess we will use two values, derived from secondary sources and our own judgment, for the farm net benefit without the investment which would set a maximum and a minimum value for that concept. These two alternative values which represent the opportunity cost of the family labor, land and capital contributed by the farm family before the investment will result in two values for the internal rate of return (IRR) after financing of the investment within which the actual IRR will fall.

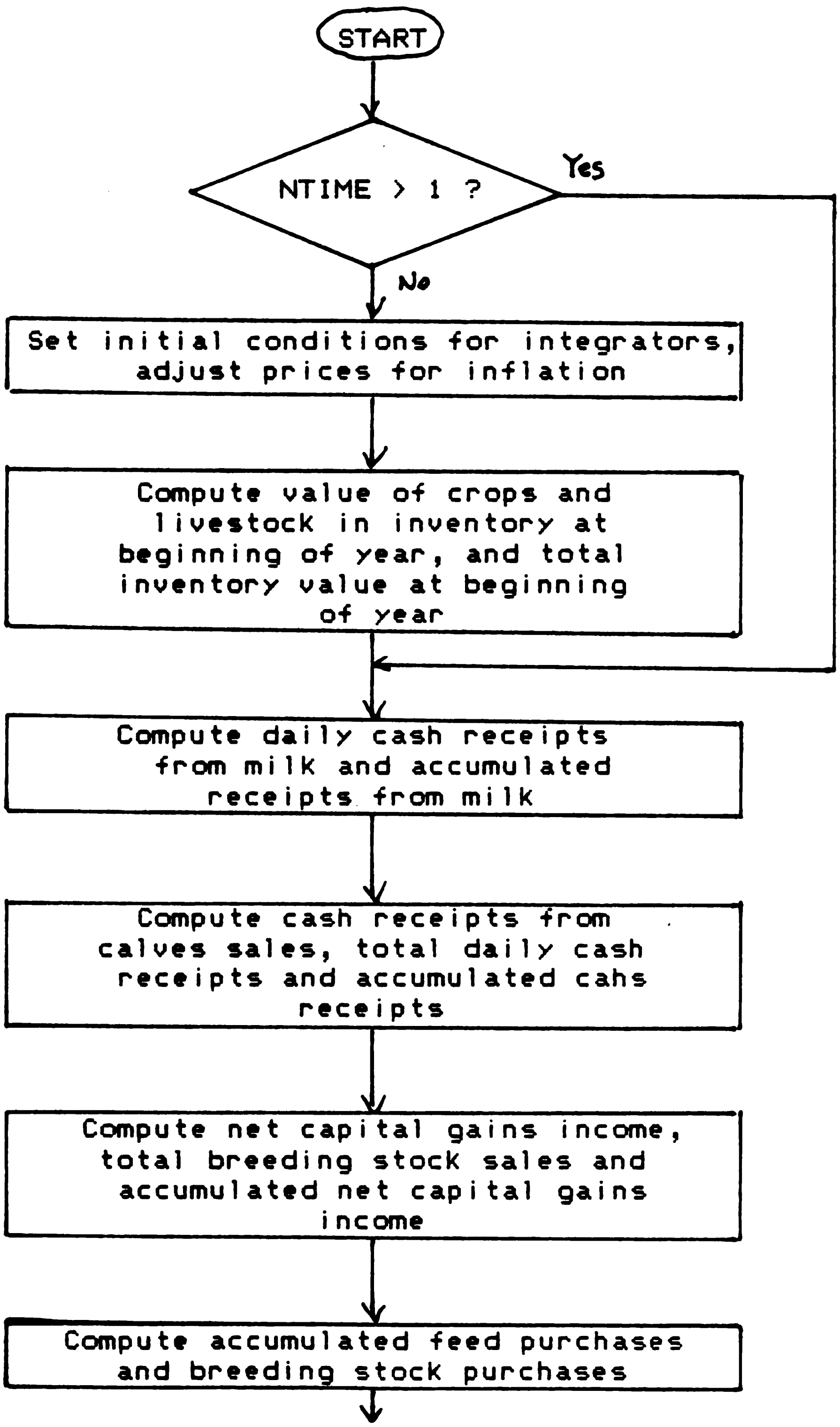
The problems mentioned above affect another set of concepts that are computed in the last part of subroutine FINACC: the average cost concepts computed in equations (12.98) to (12.100) below. It is clear these concepts do not correspond to the microeconomic concepts which bear the same name. The microeconomic theory cost concepts include all costs of the business, including an opportunity cost of equity, which is not the case here. When looking for the optimum output level, then the micreconomic rule, equate marginal cost to price level, can not be applied. Nevertheless, the cost concepts computed in FINACC may provide a good orientation of the efficiency of the farm business and may help in finding the optimal output level as well as the optimal input-input combination.

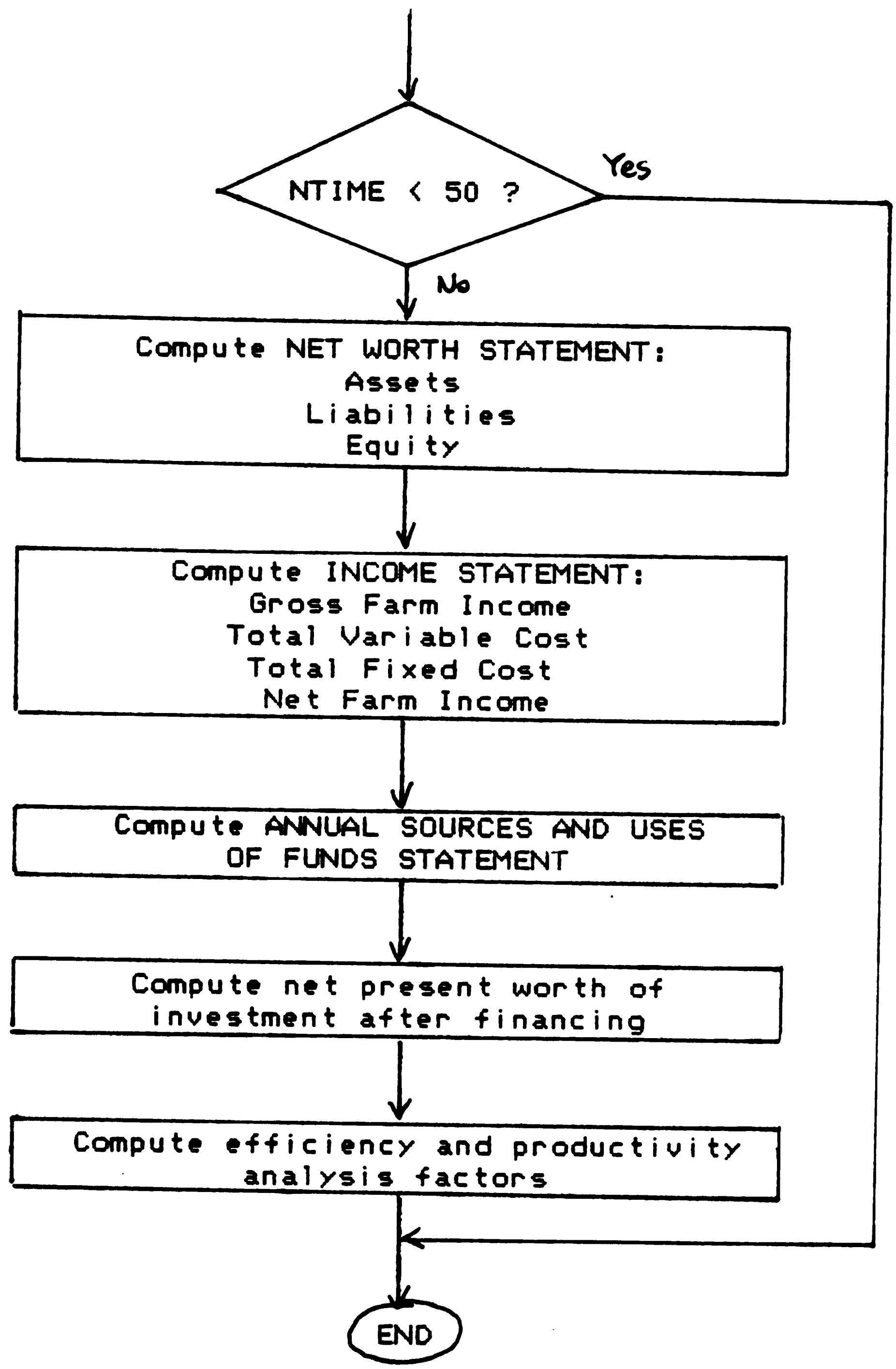
12.2. FINACC Description.

Figure 12-4 below shows the computational flow throughout this subroutine. We now proceed to an equation by equation description of the FINACC submodel.

At the beginning of every year the subroutine sets initial conditions for integrators, fixes the desired family income, adjust prices of inputs and outputs for inflation, allowing for different rates of inflation for outputs and inputs, and computes the value of crops and livestock in inventory at the beginning of year. It then skips these computations until the beginning of the following year.

Fig 12-4: FINACC Flowchart




NTIME < 50 ?
Yes
No
Compute NET WORTH STATEMENT:
Assets
Liabilities
Equity
Compute INCOME STATEMENT:
Gross Farm Income
Total Variable Cost
Total Fixed Cost
Net Farm Income
Compute ANNUAL SOURCES AND USES OF FUNDS STATEMENT
Compute net present worth of investment after financing
Compute efficiency and productivity analysis factors
END

First, adjustment for inflation takes the following general form:

PRICE = PRICE*(1+INFLATION RATE) (12.1)

The value of crops in inventory at the beginning of year is set equal to the value of crops in inventory at end of previous year. The same is true for the value of livestock in inventory at beginning of year.

VCRPINB(YR) = VCRPINE(YR-1) (12.2)

VLIVINB(YR) = VLIVINE(YR-1) (12.3)

VCRPINB(YR) = Value of crops in inventory at beginning of year (pts)

VCRPINE(YR-1)= Value of crops in inventory at end of year (pts)

VLIVINB(YR) = Value of livestock in inventory at beginning of year (pts)

VLIVINE(YR-1)= Value of livestock in inventory at end of year (pts)

YR = Year counter

Total inventory value at beginning of year is:

TVALINB(YR) = VCRPINB(YR)+VLIVINE(YR) (12.4)

TVALINB(YR) = Total inventory value at beginning of year

Now, market transactions during the year, that is milk sales, calves and other animals sales, feed purchases and breeding stock purchases, are computed, recorded, and accumulated until the end of the year.

First, cash receipts from milk:

$$TMILK(I,t) = YMLKLC(I,t)*COWPRG(I,t) + YMLKNP(I,t)*COWNPG(I,t) \quad I=1 \text{ to } 7 \qquad (12.5)$$

$$TTMILK(t) = \sum_{I} TMILK(I,t) \quad I=1 \text{ to } 7 \qquad (12.6)$$

TMILK(I,t) = Total daily milk produced by cows in cohort I, at t (lt/day)

YMLKLC(I,t) = Daily milk yield of pregnant cows in cohort I, at t (lt/head/head). Value from NUTIMP

YMLKNP(I,t) = Same as above for nonpregnant cows

COWPRG(I,t) = Cows pregnant in cohort I, at t (head). From DHERD

COWNPG(I,t) = Cows nonpregnant in cohort I, at t (head). From DHERD

TTMILK(t) = Total daily milk production at t (lt/day)

$$SLSMLK(t) = TTMILK(t)*PRMILK \qquad (12.7)$$

SLSMLK(t) = Daily cash receipts from milk sales (pts/day)

PRMILK = Price of milk (pts/lt)

Accumulated cash receipts from milk are:

$$TSLSMLK(t) = \int_{to}^{t} SLSMLK(t)\, dt \qquad (12.8)$$

TSLSMLK(t) = Accumulated cash receipts from milk sales at t (pts)

Now, cash receipts from sales of male calves and unwanted female calves are:

$$CLVSLS(t) = ((XMSLS(t)+FMSLS(t))*WHTGCL(t))*PKGCL \qquad (12.9)$$

CLVSLS(t) = Daily cash receipts from calves sales (pts/day)

XMSLS(t) = Sales of male calves at t (head/day). From DHERD

FMSLS(t) = Sales of female calves at t (head/day). From DHERD

WHTGCL(t) = Weight of growing calves at t (Kg/head). From NUTIMP

PKGCL = Price of growing calves per kg liveweight (pts/Kg lw)

Total daily cash receipts are:

$$DCSHRCP(t) = SLSMLK(t)+CLVSLS(t) \qquad (12.10)$$

DCSHRCP(t) = Daily cash receipts at t (pts/day)

Accumulated cashs receipts are:

$$CSHRCP(t) = \int_{to}^{t} DCSHRCP(t)\, dt \qquad (12.11)$$

CSHRCP(t) = Accumulated cash receipts at t (pts)

Net capital gain income, coming from sale of unwanted breeding stock, is computed next.

$$DCOWSLS(I,t) = COWSLD(I,t)*WHTLC(I,t)*PKCOW \tag{12.12}$$

DCOWSLS(I,t) = Proceeds from sales of cows in cohort I, at t (pts/day)

COWSLD(I,t) = Cows in cohort I, sold for a variety of reasons at t (head). From DHERD

WHTLC(I,t) = Weight of cows in cohort I, at t (kg/head)

PKCOW = Price of cows per kg of liveweight (pts/kg lwt)

Total cow sale proceeds per day are:

$$COWSLS(t) = \sum_{I} DCOWSLS(I,t) \quad I=1 \text{ to } 7 \tag{12.13}$$

COWSLS(t) = Total cow sale proceeds per day at t (pts/day)

Accumulated proceeds from cow sales:

$$TCOWSLS(t) = \int_{to}^{t} COWSLS(t)dt+CLLCWS(t)*WHTLC(7,t)*PKCOW \tag{12.14}$$

TCOWSLS(t) = Accumulated proceeds from cow sales at t (pts)

CLLCWS(t) = Culled cows at t (head/day). From DHERD

WHTLC(7,t) = Cows in cohort 7, at t (head). From NUTIMP

Regarding equation (12.14) we show culled proceeds out of the integration because CLLCWS(t) has a zero value all throughout the year except at parturition time when it becames equal to COW(7,t), i.e., the number of cows in cohort 7 at t.

Accumulated proceeds from heifers sales are:

$$HEIFSLS(t) = \int_{to}^{t} ((HEIFSLD(t)+CLLHEIF(t))*WHTGH(t)*PKHEIF)dt \qquad (12.15)$$

HEIFSLS(t) = Accumulated proceeds from heifers sales at t (pts)

HEIFSLD(t) = Heifers sold at t (head). From DHERD

CLLHEIF(t) = Heifers culled at t (head). From DHERD

WHTGH(t) = Weight of heifers at t (kg/head). From NUTIMP

PKHEIF = Price of heifer per kg of liveweight (pts/kg lw)

Total breeding stock sales and accumulated net capital gains income are:

$$BRDSLS(t) = TCOWSLS(t)+HEIFSLS(t) \qquad (12.16)$$

$$CKNGI(t) = BRDSLS(t) \qquad (12.17)$$

BRDSLS(t) = Accumulated breeding stock sales at t (pts)

CKNGI(t) = Accumulated net capital gains income at t (pts)

Accumulated feed purchases throughout the year are:

$$FEEDPR(t) = \int_{to}^{t} (CONCPR(t)*PRCONC)\ dt \qquad (12.18)$$

FEEDPR(t) = Accumulated feed expenditures at t (pts)

CONCPR(t) = Daily concentrate purchases at t (kg/day)

PRCONC = Price of concentrate (pts/kg)

Purchases of animals for replacement or herd expansion are:

$$BSTKPRH(t) = CLVGRW(t)*PGCL+HFGRWT(t)*PHFPRG+ COWGRW(t)*PCOWLT1 \qquad (12.19)$$

BSTKPRH(t) = Daily expenditures in animals for replacement or herd expansion (pts/day)

CLVGRW(t) = Female calves purchased (head). From DHERD

HFGRWT(t) = Purchases of young heifers (head). From DHERD

COWGRW(t) = Purchases of pregnant heifers entering first lactation (head). From DHERD

PGCL = Price of growing calves 1 week old (pts/head)

PHFPRG = Price of young heifers 1 year old (pts/head)

PCOWLT1 = Price of pregnant heifers 2 years old entering first lactation (pts/head)

Accumulated expenditures in animal purchases are:

$$ACCBSTP(t) = \int_{to}^{t} BSTKPRH(t)\ dt \qquad (12.20)$$

Next, end of year accounting calculation, elaboration of summary accounting documents and computation of a host of efficiency and productivity analysis factors occurs. These computations, as we see in the flowchart in Figure 12-4 take place only at the end of every year.

First, the net worth statement (assets, liabilities and equity in thar order) is computed. A look at Figure 12-1 will help as we go through the equations.

The value of crops and livestock at end of year is computed as:

$$VCRPINE(YR) = AVSILG(YR)*PSILAGE \tag{12.21}$$

VCRPINE(YR) = Value of crops at end of year (pts)

AVSILG(YR) = Silage available at end of year (Kg DM)

PSILAGE = Price of silage (pts/Kg DM)

The value of the breeding stock is calculated in the following way: the cows in lactation 3 or older are valuated according to their value for meat, the cows in 1st and 2nd lactation are valuated according to market prices for those types of animals. Heifers are valuated according to market prices. Growing calves are valuated according to their value for meat.

VCOWE(I,YR) = COW(I,t)*WHTLC(I,t)*PKCOW (12.22)

I=3 to 7

VCOWEY(YR) = $\sum_I$ VCOWE(YR)+COW(1,YR)*PCOWLT1+COW(2,YR)

*PCOWLT2 I=3 to 7 (12.23)

VHEIFEY(YR) = HEIFPRG(YR)*PHFPRG+HEIFNPG(YR)*PHFNPG

(12.24)

VGCLEY(YR) = GWCLV(YR)*WHTGCL(YR)+PKGCL (12.25)

VLIVINE(YR) = VCOWEY(YR)+VHEIFEY(YR)+VGCLEY(YR)

(12.26)

VCOWE(I,YR) = Value of cows in cohort I, at end of year (pts)

VCOWEY(YR) = Value of cows at end of year (pts)

VHEIFEY(YR) = Value of heifers at end of year (pts)

VGCLEY(YR) = Value of growing calves at end of year (pts)

Total inventory value at end of year is:

TVALINE(YR) = VCRPINE(YR)+VLIVINE(YR) (12.27)

Current assets are computed as follows:

CRPASUP(YR) = VCRPINE(YR) (12.28)

TCASSTS(YR) = CHACCB(YR)+ACCREC(YR)+RFSLLIV(YR)+

CRPASUP(YR) (12.29)

CRPASUP(YR) = Value of crops and supplies in inventory at end of year (pts)

TCASSTS(YR) = Value of current assets at end of year (pts)

CHACCB(YR) = Checking account balance at end of year (pts)

ACCREC(YR) = Accounts receivable at end of year (pts)

RFSLLIV(YR) = Value of livestock raised for sale at end of year (pts)

Intermediate assets are computed following the book value method, as we mentioned in the previous section. First, accumulated depreciation is calculated:

$$ACDEPEQ(YR) = \sum_{YR} (EQPOLD+EQNEW)*EQDEPR \qquad (12.30)$$

YR=1 to RLGTH

Next, the value of equipment is adjusted by the value of the accumulated depreciation:

$$EQUIPMT(YR) = (EQPOLD+EQPNEW)-ACDEPEQ(YR) \qquad (12.31)$$

ACDEPEQ(YR) = Accumulated depreciation of equipment at YR (pts)

EQUIPMT(YR) = Value of equipment at end of year (pts)

EQDEPR = Percentage of value of equipment depreciated every year

YR = Year counter

RLGTH = Duration of study period

$$BRDSTK(YR) = VLIVINE(YR) \qquad (12.32)$$

TIASSTS(YR) = EQUIPMT(YR)+BRDSTK(YR) (12.33)

BRDSTK(YR) = Breeding stock assets at end of year (pts)

Long-term assets are computed next. Two alternative methods are considered depending on the value selected for a switch operator, KSWT13. In one method, the value of farmland is included in the computation of long-term assets, in the other it is excluded.

The book value method is again used in the valuation of long-term assets:

$$\text{ACDEPAI(YR)} = \sum_{\text{YR}} \text{ASIMPII*DPRIMP} \qquad \text{YR=1 to RLGTH} \tag{12.34}$$

ASSIMPR(YR) = ASIMPII-ACDEPAI(YR) (12.35)

$$\text{ACDEPBO(YR)} = \sum_{\text{YR}} \text{BLAOTII*DEPRBAO} \qquad \text{YR=1 to RLGTH} \tag{12.36}$$

BLDAOTH(YR) = BLAOTII-ACDEPBO(YR) (12.37)

ACDEPAI(YR) = Accumulated depreciation of asset improvements at YR (pts)

ASIMPII = Initial asset improvements investment (pts). Value comes from PLTAINV

DPRIMP = Percentage of value of asset improvement depreciated per day

ASSIMPR(YR) = Value of asset improvements at end of year

(pts)

ACDEPBO(YR) = Accumulated depreciation of buildings and other structures (pts)

BLAOTII = Initial investment in buildings and other structures (pts). From PLTAINV

DEPRBAO = Percentage of value of buildings and other structures depreciated per year

BLDAOTH(YR) = Value of buildings and other structures at end of year (pts)

FARMLD(YR) = FARMLD(YR-1)*(1+APRATE) (12.38)

If KSWT13 < 1 then

TLASSTS(YR) = ASSIMPR(YR)+BLDAOTH(YR)+FARMLD(YR (12.39)

If KSWT13 > 1 then

TLASSTS(YR) = ASSIMPR(YR)+BLDAOTH(YR) (12.40)

FARMLD(YR) = Value of farmland at end of year (pts)

APRATE = Appreciation rate of farm land

TLASSETS(YR) = Value of long-term assets at end of year (pts)

Total assets is the sum of current, intermediate and long-term assets:

TASSETS(YR) = TCASSTS(YR)+TIASSTS(YR)+TLASSTS(YR) (12.41)

Liabilities are computed next. First, total current liabilities are the sum of accounts payable, principal due on intermediate and long-term debt and annual loans oustanding.

In calculating the principal due on debt outstanding, account must be made of the conditions of the loans, that is, grace period, duration and repayment method.

The principal in intermediate debt is computed as follows:

First, intermediate credit to finance purchase of breeding stock is computed:

$$XNILOAN(YR) = ACCBSTP(YR) \tag{12.42}$$

The principal on intermediate debt is:

$$PRPDUEI(YR) = \frac{BICREDT(YR)}{DRLOANI} \tag{12.43}$$

The principal in long-term debt is computed now as follows:

If YR =< GRACEL or YR > DRLOANL then

$$PRPDUEL(YR) = 0 \tag{12.44}$$

If GRACEL < YR =< DRLOANL then

$$PRPDUEL(YR) = \frac{BLLOAN}{(DRLOANL-GRACEL)} \tag{12.45}$$

Total current liabilities are:

$$TCLIAB(YR) = ACCPYB(YR)+PRPDUEI(YR)+PRPDUEL(YR)$$

+ANLOAN(YR-1) (12.46)

XNILOAN(YR)	=	Intermediate loan taken at YR (pts)
GRACEL	=	Grace period of long-term loans (years)
DRLOANI	=	Duration of intermediate loans (years)
DRLOANL	=	Duration of long-term loans (years)
PRPDUEI(YR)	=	Principal due on intermediate debt at end of year (pts)
PRPDUEL(YR)	=	Principal due on long-term debt at end of year (pts)
BLLOAN	=	Long-term debt entered into at beginning of analysis period (pts). From PLTAINV
ACCPYB(YR)	=	Accounts payable at end of year (pts)
ANLOAN(--)	=	Annual loan due at end of year (pts)
TCLIAB(YR)	=	Value of total current liabilities at end of year

Intermediate liabilities are next:

BICREDT(YR) = BICREDT(YR-1)+XNILOAN(YR)-PRPDUEI(YR) (12.47)

BICREDT(YR) = Balance of intermediate outstanding debt at end of year (pts)

Similarly for long-term liabilities:

If YR = 1 then

BLCREDT(YR) = BLLOAN-PRPDUEL(YR) (12.48)

If YR > 1 then

BLCREDT(YR)	=	BLCREDT(YR-1)-PRPDUEL(YR)	(12.49)

BLCREDT(YR)	=	Balance of long-term outstanding debt at end of year (pts)

Now, total intermediate and long-term liabilities are:

TILIAB(YR)	=	BICREDT(YR)	(12.50)
TLLIAB(YR)	=	BLCREDT(YR)	(12.51)

TILIAB(YR)	=	Total intermediate liabilities at end of year (pts)
TLLIAB(YR)	=	Total long-term liabilities at end of year (pts)

Total liabilities are the sum of current, intermediate, and long-term liabilities:

TLIAB(YR)	=	TCLIAB(YR)+TILIAB(YR)+TLLIAB(YR)	(12.52)

Equity, or net worth, is total assets minus total liabilities:

EQUITY(YR)	=	TASSETS(YR)-TLIAB(YR)	(12.53)

Before the computation of the income statement total loan repayment during the year and the change in inventory value between the beginning and end of year must be determined.

RPYLOAN(YR)	=	PRPDUEI(YR)+PRPDUEL(YR)+ANLOAN(YR-1)	(12.54)

RPYLOAN(YR) = Outstanding annual, intermediate and long-term repayed at end of year (pts)

CHCRPI(YR) = VCRPINE(YR)-VCRPINB(YR) (12.55)

CHLVI(YR) = VLIVINE(YR)-VLIVINB(YR) (12.56)

CHINV(YR) = CHCRPI(YR)+CHLVI(YR) (12.57)

CHCRPI(YR) = Change in value of crop inventory between beginning and end of year (pts)

CHLVI(YR) = Change in value of livestock inventory between beginning and end of years (pts)

CHINV(YR) = Change in total inventory value between beginning and end of year (pts)

We now proceed to elaborate the income statement. First, total income is computed as the sum of total cash receipts, total net capital gains income and change in total inventory value between the beginning and end of year:

TINCOME(YR) = CSHRCP(YR)+CKNGI(YR)+CHINV(YR) (12.58)

TINCOME(YR) = Total farm revenue at end of year (pts)

Gross farm income is total income minus total feed purchases:

FIGROSS(YR) = TINCOME(YR)-FEEDPR(YR) (12.59)

Next, operating expenses are computed. First repairs and maintenance of equipment during the year are calculated as a fixed percentage of the value of equipment at the beginning of the period of study.

RMEQUIP(YR) = (EQPOLD+EQPNEW)*PCEQP (12.60)

RMEQUIP(YR) = Expenditures on repairs and maintenance of equipment during the year (pts)

EQPOLD = Value of old equipment at beginning of period of analysis (pts). From PLTAINV

EQPNEW = Value of equipment purchased at beginning of period of analysis (pts). From PLTAINV

PCEQP = Percentage of value of equipment spent in repairs and maintenance every year

Total expenditures in machinery are repairs and maintenance of machinery plus custom work contracted during the year:

EXPMACH(YR) = RMEQUIP(YR)+CUSTOMW(YR) (12.61)

EXPMACH(YR) = Total expenditures in machinery throughout the year (pts)

CUSTOMW(YR) = Custom work contracted during the year (pts)

Payments for land rented during the year are:

RENTLND(YR) = PASTATR(YR)*RNTAT+PASTIRR(YR)*RNTIR

+PASTNIR(YR)*RNTNI+CRLANDR(YR)*RNTCRL

(12.62)

RENTLND(YR) = Payment for land rented during the year (pts)

PASTATR(YR) = improved pasture rented (ha). From PLTAINV

RNTAT = Rent of improved pasture (pts/ha/year)

PASTIRR(YR) = Irrigated pasture rented (ha). From PLTAINV

RNTIR = Rent of irrigated pasture (pts/ha/year)

PASTNIR(YR) = Nonirrigated natural pasture rented (ha). From PLTAINV

RNTNI = Rent of natural pasture (pts/ha/year)

CRLANDR(YR) = Cropland rented (ha). From PLTAINV

RNTCRL = Rent of cropland (pts/ha/year)

Total costs of silage are:

$$PSSLEXP(YR) = (\sum_{I} PASTD(I,YR)*(\sum_{\#} PRPST\#(I)) + PASTAT(YR)*(\sum_{\#} PRPAT\#) + PASTNI(YR)*(\sum_{\#} PRPNI\#) + PASTIR(YR)*(\sum_{\#} PRPIR\#))*PSILCST$$

$$I=1 \text{ to } 4 \qquad \#=1,\ 2,\ 3 \qquad (12.63)$$

PSSLEXP(YR) = Total expenditure in silage making on pastureland during the year (pts)

PASTD(I,YR) = Pasture in I phase of development at end of year (ha). From PLTAINV

PRPST# = Proportion of pasture in development reserved for silage during silage period #. From FORAGE

PASTAT(YR) = Total improved pasture controlled (ha). From PLTAINV

PRPAT # = Proportion of improved pasture reserved for silage during silage period #. From FORAGE

PASTNI(YR) = Total nonirrigated natural pasture controlled during the year (ha). From PLTAINV

PRPNI# = Proportion of nonirrigated natural pasture reserved for silage during silage period #. From FORAGE

PASTIR(YR) = Total irrigated pasture controlled (ha). From PLTAINV

PRPIR# = Proportion of irrigated pasture reserved for silage during silage period #. From FORAGE

Expenditures other than fertilizing expenditures are:

OTCREX(YR) = PSSLEXP(YR)+TPAST(YR)*OTCCST

+CRLAND(YR)*COCPH (12.64)

OTCREX(YR) = Other crop expenditures during the year (pts)

TPAST(YR) = Total pasture controlled (ha). From FORAGE

CRLAND(YR) = Total cropland controlled (ha). From PLTAINV

OTCCST = Other expenditures on pasture land per hectare (pts/ha)

COCPH = Other expenditures on cropland per hectare (pts/ha)

Fertilization expenditures are computed as follows: First, the fertilization cost of pasture and cropland per hectare is computed:

PFCPH(YR) = ((((FNTAT1+FNTAT2)/.205)*PASTAT+

((FNTNI1+FNTNI2)/.205)*PASTNI+

(FNPST/.205)*PAST)*PRNFERT)/TPAST+

(FKPSTPH/.18)*PRKFERT+(FPPSTPH/.50)*PRPFERT

(12.65)

CFCPH(YR) = (((FTOT+FTCRN)/.205)*PRNFERT)/CRLAND+

(FKCRLPH/.18)*PRKFERT+(FPCRLPH/.50)*PRPFERT

(12.66)

Second, total fertilization expenditures are now:

FERTEX(YR) = TPAST(YR)*PFCPH(YR)+CRLAND(YR)*CFCPH(YR)

(12.67)

PFCPH(YR) = Fertilization cost of pasture per hectare (pts/ha)

FNTAT# = Nitrogen fertilization (in Kg N) per hectare in improved pasture during season # (#=1, 2) (kg N/ha)

FNTNI# = Nitrogen fertilization per hectare in nonirrigated improved pasture during season # (#=1, 2) (kg N/ha)

FNPST = Nitrogen fertilization per hectare in pasture in development (kg N/ha)

PRNFERT = Price of a kilogram of "Nitrato amonico-calcico" of 20.5% N content (pts/kg)

FKPSTPH = Potasium fertilization per hectare in all types of pasture (kg K/ha)

PRKFERT = Price of a kilogram of "Cloruro potasico" of 18.% K content (pts/kg)

FPPSTPH = Phophorus fertilization per hectare in all types of pasture (kg P/ha)

PRPFERT = Price of a kilogram of "Superfosfato de cal" of 50.% P content (pts/kg)

CFCPH(YR) = Fertilization cost of cropland per hectare (pts/ha)

FTOT = Nitrogen fertilization per hectare of the winter cereal crop (kg N/ha)

FTCRN = Nitrogen fertilization per hectare of the corn crop (kg N/ha)

FKCRLPH = Potasium fertilization per hectare of cropland (kg K/ha)

FPCRLPH = Phosphorus fertilization per hectare of cropland (kg P/ha)

FERTEX(YR) = Total expenditures in fertilization during the year (pts)

Expenditures in livestock:

EXPLIV(YR) = TLCOWS(YR)*CAIPC+EQCOWS(YR)*HCPU

(12.68)

EXPLIV(YR) = Total expenditures on livestock care during the year (pts)

TLCOWS(YR) = Total lactating cows at parturition time (head)

CAIPC = Cost of artificial insemination per cow (pts/head)

EQCOWS(YR) = Number of cow equivalents at end of year (head). From FEEDACC

HCPU = Cost of health care per equivalent cow (pts/head)

Now total operating expenditures are computed as follows:

TOPEXP(YR) = (HLABOR(YR)+EXPMACH(YR)+RENTLND(YR)

+FERTEX(YR)+OTCREX(YR)+EXPLIV(YR)

+EXPMISC(YR)+ANLOAN(YR-1)*RTALOAN)*(1+PCCONT)

(12.69)

TOPEXP(YR)	=	Total operating expenditures during the year (pts)
HLABOR(YR)	=	Expenditures on labor hired during the year (pts)
EXPMISC(YR)	=	Expenditures on miscellaneous during the year (pts)
RTALOAN	=	Rate of interest on annual loans
PCCONT	=	Contingency percentage

Total variable cost is total purchases of feed plus total operating expenditures

TVCOST(YR) = FEEDPR(YR)+TOPEXP(YR) (12.70)

TVCOST(YR) = Total variable cost (pts)

Fixed expenditures are now computed. First are land property taxes:

TXLAND(YR) = TPAST(YR)*TXPST+CRLAND(YR)*TXCRPL (12.71)

TXLAND(YR)	=	Total taxes on land holdings (pts)
TXPST	=	Per hectare tax on pasture (pts/ha)
TXCRPL	=	Per hectare tax on cropland (pts/ha)

Expenditures in repairs, maintenance, insurance, etc, of intermediate and long-term assets are computed as a percentage of their beginning of period values.

RMLNDIM(YR) = ASIMPII*PCASI+BLAOTII*PCBAO (12.72)

RMIEXP(YR) = RMLNDIM(YR) (12.73)

RMLNDIM(YR) = Expenditures in repairs, maintenance, insurance of asset improvement and buildings and other structures (pts)

ASIMPII = Beginning of period investment in asset improvements (pts). From PLTAINV

PCASI = Percent of initial investment in asset improvements spent each year in repairs, maintenance and insurance.

BLAOTII = Beginning of period investment in buildings and other structures (pts). From PLTAINV

PCBAO = Percent of initial investment in buildings and other structures

Interest paid on intermediate and long-term outstanding debt is:

DLILOAN(YR) = BICREDT(YR)*RTILOAN+BLCREDT(YR)*RTLLOAN (12.74)

DLILOAN(YR) = Interest paid on intermediate and long-term outstanding debt (pts)

RTILOAN = Rate of interest on intermediate debt outstanding (pts)

RTLLOAN = Rate of interest on long-term debt outstanding (pts)

Asset depreciation following the straight-line depreciation method is next:

DEPREQM(YR) = (EQPOLD+EQPNEW)*EQDEPR (12.75)

DEPRIMP(YR) = ASIMPII*DPRIMP+BLAOTII*DEPRBAO (12.76)

DEPRHRD(YR) = VLIVINB(YR)*DPRHRD (12.77)

DEPREQM(YR) = Depreciation of equipment during the year (pts)

DEPRIMP(YR) = Depreciation of asset improvements and building and other structures (pts)

DEPRHRD(YR) = Depreciation of breeding stock per year (pts)

DPRHRD = Percentage of value of breeding stock depreciated every year

Total fixed expenses are now:

TFIXEXP(YR) = TXLAND(YR)+RMIEXP(YR)+DLILOAN(YR)

+DEPREQM(YR)+DEPRIMP(YR)+DEPRHRD(YR)

(12.78)

TFIXEXP(YR) = Total fixed expenditures (pts)

Total expenditures except feed purchases are:

TEXPD(YR) = TOPEXP(YR)+TFIXEXP(YR) (12.79)

TEXPD(YR) = Total expenditures except feed purchases (pts)

Total cost is the sum of total variable cost plus total fixed expenditures:

TCOST(YR) = TVCOST(YR)+TFIXEXP(YR) (12.80)

The end result of the income statement is the computation of the net farm income which is total income minus total cost.

$$FINET(YR) = TINCOME(YR)-TCOST(YR) \quad (12.81)$$

We now proceed to compute the final accounting document of the farm business, the annual sources and uses of funds statement.

There are two alternative ways of elaborating this document that the model user may choose. As is usual in our model a switch operator controls the election of either alternative.

In the first alternative total cash inflows minus total cash outflows give the cash available for family living expenditures and savings which is then a residue.

If KSWT14 =< 1 then

Total cash inflow or sources of funds are:

$$TCASHIN(YR) = CSHRCP(YR)+CKNGI(YR)+TSLOAN+XNILOAN \quad (12.82)$$

Total cash farm operation outflows are:

$$CSHFEXP(YR) = TCOST(YR)-DEPRHRD(YR)-DEPRIMP(YR) -DEPRHRD(YR) \quad (12.83)$$

Family living expenditures and savings are total cash inflow minus the sum of cash farm expenditures, investments during the year and repayment of loans.

FFEXPSV(YR) = TCASHIN(YR)-CSHFEXP(YR)-TIINVST -ACCBSTP(YR)-RPYLOAN(YR) (12.84)

TCASHIN(YR) = Total cash inflow during the year (pts)

CSHRCP(YR) = Total cash receipts during the year (pts)

CKNGI(YR) = Net capital gains income realized during the year (pts)

TSLOAN = Total starting loan at the beginning of the period. After the first year it becomes equal to zero (pts). Value from PLTAINV

CSHFEXP(YR) = Cash farm expenditures during the year (pts)

FFEXPSV(YR) = Farm family expenditures and savings (pts)

TIINVST = Total initial investment at the beginning of the period. After the first year it becomes equal to zero (pts). Value from PLTAINV

ACCBSTP(YR) = Breeding stock purchases during the year (pts)

RPYLOAN(YR) = Repayment of outstanding debt during the year (pts)

In the second alternative, total cash outflows include a predetermined figure for family living expenditures and savings. In this case if total cash outflow exceeds total cash inflow the cash deficit is absorbed by an annual loan. If total cash inflow exceeds total cash outflow, the cash surplus is used to increase the farm family living expenditures and savings:

If KSWT14 > 1 then

TCSHOUT(YR) = CSHFEXP(YR)+FFINCTG(YR)+TTINVST+ ACCBSTP(YR)+RPYLOAN(YR) (12.85)

TCASHIN(YR) is defined as in equation (11.79) above

If TCSHOUT(YR) > TCASHIN(YR) then

ANLOAN(YR) = TCSHOUT(YR)-TCASHIN(YR) (12.86)

If TCSHOUT(YR) =< TCASHIN(YR) then

ANLOAN(YR) = 0 (12.87)

FFEXPSV(YR) = FFINCTG(YR)+(TCASHIN(YR)-TCSHOUT(YR)) (12.88)

TCSHOUT(YR) = Total cash out during the year (pts)

FFINCTG(YR) = Farm family income target (pts). Exogenous controllable input

ANLOAN(YR) = Annual loan (pts)

The farm family living expenditures and savings constitute the returns to family labor and capital (land and other types of capital) commited to the farm business.

We now compute the net present worth of investment after financing which provides us with a measure upon which the model user could decide whether to invest or not.

First, at the end of the investment period the residual value of investment is calculated:

$$SALVAL = \frac{EQUITY}{(1+RI)^{RLGTH}} \quad (12.89)$$

The net present worth of investment is now:

$$PRESWTH = SALVAL - TIINVST + \sum_{YR} \frac{(FINET(YR) - RPYLOAN(YR))}{(1+RI)^{YR}}$$

$$YR=1 \text{ to } RLGTH \quad (12.90)$$

YR = Year counter

RLGTH = Lenght of investment period (years)

SALVAL = Residual value of investment at end of investment period (pts)

TIINVST = Total initial investment (pts). From PLTAINV

RI = Discounting rate of return. Exogenous input

PRESWTH = Net present worth of investment at end of investment period (pts)

Finally, FINACC computes a host of efficiency and productivity analysis factors useful when judging the performance of the farm business.

Total milk produced is equal to total milk sales divided by the price of milk:

$$TMLKPRD(YR) = \frac{TSLSMLK(YR)}{PRMILK} \quad (12.91)$$

Milk produced per hectare is total milk produced divided by total land area:

$$UMPH(YR) = \frac{TMLKPRD(YR)}{XLAND(YR)} \quad (12.92)$$

XLAND(YR) = Total land controlled (ha). From FORAGE

Rolling herd milk yield average is total milk produced divided by the number of lactating cows in the herd during the lactation cycle:

$$RHYMLK(YR) = \frac{TMLKPRD(YR)}{TLCOWS(YR)} \quad (12.93)$$

The value of livestock production per cow is total cash revenue divided by total lactating cows:

$$VLIVPPC(YR) = \frac{(CSHRCP(YR)+CKNGI(YR))}{TCLOWS(YR)} \quad (12.94)$$

Returns above total feed costs per lactating cow are:

$$RAFCPC(YR) = \frac{(CSHRCP(YR)+CKNGI(YR)-FEEDPR(YR))}{TLCOWS(YR)} \quad (12.95)$$

Returns above total variable cost are:

$$RAVCPC(YR) = \frac{(CSHRCP(YR)+CKNGI(YR)-TVCOST(YR))}{TLCOWS(YR)} \quad (12.96)$$

The value of livestock production per hectare is total cash revenue divided by total hectares of land:

$$VLIVPPH(YR) = \frac{(CSHRCP(YR)+CKNGI(YR))}{XLAND(YR)} \quad (12.97)$$

In computing the average variable cost of milk production we reduce total variable cost by the income received from breeding stock sales and calf sales:

$$AVCMLK(YR) = \frac{(TVCOST(YR)-CKNGI(YR)-CLVSLS(YR))}{TMLKPRD} \quad (12.98)$$

The average fixed cost of milk production is total fixed expenditures divided by total milk production:

$$AFCMLK(YR) = \frac{TFIXEXP(YR)}{TMLKPRD(YR)} \quad (12.99)$$

Total average cost of milk production is the sum of average variable cost plus average fixed cost.

$$ACMLK(YR) = AVCMLK(YR)+AFCMLK(YR) \quad (12.100)$$

Feed cost per kilogram of milk produced is feed purchases divided by total milk produced:

$$FCPUO(YR) = \frac{FEEDPR(YR)}{TMLKPRD(YR)} \qquad (12.101)$$

The kilograms of milk produced per kilogram of concentrate fed are:

$$FFPKM(YR) = \frac{TMLKPRD(YR)}{\left(\frac{FEEDPR(YR)}{PRCONC}\right)} \qquad (12.102)$$

PRCONC = Price of concentrate (pts/kg)

The kilograms of milk produced per kilogram of grass consumed are:

$$PMPKG(YR) = \frac{TMLKPRD(YR)}{TTGS(YR)} \qquad (12.103)$$

TTGS(YR) = Total grass consumed during the year (kg DM). Value from FEEDACC

The kilograms of milk produced per kilogram of silage fed are:

$$PMPKS(YR) = \frac{TMLKPRD(YR)}{TTSL(YR)} \qquad (12.104)$$

TTSL(YR) = Total silage consumption during the year (kg DM). Value from FEEDACC

The kilograms of milk produced per kilogram of dry matter intake are:

$$PMPKD(YR) = \frac{TMLKPRD(YR)}{TTDMI(YR)} \tag{12.105}$$

TTDMI(YR) = Total dry matter intake during the year (kg DM). Value from FEEDACC

The dry matter intake per lactating cow is total dry matter consumption by cows divided by total lactating cows:

$$DMCPLC(YR) = \frac{TTDMICW(YR)}{TLCOWS(YR)} \tag{12.106}$$

TTDMICW(YR) = Total dry matter intake by cows during the year (kg DM). From FEEDACC

The concentrate consumption per lactating cow during the year is total concentrate consumption by cows divided by total lactating cows:

$$CCPLC(YR) = \frac{TTCONCW(YR)}{TLCOWS(YR)} \tag{12.107}$$

TTCONCW(YR) = Total concentrate consumption by cows during the year (kg DM). From FEEDACC

The forage consumption per lactating cows is, analogously:

$$FCPLC(YR) = \frac{TTFORCW(YR)}{TLCOWS(YR)} \tag{12.108}$$

TTFORCW(YR) = Total forage consumption by cows during the year (kg DM). From FEEDACC

The grass consumption per lactating cow is:

$$\text{GCPLC(YR)} = \frac{\text{TTGSCW(YR)}}{\text{TLCOWS(YR)}} \tag{12.109}$$

TTGSCW(YR) = Total grass consumption by cows during the year (kg DM). From FEEDACC

The silage consumption per lactating cow is:

$$\text{SCPLC(YR)} = \frac{\text{TTSLCW(YR)}}{\text{TLCOWS(YR)}} \tag{12.110}$$

TTSLCW(YR) = Total silage consumption by cows during the year (kg DM). From FEEDACC

The subroutine FINACC concludes with an extensive set of printing statements which compose the accounting documents of the farm business.

CHAPTER 13

Model Validation and Testing

In this chapter we discuss the credibility of the dairy/forage simulation model described in Chapters 6 to 12.

Credibility of models, concepts or theories is gained subjecting them, according to many authors, to verification and validation tests. Where many authors disagree, however, is in the meaning they attach to these two concepts. It seems that the underlying definitions, on which almost everybody is in accord, are attached indistinctly to one or the other concept. We can say that system analysts seem to have failed the consistency test in this respect.

The confusion over the meanings of validation and verification is understandable. Both concepts are used in common language interchangeably. For instance, if we look up the meaning of the two concepts on one standard U.S. dictionary like the American Heritage Dictionary (Second College Edition, Houghton Mifflin Company, Boston, U.S.A. 1982) we find the following definitions: (a) Verify: To prove the truth of by the presentation of evidence or testimony. Substantiate; (b) Validate: Substantiate, verify. On the basis of these definitions then both terms are interchangeable and we should eliminate one as redundant.

However, the dictionary offers some further information that may incline us to keep both terms. It defines the term "valid" as (1): Well grounded; sound. (2): Producing the desired results; efficacious. These concepts seem to have been adopted by a majority of system analysts and attached mainly (there are exceptions) to the validation label. For instance:

G.L. Johnson and G. Rossmiller [41] following various philosophies use the following definitions:

> "Usually validation [means] testing a concept, theory, or model for internal logical consistency. Verification generally means testing a concept or a model with respect to its ability to reflect accurately the real world situation or phenomenon it is intended to represent through its capacity to track historical data and to project accurately the behavior of important variables of a system into the future. Validation is a test of coherence, whereas verification is a test of correspondence." (page 50)

In the same vein A.Wright [79] states:

> "Verification of a model is concerned with establishing whether the model is a true or

> correct representation of reality.
>
> Validation is not so much concerned with the correctness of a model, but rather whether it is effective or suitable for a specific purpose. Thus a model is validated in relation to the purpose for which it was constructed, wheras a model is verified in relation to absolute truth. The term validation is thus particularly relevant for models used in systems synthesis where the objectives are to improve system design and/or control"

Keeping these two concepts (verification and validation) in mind when assessing the credibility of simulation models is important since there are many types of simulation models and, although some may, and should, be both verified and validated, many others may only, due to their mature and that of the system they attempt to simulate, be validated.

The next question presenting itself to the researcher is how to verify and validate a simulation model. There is no rigorous procedure that tells the neophyte simulation analyst how to establish credibility for a model. There seems to be a consensus that validation of a model like all subjective evaluation, is judgemental but not necessarily unobjective.

The literature offers some orientation on how to go about validating and verifying a simulation model. J.R. Anderson [4] reviews two sets of stepwise procedures for verification/validation: Naylor and Finger suggest a three-step procedures: (a) Ensuring that assumptions accord with the theory, experience and general knowledge judged relevant; (b) Subjecting assumptions to empirical testing where this is possible; (c) Comparing model performance with the real systems performance. Hermann's five-step scheme goes as :(a) Ensuring that internal linkages are as intended (internal validity); (b) Ensuring that model output is superficially reasonable (face validity); (c) Checking model relationships against known counterparts (variable-parameter validity); (d) Predicting observed events and patterns (event or scientific validity); (e) Attempting to distinguish simular performance from that of systems that the simulation is not intended to represent (hypothesis validity). Step (a) of Naylor and Finger and steps (a), (b) and (c) of Hermann's scheme can be said to be validation tests. The remaining steps may be considered verification tests.

Let us first consider verification. A simulation model can be considered as a time series generator and when the model purports to simulate an existing real world system verification checking may be performed by comparing the time series generated by the real system with the corresponding time series generated by the model.

S.R. Johnson & G.C. Rausser [42] have produced a quite exhaustive table of "Evaluation Criteria for Investigating the Explanatory and Predictive Power of Systems Models" (pp.186-187). As the table title indicates models are to be judged as being verified when they are able to generate, when run under the same exogenous conditions, patterns of past change in the real systems and to predict accurately values for the state or output variables beyond the range of data that might have been used in the construction of the model. There is a full range of criteria to evaluate the explanatory and predictive power of simulation models and they go from a variety of classical "goodness-of-fit" and tracking criteria to sophisticated spectral analysis criteria. Simulation models of real systems, in whose construction, for instance, econometric methods have played a large role are especially suited to this kind of rigorous verification testing. Other type of models, of which the model reported on here is an example, do not easily allow this sort of testing. We can say, in fact, that some simulation models can not be verified, only validated, leaving them always open to the charge of not being verifiable (and, by implication, falsifiable).

A. Wright [79] explains why even validation testing of some simulation models is unconclusive:

> "The validation of system models presents a number of major problems... Although validation implies some sort of comparison between model and reality, there may be little quantitative information about the real system that can be used as a basis for comparisons. The real system may

> not even exist, as is the case when a model is being used to design a new system. In these cases, validation of the model must rely heavily on subjective judgement.
>
> The validation of bio-economic models is always likely to be a rather non-rigorous procedure relying heavily on subjective judgement. This is not so much a limitation of the simulation technique as a characteristic of the systems that are being studied."

This quotation sheds some light on the validation testing of our model. As we stated in Chapter 5, our aim when starting this research was to build a model of a farming situation to explore new management practices and farm growth strategies. Our objective was not to build a model of a particular farm but to create a synthetic model of a farm situation which would be used to conduct analysis capable of generating information valid for a given set of farms. In this sense the a real system to which we should compare the model does not exist, thereby making whole-model verification testing infeasible.

A qualification should be attached, however, to our earlier statements that the kind of simulation models we are talking about can not be verified. They can not be so if we consider the whole model. Nevertheless, our model was constructed from pieces, some of which were the end result of rigorous research, and to which verification tests, of the kind mentioned earlier, can be applied. Examples of components subjected to partial verification are the lactation curve, the voluntary dry matter equation and the NRC equations used in the NUTIMP subsystem. In this sense, at least we can establish the confidence which can be attached to the operation of our model.

Validation of bio-economic simulation models is a non-rigorous procedure. One way to go about it is to examine the operation of the model to see if it does what it was intended to do. Step (a) of Naylor & Finger procedure and steps (a), (b) and (c) of Hermann's scheme (internal, face and variable-parameter validity) have to do with just that, i.e, confirming that the model operates in accord with expectations.

This is the validation procedure we will follow. In the next section we examine the output of several critical state variables generated by our model and to determine if their patterns through time agree with earlier expectations and with prior knowledge. In the following section we show the results of some sensitivity analyses performed on critical parameters about whose true value we are uncertain. In the final section we offer some final comments about the validation testing achieved so far and about two other tests, clarity and workability, that are also considered to be important in gaining credibility for any simulation research.

13.1. Model Validation

We now determine whether the model operates according to pre-modelling anticipations. A set of critical state variables have been selected in order to determine if the model posseses internal, face and variable-parameter validity in Hermann's sense and if it complies with step (a) of Naylor-Finger's stepwise procedure.

All the model runs producing the tables that we show below have been made keeping a set of maintained assumptions, especially concerning the monetary parameters, which are collected in Appendix 3.

An important characteristic of dairy farming systems in Galicia is, as we mentioned earlier, the markedly seasonal pattern of daily grass production with two distinct seasons of grass production throughout the year. As we also said, accurate simulation of this seasonal pattern was essential for a realistic picture of the dynamic evolution of the dairy farm to emerge.

Table 13-1 and Figure 13-1 below show the spread of the annual production of grass over the two seasons. Annual grass yields for the two seasons were 6800 and 1700 kg of dry matter for season 1 and season 2. This production was spread throughout the two seasons by two distributed delays of degrees 6 and 5 respectively (the degree of a distributed delay is the order of the differential equation that the delay simulates. See Manestch and Park [50]). We see in table 13-1 that the accumulated outputs of the delays correspond with a small error to what was input into the delay (the error is less than .1% for the 1st season yield and less than 1.% for the 2nd season yield).

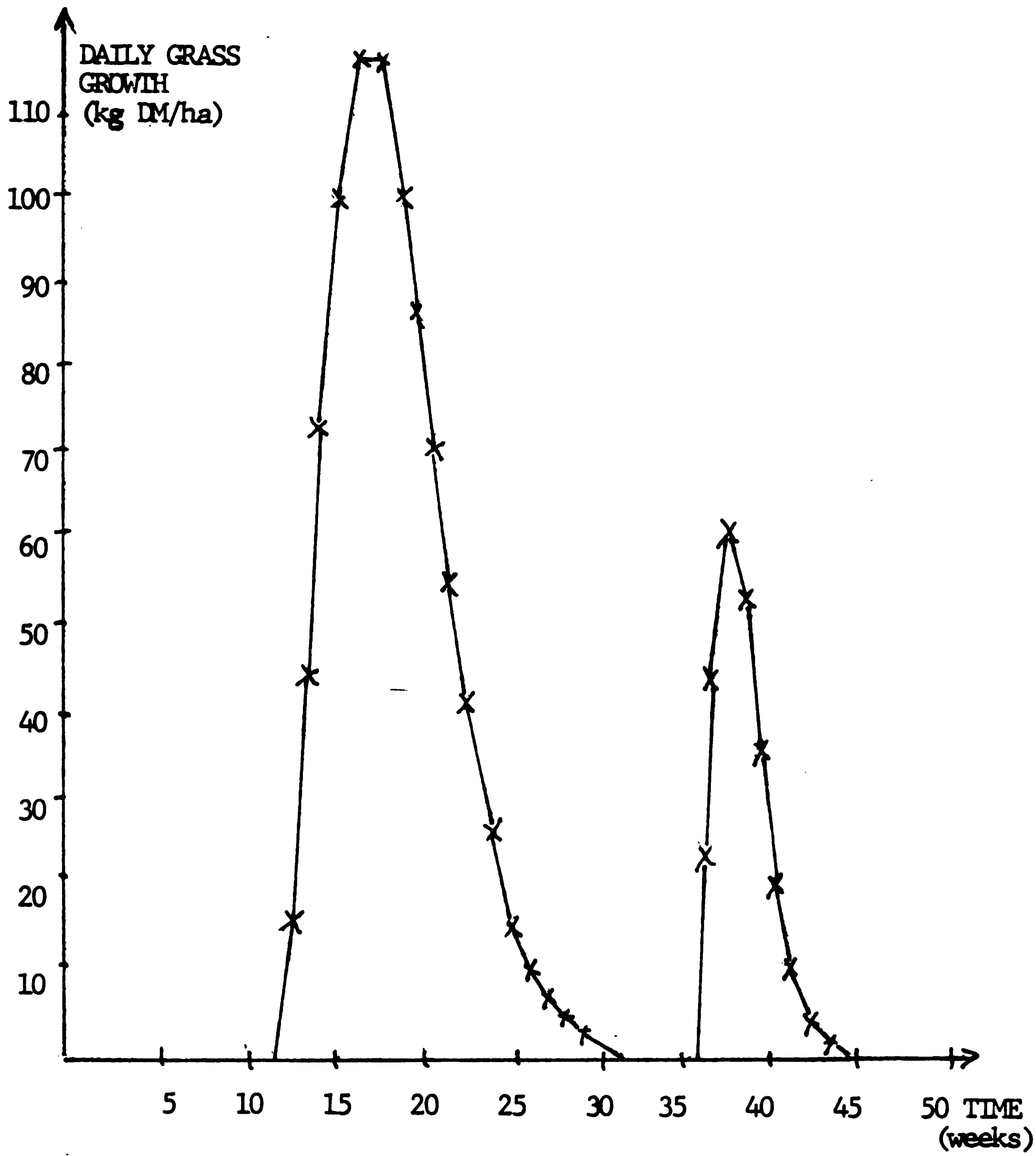
As we see in Table 13-1 and Figure 13-1, there is no grass production at all during the first three months, roughly, of the year. Then daily grass yield increases rapidly up to week 18, when it reaches a peak. Week 18 corresponds, approximately, to beginning or mid May. After the peak, daily grass production declines and becomes zero again by week 34, which corresponds to the end of August or the beginning of September. There is no production from week 34 to 36. By the end of September the second growth season starts. From week 37 to 45 that is from beginning of September to the end of November, we have another bell-shaped surge of daily grass growth.

Table 13-1

Simulated Daily Grass Production (Kg DM/ha/day)

Week	Season1	Season2	Week	Season1	Season2
1	0	0	26	15	0
2	0	0	27	10	0
3	0	0	28	7	0
4	0	0	29	5	0
5	0	0	30	3	0
6	0	0	31	2	0
7	0	0	32	1	0
8	0	0	33	1	0
9	0	0	34	0	0
10	0	0	35	0	0
11	0	0	36	0	0
12	0	0	37	0	43
13	15	0	38	0	62
14	44	0	39	0	53
15	76	0	40	0	35
16	102	0	41	0	20
17	115	0	42	0	10
18	115	0	43	0	5
19	105	0	44	0	2
20	90	0	45	0	1
21	73	0	46	0	0
22	57	0	47	0	0
23	43	0	48	0	0
24	31	0	49	0	0
25	22	0	50	0	0
			Total	6803	1686

Figure 13-1: Simulated Daily Grass Production



Tables 13-2 and 13-3 and Figures 13-2 and 13-3 show the seasonal patterns for three critical state variables generated in subroutine NUTIMP: Daily milk yield, daily dry matter intake and weight status. We only show in the tables and figures mentioned above the values of the state variables corresponding to a cow in her 6th lactation, the state variables corresponding to cows in other lactations following essentially similar patterns.

What we try to do here is to show that the temporal pattern of those state variables conform to pre-modelling expectations as incorporated in Figure 10-1. The two runs producing Table 13-2 and Figure 13-2 and Table 13-3 and Figure 13-3 respectively were obtained under different assumptions reflecting the two different mechanisms built into the model for the calculation of milk yield production and dry matter intake. In method (a), as we saw in Chapter 10, we accept the NRC recommended concentration of ME as a function of body weight and potential daily milk yield and given the concentration of ME on purchased concentrates and available forage, the concentrates and forage fed daily result. In the projection of dry matter intake we use Brown & Chandler equation since it performs much better than the table function derived from NRC data. We should recall that in method (a) the biological priority of the cow is milk production, body weight maintenance taking a secondary place.

As we see in Table 13-2 and Figure 13-2 the shapes of daily milk yield, dry matter intake and body weight follow quite closely the shapes that are shown in Figure 10-1, which we took as our modelling objective for this part of the model.

Table 13-2

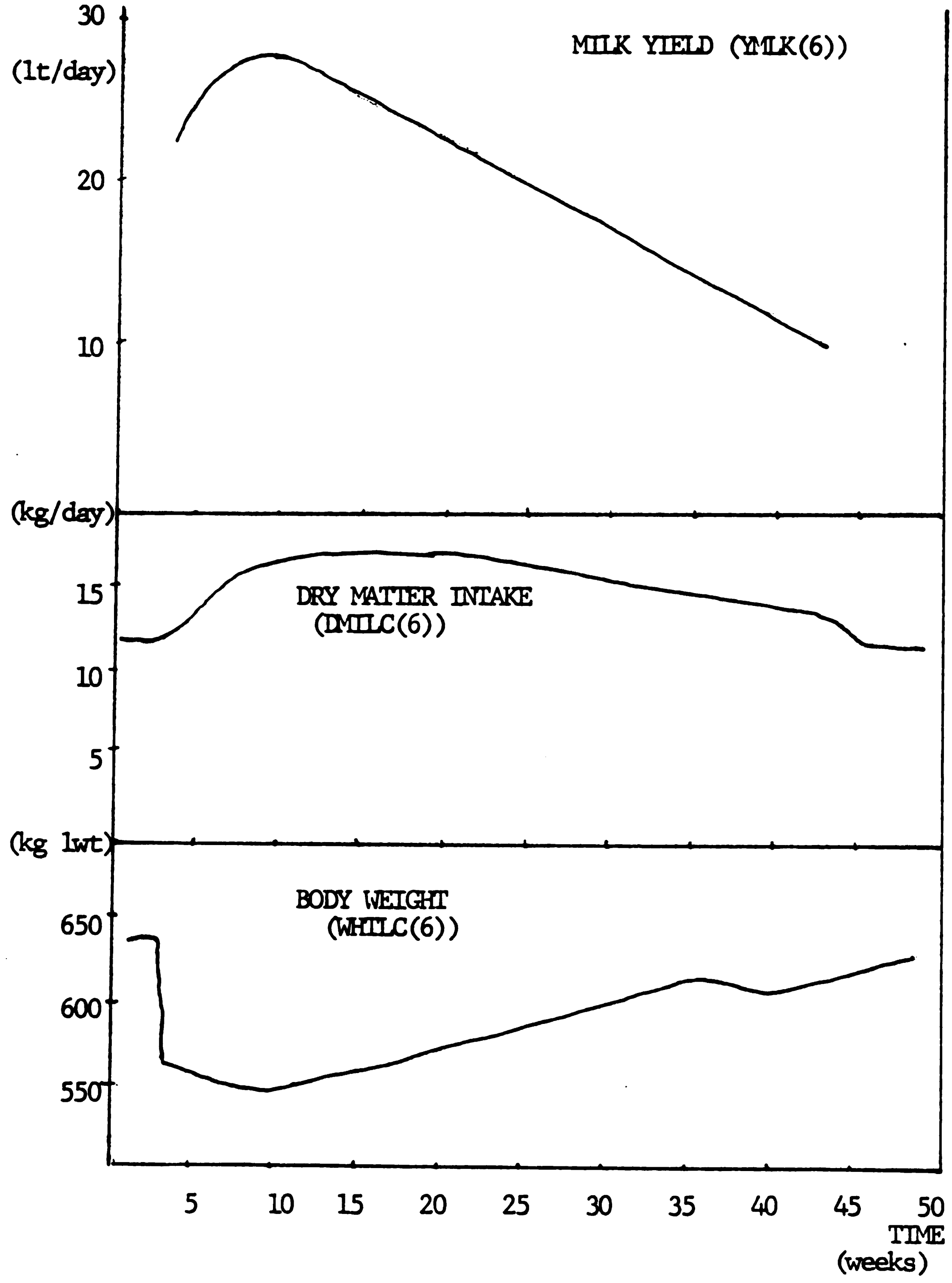
Simulated Patterns of Change of Daily Milk Production [YMLK], Dry Matter Intake [DMILC], and Body Weight [WHTLC], for a Cow in the Sixth Lactation. Method (a).

Week	YMLK(6)	DMILC(6)	WHTLC(6)	Week	YMLK(6)	DMILC(6)	WHTLC(6)
1	---	12.	637.	26	19.02	16.60	592.
2	---	12.	640.	27	18.44	16.47	595.
3	19.93	12.	560.	28	17.87	16.33	599.
4	23.46	13.82	556.	29	17.31	16.19	603.
5	25.34	14.93	553.	30	16.76	16.04	604.
6	26.44	15.67	550.	31	16.22	15.86	605.
7	27.06	16.20	549.	32	15.70	15.69	607.
8	27.36	16.59	548.	33	15.18	15.51	608.
9	27.44	16.87	547.	34	14.68	15.33	610.
10	27.34	17.09	548.	35	14.19	15.14	611.
11	27.12	17.24	549.	36	13.71	14.96	610.
12	26.81	17.35	550.	37	13.25	14.75	609.
13	26.41	17.42	552.	38	12.80	14.54	609.
14	25.96	17.46	555.	39	12.30	14.34	608.
15	25.47	17.48	557.	40	11.93	14.13	608.
16	24.93	17.47	561.	41	11.52	13.93	607.
17	24.38	17.45	564.	42	11.11	13.73	606.
18	23.80	17.41	568.	43	10.72	13.52	606.
19	23.21	17.36	573.	44	---	12.	612.
20	22.62	17.30	575.	45	---	12.	616.
21	22.01	17.20	577.	46	---	12.	620.
22	21.41	17.10	580.	47	---	12.	623.
23	20.80	16.98	582.	48	---	12.	627.
24	20.21	16.86	585.	49	---	12.	630.
25	19.61	16.73	589.	50	---	12.	632.

Assumptions: SYMILK = 6000.; KSWT3 = 1; KSWT8 = 2; DMIDRY = 12.

YMLK(6) = Daily Milk Yield (lt/day)
DMILC(6)= Dry Matter Intake (kg DM/day)
WHTLC(6)= Body Weight (kg lwt)

Figure 13-2: Patterns of Change of Selected Output Variables under Method (a) Conditions



We should pay attention especially at the period between week 3 (parturition time) and week 10. During that period, as we explained in Chapter 10, an energy imbalance develops which the cow manages by using nutrients deposited in body stores. We see that daily milk yield rises rapidly reaching a peak during the 9th week, starting then to decline at a lower rate. Simultaneously, body weight from parturition declines to also reach a minimum during week 9. Dry matter intake increases also from parturition time but at a slower rate than milk yield, reaches its peak at week 15 and then declines. Overall the dry matter intake path is much smoother than that of daily milk yield.

In method (b), we noted earlier, the manager defines the ration fed to animals by setting the ratio concentrate to dry matter intake during the four feeding seasons that we consider in our model. By setting this ratio the manager also defines the concentration of ME and CP fed to the animals throughout the year. In this method the biological priority of the cow is body weight maintenance with actual milk yield failing to reach its potential whenever an energy or protein deficit arises. As in the previous method and for the same reasons, the dry matter equation of Brown & Chandler was activated.

The following feeding regime was followed. From parturition time to two weeks after pregnancy time a ration with a 60:40 concentrate-forage ratio was fed to the cows. From the end of the previous period to three weeks before the end of the lactation period the ration was changed to a 20:80 ratio. From that time to again parturition time the following year, only forage was given to the cows.

In Table 13-3 and, especially, Figure 13-3 we can see the temporal profiles of milk yield, dry matter intake and body weight thoughout the year. The dry matter intake shape is essentially the same as the one produced under method (a) the only difference being a slight increase in dry matter intake since the cow keeps a higher weight during the year which pulls the dry matter equation upwards.

In the upper diagram of Figure 13-3 we see the actual milk yield shape under (in full line) the aforementioned feeding regime and potential milk yield (dotted line) which is the same as the one in Figure 13-2. We see that from week 3 to 12 actual milk yield is lower then potential milk and body weight higher than in method (a)'s run. The reason for that is a lower ME concentration in the ration fed under method (b). Since body weight maintenance is now a priority the deficit (imbalance) works itself out by reducing milk production. At week 13 we observe a sudden surge in actual milk production which takes it to the potential milk yield level. From that point to three weeks before the end of lactation actual milk yield equals, roughly, potential yield. The cause of the surge in milk yield, and later production according to potential, is the fact that, although the same feeding regime (60:40) is kept until two weeks after pregnancy time (week 16), the forage component of the ration is now only grass which has a higher concentration of ME and CP than silage. Week 13 is the time to set the cows to graze as the first grass producing season gets under way (see Table 13-1 and Figure 13-1 which will confirm that).

Table 13-3
Simulated Patterns of Change of Daily Milk Production Potential [YMLK], Actual Milk Production [YMLKLC], Dry Matter Intake [DMILC], and Body Weight [WHTLC], for a Cow in Sixth Lactation. Method (b).

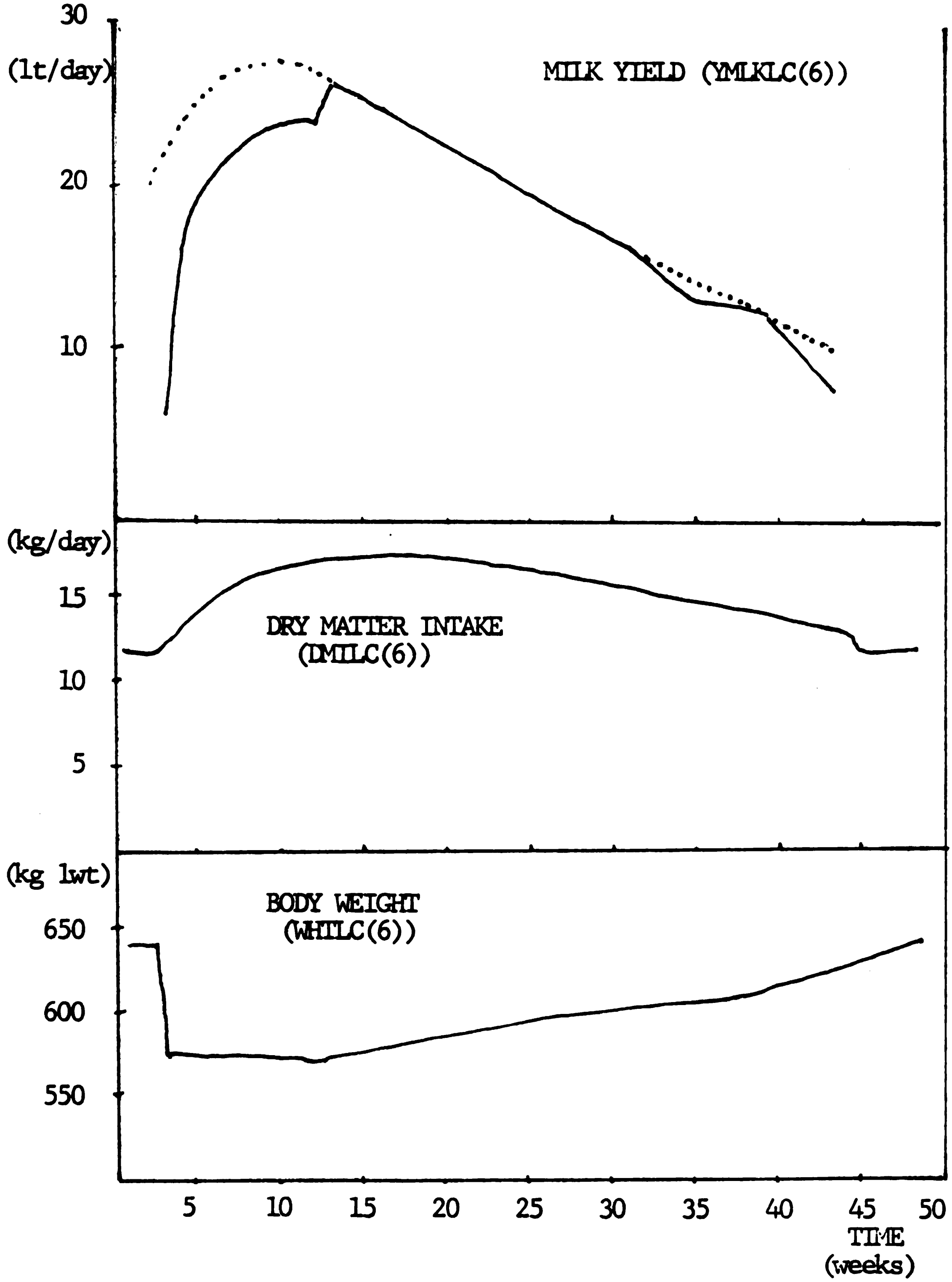
Week	YMLK(6)	YMLKLC(6)	DMILC(6)	WHTLC(6)
1	-----	-----	12.	637.
2	-----	-----	12.	639.
3	19.93	6.28	12.50	569.
4	23.48	18.00	13.89	569.
5	25.34	19.99	15.05	569.
6	26.44	21.33	15.84	569.
7	27.06	22.29	16.40	569.
8	27.36	23.00	16.81	569.
9	27.44	23.51	17.12	569.
10	27.34	23.88	17.33	569.
11	27.12	23.81	17.48	570.
12	26.81	23.53	17.59	571.
13	26.41	26.40	17.65	572.
14	25.96	25.95	17.69	575.
15	25.47	25.45	17.71	579.
16	24.93	24.92	17.72	583.
17	24.38	24.37	17.71	588.
18	23.80	23.00	17.68	588.
19	23.21	22.73	17.59	588.
20	22.62	22.43	17.48	589.
21	22.01	22.00	17.36	589.
22	21.41	21.40	17.23	590.
23	22.80	22.80	17.09	591.
24	20.21	20.20	16.95	592.
25	19.61	19.60	16.80	594.
26	19.02	19.01	16.65	595.
27	18.44	18.43	16.49	595.
28	17.87	17.86	16.32	597.
29	17.31	17.30	16.15	598.
30	16.76	16.75	15.97	599.
31	16.22	16.08	15.79	600.
32	15.70	15.36	15.61	601.
33	15.18	14.64	15.43	602.
34	14.68	13.91	15.25	603.
35	14.19	13.17	15.06	604.
36	13.71	12.43	14.88	606.

37	13.25	11.68	14.69	607.
38	12.80	12.79	14.51	609.
39	12.36	12.35	14.33	611.
40	11.93	11.66	14.15	613.
41	11.52	8.79	13.97	615.
42	11.11	8.06	13.79	617.
43	10.72	7.30	13.61	619.
44	-----	----	12.	625.
45	-----	----	12.	629.
46	-----	----	12.	633.
47	-----	----	12.	636.
48	-----	----	12.	638.
49	-----	----	12.	641.
50	-----	----	12.	643.
	6000.	5493.		

Assumptions: SYMILK = 6000; KSWT3 = 2; KSWT8 = 2;

KSWT12 = 2 (60, 20, 0, 0); DMIDRY = 12

Figure 13-3: Patterns of Change of Selected Output Variables under Method (b) Conditions



Another part of the NUTIMP subroutine that requires validation testing is the mechanism simulating the biological process of heifer growth, which is represented in Figure 10.4 (chapter 10), and operationalized by equations (10.9), (10.10), (10.20) to (10.26), and (10.29) to (10.34). Equation (10.31) especially may be thought to be suspect since it was taken from another study. As we see in Fig 10.4 this mechanism is driven by a desired rate of weight gain per day that the manager selects. Given the way this mechanism was designed we may say that it performs according to expectations if the actual rate of weight gain per day matches the desired rate of weight gain that drives the mechanism. Otherwise, an inconsistency exists somewhere and we should reject the model as erroneous.

Table 13-4 below shows the evolution of the actual rate of weight gain during the year, under the assumption that the desired rate of weight gain is .8 Kg/day (DWGNGH = .8). As we can see in the Table the actual rate of weight gain matches with minor fluctuations the desired rate of weight gain.

Table 13-4

Simulated Pattern of Change of Heifer Daily Weight Gain [WGNH].

	Weight gain		Weight Gain
Week	WGNH (kg/day)	Week	WGNH (kg/day)
1	.44	26	.79
2	.43	27	.79
3	-.01	28	.80
4	.73	29	.80
5	.74	30	.80
6	.74	31	.83
7	.75	32	.82
8	.75	33	.82
9	.76	34	.82
10	.76	35	.82
11	.77	36	.81
12	.78	37	.80
13	.75	38	.83
14	.75	39	.82
15	.74	40	.81
16	.74	41	.80
17	.75	42	.78
18	.75	43	.77
19	.76	44	.66
20	.76	45	.67
21	.77	46	.64
22	.77	47	.62
23	.78	48	.59
24	.79	49	.56
25	.79	50	.53

Desired weight gain of heifers, DWGNGH = .80

Three more tables (A2-1, A2-2, A2-3) are shown in Appendix 2 where we can see the patterns through time for total CP requirements of cows in the sixth lactation, (A2-1), concentration of ME and CP in silage available throughout the year (A2-2) and body weight status of growing calves, heifers and cows in sixth lactation (A2-3).

13.2. Sensitivity Analysis.

A minimum validation testing of a simulation model requires some sensitivity analysis carried out on important and critical design parameters in the system.

According to T. Manestch [48]

> "[Sensitivity Testing] involves making significant changes in values of model coefficients or parameters, normally one at a time, and observing the changes that result in the key outputs of the model. The parameters selected for sensitivity testing are ones for which we have the poorest estimates. The sensitivity tests provide two important kinds of information. They indicate where we need to collect better data to improve parameter value of sensitive parameters that have significant impacts on model outputs of interest. This information leads to priorities and efficiencies in data collection. Further, these sensitivity tests produce changes in model behavior that we can check against our knowledge of how the model ought to behave under the given circumstances"

Sensitivity analysis is then aimed at testing the robustness or soundness of the model when changes are made in structural parameters whose reliability is in doubt.

The end product of a sensitivity analysis is, according to J.R. Anderson [4] a declaration by the analyst that the model is "sensitive" to none, one or more parameters. This means that the lack of knowledge about the time value of a sensitive parameter affects seriously "the ability of the model to mime the simuland for analytical purposes", thus reducing the credibility of whatever conclusions or prescriptions may be reached through experimentation with the model.

Table 13-5 shows the state variables and their definitions to help us to assess the results of our sensitivity analyses.

We now proceed to show and comment on the results of sensitivity analysis runs performed with the model. Five critical parameters were studied. The first one is SYMILK, the parameter setting the annual milk yield potential of the dairy herd. This parameter is subjected to sensitivity testing with the model operating under methods (a) and (b) as explained earlier. The second parameter is TN1 the scaling factor of the dry matter equation in subroutine NUTIMP. The third and fourth parameters which are varied simultaneously are CMEGSIN and CPTGSIN, that is the content on ME and CP respectively of grass grazed. The fifth and last is TN3 which measures grass utilization by cows when grazing. This parameter may be considered a proxy for the quality of forage management of the farmer (more later when we examine the results of that run).

Table 13-5

Selected Output Variables for Sensitivity Analysis and Model Performance Evaluation.

Variable Name		Definition
1.WHTLC(6)(B-Y)	(kg lwt)	Body weight of cows in 6th lactation at beginning of year
2.WHTLC(6)(E-Y)	,,	Body weight of cows in 6th lactation at end of year
3.SILGSUR(B-Y)	kg DM	Silage carryover at beginning of year
4.SILGSUR(E-Y)	,,	Silage carryover at end of year
5.GRSSURP(E-Y)	,,	Grass carryover at end of year
6.TCONCPR	(kg)	Total concentrate purchase in kg during the year
7.TICONCW	,,	Total concentrate consumption by cows during the year
8.EQUITY	(pts)	Equity
9.FEEDPR	,,	Concentrate purchases in pts during the year
10.FINET	,,	Farm net income
11.FFEXPSV	,,	Cash available at end of year for family consumption
12.RHYMLK	(lt/cow)	Rolling herd milk yield average
13.RAVCPC	(pts/cow)	Returns above variable cost per cow
14.AVCMLK	(pts/lt)	Average variable cost of milk production
15.AFCMLK	,,	Average fixed cost of milk production
16.ACMLK	,,	Average total cost of milk production (14+15)
17.FFPKM	(lt/kg)	Liters of milk per kilogram of concentrate fed
18.TMLKPRD	(lt)	Total milk production
19.DMCPLC	(kg/cow)	Dry matter consumption per lactating cow
20.CCPLC	,,	Concentrate consumption per lactating cow
21.FCPLC	,,	Forage consumption per lactating cow
22.GCPLC	,,	Grass consumption per lactating cow
23.SCPLC	,,	Silage consumption per lactating cow
24.TLCOWS	,,	Dairy herd size (# of lactating cows)
25.TYMILK(6)	(lt/cow)	Annual milk yield of cows in 6th lactation

In Table 13-6 we see the results of the sensitivity runs when we vary SYMILK in the range (5000-9000) by 1000 liter increment. The run was made with the model operating under method (a) conditions so actual milk yield is equal to potential milk yield. Let's now summarize the results:

1. In the first two rows we can see that weight at end of year for cows in the sixth lactation increases with milk potential, reaches a maximum at the 6000 lt level, where it reaches roughly its weight at the beginning of the year, and then declines for higher milk potentials. We see that body weight conservation throughout the year is fairly consistent with milk potentials between 5000 and 7000 lt/year, with the best weight turnaround achieved at the 6000 lt. level.

2. Nonutilized silage and grass (rows 4 and 5) increase with milk yield potential. The reason is that higher energy demand to sustain higher yields have to be met with higher dry matter intakes (row 19) and with rations made up of a higher proportion of concentrate (rows 6,7, and 20). This liberates quite a lot of the grass and silage available (rows 21, 22, and 23) meaning that the stocking rate can be increased substantially as milk yield potential increases.

Table 13-6

Sensitivity of Output Variables to Changes in Annual Milk Yield Potential [SYMILK]. Method (a).

SYMILK (lt)	5000.	6000.	7000.	8000.	9000.
1.WHTLC(6)(B-Y) (kg lwt)	637.	637.	637.	637.	637.
2.WHTLC(6)(E-Y) (kg lwt)	626.	632.	621.	587.	554.
3.SILGSUR(B-Y) (kg DM)	13690.	13690.	13690.	13690.	13690.
4.SILGSUR(E-Y) (kg DM)	16235.	18678.	19570.	21027.	22896.
5.GRSSURP(E-Y) (kg DM)	1974.	2596.	4476.	5280.	6660.
6.TCONCPR (kg)	24158.	32607.	39114.	44101.	49606.
7.TTCONCW ,,	15569.	22604.	28129.	32317.	36941.
8.EQUITY (pts)	1736561.	1742563.	1734411.	1714161.	1694771.
9.FEEDPR ,,	405857.	547796.	657119.	740899.	833379.
10.FINET ,,	132792.	242716.	364090.	493354.	614331.
11.FFEXPSV ,,	328148.	432070.	561597.	711111.	851478.
12.RHYMLK (lt)	4478.	5374.	6269.	7165.	8061.
13.RAVCPC(pts/cow)	58717.	66140.	75392.	86071.	96097.
14.AVCMLK (pts/lt)	7.151	7.795	7.963	7.889	7.913
15.AFCMLK ,,	10.343	8.619	7.388	6.464	5.746
16.ACMLK ,,	17.494	16.414	15.350	14.354	13.659
17.FFPKM (lt/kg)	2.595	2.307	2.244	2.275	2.275
18.TMLKPRD (lt)	62694.	75232.	87771.	100310.	112849.
19.DMCPLC (kg/cow)	4916.	5204.	5397.	5534.	5633.
20.CCPLC ,,	1112.	1619.	2009.	2308.	2639.
21.FCPLC ,,	3804.	3585.	3387.	3226.	2994.
22.GCPLC ,,	1737.	1668.	1537.	1481.	1384.
23.SCPLC ,,	2067.	1917.	1850.	1745.	1610.
24.TLCOWS (cow)	14.	14.	14.	14.	14.

Assumptions: KSWT3 = 1, KSWT8 = 2, DMIDRY = 12.

3. The profitability of the farm (rows 10 and 11) increases markedly with milk yield potential as we would expect. The financial results shown constitute an underestimation of potential profits which would have increased more than they did had we allowed the stocking rate to vary (row 24 shows the number of lactating cows in the herd).

4. The average variable cost of milk production (row 14) increases with milk potential up to the 7000 lt. level, declining slightly for potentials of 8000 and 9000. This is due undoubtedly to the higher consumption of concentrate with higher yield potentials. The average fixed cost on the other hand (row 15) declines steeply due to a given fixed cost spreading over a much higher total milk production (row 18). The fall in average fixed cost more than compensates for the increase in the average cost of milk production (row 16). The gains in efficiency, as measured by the average cost of milk production, resulting from improvements in the genetic endowment of the dairy cows are obvious.

Table 13-7 shows the result of sensitivity testing for the same parameter, SYMILK, but with the model running under method (b) conditions. In this case body weight maintenance is the biological priority of the cow.

1. Body weight at end of year declines with milk potential

(rows 1 and 2) reaching a bottom not far below the weight at beginning of year. Actual milk yield increases with milk potential (row 25) although the gap between actual and potential yield increases with milk potential (i.e; the difference SYMILK-TYMILK(6)).

2. Grass and silage available at the end of year (rows 4 and 5) decrease with milk potential as the higher energy demand required to produce higher yields is met with an increasing dry matter intake (row 19) and with an increasing consumption of concentrate and forages in the same proportion set by the feeding regime selected for the run (60:40 and 20:80 for the two main feeding seasons) (rows 20 and 21). This is unlike the case before where the stocking rate could only be increased, under this feeding regime, for milk yield potential of 5000, and 6000 lt.

3. As in the case before, profitability of the farm (rows 10 and 11) increases markedly with milk potential. However, unlike in the case before, the results show an underestimation of the profitability of the farm for milk potentials 5000 and 6000 since, as we have already said, the stocking rate could have been increased in those two cases.

4. Average variable cost, and average fixed cost of milk production (rows 14 and 15) decline with the increase in milk potential. Movements in the same direction of both

components of the average costs of milk production result in a corresponding decrease in this later concept (row 16). The patterns for average variable cost when compared to the case before results from an increase in the transformation of concentrate into milk as we can see in row 17.

Table 13-7

Sensitivity of Output Variables to Changes in Annual Milk Yield Potential [SYMILK]. Method (b).

Run#1a	1	2	3	4	5
SYMILK (lt)	5000.	6000.	7000.	8000.	9000.
1.WHTLC(6)(B-Y) (kg lwt)	637.	637.	637.	637.	637.
2.WHTLC(6)(E-Y) (kg DM)	666.	643.	632.	626.	626.
3.SILGSUR(B-Y) (kg DM)	13650.	13650.	13650.	13650.	13650.
4.SILGSUR(E-Y) (kg DM)	17975.	16905.	15917.	14582.	12787.
5.GRSSURP(E-Y) (kg DM)	2685.	1647.	691.	187.	187.
6.TCONCPR (kg)	28660.	29973.	31174.	32290.	33347.
7.TICONCW ,,	19350.	20451.	21459.	22395.	23282.
8.EQUITY (pts)	1763848.	1748518.	1739902.	1736121.	1735297.
9.FEEDPR ,,	481489.	503551.	523725.	542476.	560227.
10.FINET ,,	29972.	190632.	327510.	444004.	541252.
11.FFEXPSV ,,	197682.	373672.	519166.	639442.	737514.
12.RHYMLK (lt)	4206.	4968.	5601.	6128.	6563.
13.RAVCPC(pts/cow)	49398.	61968.	72361.	80592.	87957.
14.AVCMLK(pts/lt)	8.582	7.694	7.150	6.794	6.554
15.AFCMLK ,,	11.010	9.323	8.269	7.558	7.057
16.ACMLK ,,	19.592	17.017	15.419	14.351	13.612
17.FFPKM (lt/kg)	2.055	2.320	2.515	2.657	2.755
18.TMLKPRD (lt)	58889.	69549.	78410.	85791.	91875.
19.DMCPLC (kg/cow)	5008.	5238.	5449.	5647.	5839.
20.CCPLC ,,	1382.	1461.	1533.	1600.	1663.
21.FCPLC ,,	3626.	3777.	3916.	4047.	4176.
22.CGPLC ,,	1650.	1728.	1800.	1868.	1934.
23.SCPLC ,,	1976.	2049.	2116.	2180.	2242.
24.TLCOWS (cow)	14.	14.	14.	14.	14.
25.TYMILK(6) (lt)	4667.	5493.	6120.	6626.	7049.

Assumptions: KSWT3 = 2, KSWT8 = 2, KSWT12 = 2 (60, 20, 0, 0)

DMIDRY = 12.

We can conclude from Tables 13-6 and 13-7 that the model is, as we would expect, rather sensitive to the SYMILK parameter. We have however some other information upon which to base our selection of a value for this parameter. During the period 1977 to 1981, the group of improved dairy farms controlled by the Agencia de Desarrollo Ganadero achieved herd average milk yields between 4011. (for 1977) and 4503. lt. (for 1981) ("Controles en Explotaciones de Vacuno Lechero del Norte y Galicia. Analisis de Resultados 1977-1981, "Agencia de Desarrollo Ganadero, Boletin No 15, Madrid, Septiembre 1982). This seems to indicate that the better farms in Galicia have cows with a genetic potential between 5000 and 6000 lt. per year. The 6000 lt level is the one we would use in remaining sensitivity runs and in the model experimentation runs reported in next chapter.

In Table 13.8 we can see the results of the sensitivity analysis of the parameter TN1. The scaling factor of the dry matter intake equation. TN1 was changed from .9 to 1.15 by .05 intervals. Higher values of TN1 will result in the dry matter equation moving upwards and hence in higher intakes for a given milk yield and weight status. The assumptions under which the runs were made are the same as those holding for the runs reported in Table 13-7 (i.e; under method (b) conditions).

Table 13-8

Sensitivity of Output Variables to Changes in the Scaling Parameter of the Dry Matter Intake Equation.

TN1	.9	.95	1.	1.05	1.10	1.15
1.WHTLC(6)(B-Y)	620.	616.	616.	616.	616.	616.
2.WHTLC(6)(E-Y)	601.	595.	599.	610.	651.	704.
3.SILGSUR(B-Y)	15000.	13737.	13737.	13737.	13737.	13737.
4.SILGSUR(E-Y)	22557.	20420.	19366.	18185.	16793.	13890.
5.GRSSURP(E-Y)	5286.	4334.	3195.	1281.	356.	0.
6.TCONCPR	26092.	27151.	28345.	29617.	31023.	32533.
7.TTCONCW	17213.	18085.	19086.	20153.	21332.	22597.
8.EQUITY	1718828.	1714284.	1717335.	1726636.	1754173.	1789519.
9.FEEDPR	438340.	456134	476189.	497566.	521191.	546551.
10.FINET	-49796.	31767.	117394.	178586.	221149.	261736.
11.FFEXPSV	148146.	231832.	314387.	366298.	381324.	386566.
12.RHYMLK	3962.	4344.	4712.	4955.	5038.	5077.
13.RAVCPC	45917.	51837.	57734.	61442.	62515.	62889.
14.AVCMLK	8.799	8.349	7.963	7.771	7.747	7.762
15.AFCMLK	11.663	10.632	9.801	9.320	9.167	9.097
16.ACMLK	20.462	18.991	17.764	17.091	16.914	16.859
17.FFPKM	---	---	---	---	---	---
18.TMLKPRD	55468.	60813.	65970.	69374.	70531.	71074.
19.DMCPLC	4438.	4632.	4860.	5113.	5407.	5731.
20.CCPLC	1230.	1292.	1363.	1439.	1524.	1614.
21.FCPLC	3208.	3340.	3497.	3673.	3884.	4117.
22.GCPLC	1458.	1528.	1610.	1704.	1816.	1942.
23.SCPLC	1750.	1812.	1886.	1969.	2067.	2175.
24.TLCOWS	14.	14.	14.	14.	14.	14.
25.TYMILK	4235.	4659.	5105.	5479.	5608.	5663.

Assumptions: SYMILK = 6000, KSWT3 = 2, KSWT8 = 2,

KSWT12 = 2 (60, 20, 0, 0), DMIDRY = 11.

The most important observation we can make when looking at Table 13-8 is that the better body weight turnaround (from beginning to end of year) corresponds to the value 1.05. In general the model is quite sensitive to the scaling factor but we have no reason to expect that a location influence which could be incorporated in the scaling parameter would be much higher than 5% above Brown and Chandler's estimate. Also, the 1.05 value results in the better match between the dry matter equation and the other parts of the model (as we can observe by looking at the pattern of change on body weight).

The next sensitivity analysis is concerned with the quality (concentration of ME and CP) of the grass grazed (CMEGSIN and CPTGSIN) by the cows. The composition of the pasture and the assumptions we make about the participation of every species in the pasture are reported in Table 13-9 below:

Table 13-9

Composition and Quality of Improved Pasture

	ME	CP	%	ME	CP
Ryegrass, italian	2.49	242.	25.	.62	60.5
Fescue, meadow	2.31	124.	25.	.57	31.0
Clover, crimson	2.36	170.	25.	.59	42.5
Orchardgrass	2.53	184.	25.	.63	46.0
Pasture:				2.41	180.0

The values in the first two columns of Table 13-9 have been obtained from the NRC document (Table 4) and correspond to the early vegetative state of every species. The assumptions of a stable value throughout the year for both parameters and of an unchanging mix of the different species making up the pasture, represent, we must admit, evidence of ignorance in our part about how the nutritional quality of the grass changes during the year.

In Table 13-10 below we report the results of the sensitivity runs. The parameters CMFGSIN and CPTGSIN were varied from 80. to 120. % of the base values reported in Table 13-9 with the following results:

1. The utilization of grass grazed increases rapidly as the quality of the grass increases (row 5). Total consumption of concentrates decreases (row 6 and 9) although total comsumption of concentrates by cows increases (rows 7 and 20). The reason is that heifers and growing calves on one hand and cows on the other have rations calculated differently. For heifers and growing calves the ratio concentrate:forage in the rations depends on the quality of the concentrate and the forage whose combination must produce a predetermined quality of the ration. As the quality of the forage increases the need for concentrate in order to reach a given ration quality decreases. Cows, on

the other hand, are subjected to the standard feeding regime that we mentioned earlier (60:40 and 20:80 for the two main feeding seasons) so as the quality of the grass grazed increases body weight, as well as milk yield, increases, resulting in an increased dry matter intake. This higher intake, given the rigid feeding regime imposed on the cows, results in a higher consumption of every type of feed by the cows (rows 19 to 22).

Table 13-10

Sensitivity of Output Variables to Changes in
The Quality (ME and CP) of the Pasture Grazed

CMEGSIN	1.930	2.171	2.412	2.635	2.894
CPTGSIN	144.	162.	180.	198.	216.
1.WHTLC(6)(B-Y)	616.	616.	616.	616.	616.
2.WHTLC(6)(E-Y)	595.	601.	610.	643.	685.
3.SILGSUR(B-Y)	13737.	13737.	13737.	13737.	13737.
4.SILGSUR(E-Y)	18579.	18417.	18185.	17817.	17038.
5.GRSSURP(E-Y)	3397.	2808.	1904.	892.	0.
6.TCONCPR	31253.	30568.	29617.	28789.	27684.
7.TTCONCW	20063.	20095.	20153.	20265.	20385.
8.EQUITY	1714697.	1719229.	1726636.	1748710.	1776379.
9.FEEDPR	525044.	513534.	497566.	483652.	465085.
10.FINET	307.	94360.	178586.	242089.	304517.
11.FFEXPSV	199958.	289480.	366298.	407728.	442487.
12.RHYMLK	4473.	4751.	4955.	5010.	5012.
13.RAVCPC	49560.	55955.	61442.	64401.	66884.
14.AVCMLK	9.185	8.431	7.771	7.307	6.817
15.AFCMLK	10.324	9.721	9.320	9.217	9.214
16.ACMLK	19.509	18.151	17.091	16.525	16.030
17.FFPKM	2.004	2.176	2.342	2.437	2.535
18.TMLKPRD	62624.	66515.	69374.	70145.	70174.
19.DMCPLC	5076.	5089.	5113.	5162.	5215.
20.CCPLC	1433.	1435.	1439.	1447.	1456.
21.FCPLC	3643.	3653.	3673.	3714.	3759.
22.GCPLC	1688.	1695.	1704.	1725.	1749.
23.SCPLC	1955.	1960.	1969.	1989.	2010.
24.TLCOWS	14.	14.	14.	14.	14.
25.TYMILK(6)	4878.	5191.	5479.	5554.	5558.

Assumptions: SYMILK = 6000., KSWT3 = 2, KSWT8 = 2,

KSWT12 = 2 (60, 20, 0, 0), DMIDRY = 11.

CMEGSIN = Concentration of ME on Grass Grazed

CPTGSIN = Concentration of CP on Grass Grazed

2. Rolling herd average milk yield as well as total milk production (rows 12 and 18) increase with higher quality of the grass.

3. The financial results are quite sensitive to the quality of the grass (rows 10 and 12), especially net farm income (row 10).

4. Average variable cost and average fixed cost (rows 14 and 15) both drop with increasing grass quality, especially the first, consequently pulling down total average cost (row 16). A noticeable fall of the average variable cost resulted from improved efficiency in the transformation of concentrate into milk as grass quality increases (row 17).

In our model we assume that all grass produced can be consumed by the cows at any time during the year. This implies that this aspect of pasture management is performed as efficiently as possible.

In our last sensitivity analysis we study the implications of variations in grass utilization by the herd. Efficient grass utilization by the dairy herd through grazing depends primarily on the implementation of good rotation practices resulting in the cows eating all grass produced in every plot of pasture. Variations in the grass utilization parameter (TN3) permit us to study the implications of less than perfect pasture handling by the manager.

This sensitivity analysis is performed by attaching a multiplier to equation (8.23) (TN3) and changing its value from 1. to .7 by .1 increments as shown in Table 13-11. The assumptions under which the runs were made are the same that held for the previous sensitivity runs. One important difference with respect to the other runs is that this time we allowed the model to run for two years letting it adjust the herd size to the actual forage production. It is the second year state variables values that we show in Table 13-11.

1. As we would expect, the herd size decreased during the second year with declining grass utilization (row 24). However this declining pattern conceals another inter-annual distinct pattern for TN3 value. With TN3 = 1. herd size increases from 14. in the first year to 15. in the second year. For TN3 = .9 herd size remains stable at its starting value 14. .

Table 13-11

Sensitivity of Output Variables to Changes in Grass Utilization by the Herd [TN3].

TN3	1.	.9	.8	.7
1.WHTLC(6)(B-Y)	653.	644.	644.	644.
2.WHTLC(6)(E-Y)	652.	645.	645.	645.
3.SILGSUR(B-Y)	18100.	11736.	12280.	12841.
4.SILGSUR(E-Y)	13168.	5597.	7056.	8531.
5.GRSSURP(E-Y)	187.	168.	150.	131.
6.TCONCPR	33603.	32244.	30415.	28585.
7.TTCONCW	21840.	20562.	19156.	17750.
8.EQUITY	1634124.	1733729.	1658008.	1582279.
9.FEEDPR	564523.	541705.	510965.	480231.
10.FINET	448568.	257934.	195408.	132823.
11.FFEXPSV	379555.	350668.	285926.	221126.
12.RHYMLK	4688.	4807.	4864.	4931.
13.RAVCPC	58963.	59605.	59079.	58459.
14.AVCMLK	7.436	7.694	7.949	8.238
15.AFCMLK	9.339	9.580	10.013	10.505
16.ACLMK	16.774	17.274	17.961	18.743
17.FFPKM	2.093	2.087	2.079	2.070
18.TMLKPRD	70317.	67301.	63236.	59169.
19.DMCPLC	5229.	5272.	5286.	5303.
20.CCPLC	1456.	1469.	1474.	1479.
21.FCPLC	3773.	3803.	3813.	3824.
22.GCPLC	1731.	1728.	1726.	1724.
23.SCPLC	2042.	2075.	2087.	2100.
24.TLCOWS	15.	14.	13.	12.
25.TYMILK(6)	5499.	5494.	5494.	5493.

Assumptions: SYMILK = 6000, KSWT3 = 2, KSWT8 = 2,

KSWT12 = 2 (60, 20, 0, 0), DMIDRY =12.,

YR = 2., DTCOW(YR=1) = 14.

2. This change in herd size significantly affects financial results (rows 10 and 11) which decline with declining grass utilization. All the average cost concepts increase with declining grass utilization (rows 14, 15 and 16).

3. Rolling herd milk yield average increases with declining grass utilization (row 12). This is caused by the manner in which herd size adjustments take place. Herd increases result by adding cows in 1st lactation, with lower milk yield, which depresses the herd average. Herd decreases result by deleting cows in 1st lactation which result in increasing the herd average.

4. The change in the demographic structure of the herd brought about by changes in grass utilization result in increasing intakes per cow of every type of feed, except grass grazed which falls with declines in grass utilization (rows 19 to 23).

13.3. Final Comments.

We saw that the model is quite sensitive to the particular set of parameters selected. Information from a variety of sources can help us in selecting the value of these parameters that we will use for our experiment runs. That is the case for SYMILK. For others the operation of the model during the sensitivity runs confirms the soundness of the value that we used during model building. That is the case for TN1, the scaling parameter of the dry matter intake equation. Another parameter, TN3, is used to characterize the quality of pasture management by the farmer. More information is required to fix the upper and lower bounds for its range of variation in order to conduct realistic and relevant experiments. For the remaining parameters, CMEGSIN and CPTGSIN, further field research would be undoubtedly required in order to improve our knowledge about how they evolve throughout the year, that would result, most likely, in a major reformulation of subroutine FORAGE.

A major effort involving field research of a type that is described below (see quotation from Bywater and Dent later) must be undertaken to fully validate the NUTIMP subroutine. When building this subroutine we used quantitative information available for the U.S.A. and Canada for Holstein cows. Although the breed used in Galicia is also the Holstein kind there is seemingly a large variation in the performance of Holstein cows developed through selection in different regions of the world. This means that close checking (continual calibration) of the model output with field data coming from research under local conditions and if need arise reestimation of the suspect equations must be made before issuing prescriptions based on model experimentation.

Sufficient validation of a synthetic farm model of the type we have built undoubtedly requires more information than we have available and research we do not have the means to conduct.

Sufficient validation of simulation models of farming systems requires a process exactly opposite to that of validation of models which are built in the image of a particular real system.

When a model is constructed of a real system the final verification test is whether the model is able to generate, with a sufficient approximation, the time series that the real system itself has produced or will be producing under different conditions. That is, the model is required to operate in accord with the real system which itself is observable.

When a model is constructed of a hypothetical situation as opposed to a real system as it is in our case, a sufficient validation can only take place by creating a real system in the image of the model to see how the time series generated by the model and the real system compare.

This last approach has already been taken by some researchers recently. Let us quote A.C.Bywater and J.B.Dent [11].

> "A parallel and important development in this context is the use of small-scale "farmlets" or "system plots" to investigate and evaluate whole production systems. This approach has been used successfully at Ruakura (Hutton and Parker, 1965)and at the Grassland Research Institute, Hurley, where attempts have been made to integrate the field trials with computer simulation models (Brochington, 1973). The application of computer models in an interactive manner with "live" units is the most significant aspect of the approach; this combination may be of mutual benefit to both components and may overcome many of the problems associated with setting up new systems on a commercial scale. The costs are obviously reduced and the planning and control of the systems plot can be effected through the model whilst, in the other direction, there is an excellent oppurtunity for the validation of model mechanisms. For some models, this indeed may be the only possible vehicle for validation; within the farmlet environment close monitoring of various intermediate parameters and components of the model is possible."

In Galicia researchers at the Centro Regional de Investigacion y Desarollo Agrario, are already using the farmlet or whole system approach in their investigations (Ramon Gonzalez Santillana, Antonio Gonzalez Arraez and Maria de los Angeles Barrecheguren [32]. Combination of this whole systems research with the dairy/forage system model would result in increasing the number of factors included in any particular investigation, in improved validation, and enhanced reliability of the model.

Validation and verification are not the only test that a simulation model is required to pass. For some authors, (G.L.Johnson and G.E. Rossmiller [41], T.Manestch [48]) two other tests must be passed in order for the model to gain enough credibility. The first one is clarity which implies in words of G.L.Johnson and G.E.Rossmiller:

> "The model's concepts and theories must be explainable and understandable to those who use them if they are to be accepted; scientifically. They must be clear and unambiguous before the tests of coherence and correspondence can be applied."

We have passed the clarity test sufficiently well and conducted at least some coherence and correspondence tests.

The last test to be passed by any model is the workability test. Again in the words of Johnson and Rossmiller [41]:

> "The workability test evaluates the prescriptions based on the model in terms of how well they perform in the real world, judged by the good results achieved and bad consequences avoided. Simply stated, the workability test requires that models help solve problems of real-world decision makers, not just answer positive and normative question of disciplinarians or other curious people. Thus workability is a test of the model's prescriptive ability."

We should add that the workability test is passed if the prescriptive ability of the model is superior to that of alternative and available analytical tools, account taken of the cost implied in their respective development.

It is clear that the actual status of the dairy/forage simulation model here reported is far from that ideal status of model credibility which is gained through having: "suficiently" passed the verification, validation, clarity, and workability test. We can only say that the model operates with "enough" (a subjective judgment) internal consistency and "apparent" correspondence with reality.

It allows, as we will see in the next chapter, a variety of analyses to be conducted which cannot at present be done in any other way.

Finally, we must recognize that gaining credibility is an iterative process, never ending, which involves testing, field research, new data collection, model reformulations, new testing and so on. What we reported in this Chapter is a first pass, incomplete, through the credibility checking loop.

PART III

MODEL EXPERIMENTS AND CONCLUSIONS

CHAPTER 14

Analysis and Experiments with the Model

The model experimentation stage of the simulation modelling approach follows logically the model validation and verification phase. Putting aside the fact that many questions remain about whether sufficient validation of the present model has been achieved, we proceed in this chapter to report and comment on a series of experimentation runs conducted on the model. This will indicate the model's range of application.

The multiplicity of controllable and uncontrollable inputs, parameters and output variables involved and generated by a simulation model such as this makes experimentation on the model a rather arduous task. The complexity of the simulation model, which attempts to match and replicate the complexity of real systems, allows, unlike other types of methods, many types of experiments to be conducted, from simple exploratory runs to optimizing or quasi-optimizing analysis.

Following A.Wright [79] we can distinguish four types of experimentation schemes for deterministic simulation models. These are:

(a) To compare alternative courses of action or decision rules.
(b) To estimate the response of the system to changes in the level of one input or a set of inputs.
(c) To explore the response surface generated by different combinations of input levels.
(d) To estimate the input combination required for an optimal or near optimal level of output.

In Chapter 5 we stated our research objectives in terms of the types of analysis that the model would be able to handle and the types of questions upon which model experimentation would be able to shed some light. This chapter attempts to meet these research and analysis expectations with actual experiments on the model.

In the next five sections completing this chapter we will: First (section 14.1), state our assumptions concerning critical parameters and initial values of state variables. Second (section 14.2), we will show the results of a set of short term management practices involving decision rules such as scheduling of calving and conservation policies, and four alternative feeding rules that the manager may adopt. Third (section 14.3), we will replicate the best of the four runs for different feeding rules under a different set of input and output prices and proceed to compare the results with those obtained in the second section. Fourth (section 14.4), we report the results of several farm growth analysis made under different resource bases. The analysis reported in the fourth section constitute an assessment of the credit program of the Agencia de Desarrollo Ganadero. In the last section (section 14.5) we briefly summarize results.

14.1. Assumptions.

The basic parameters and initial levels of state variables are collected in the tables of Appendix 2. These come from a variety of spanish sources, mainly reports and articles produced by the staff of the Galician experimental station (Centro Regional de Investigacion y Desarrollo Agrario N-1) which has been working on the development of improved dairy farming systems and improvement of pasture land for the last 10 or 15 years. Other data come from the relevant literature on dairy systems, the NRC document, the diagnostic study of the Agencia de Desarrollo Ganadero and finally reasonable assumption on our part, as for instance the value assumed for the annual milk potential parameter (SYMILK).

The concentration of metabolic energy (ME) and crude protein (CP) in the commercial dairy feed-mix available to the dairy cattle can be seen in Table 14-1.

Concerning the yield data, we have used information contained in R. Gonzalez Santillana & A. Gonzalez Arraez [31], R. Gonzalez Santillana, A. Gonzalez Arraez and M. de los Angeles Barrecheguren [32], Jaime Lloveras Vilamanya [44]. Data on the yield build-up process on developed bushland ("monte") come from a series of papers produced by F. Sineiro and others which are published in the annual reports of the CRIDA-01, at La Coruna (years 1977-1981). These data are shown in Table A2-2, Appendix 1. Only one point on each yield-fertilizer functions was available which makes it impossible to make experimental runs with a varying fertilizer application rate. The relevant data are also contained in Table A2-2.

Table 14-1

Concentration of ME and CP in commercial concentrates fed to dairy animals, Galicia, Spain, circa 1980-83.

Composition of ration: Dairy feed-mix

Feed	(1) Percent	(2) ME(Mcal/kgDM)	(3) CP/gr/kgDM
Barley	20.	3.24	139.
Corn	55.	3.47	100.
Soybean meal	10.	3.15	518.
Sunflower meal	10.	2.67	441.
Urea	.5	--	--
Other feeds, Minerals, and Vitamins	4.5	--	--
Feed-Mix		3.13 - 3.28	178-187

Source:

Column(1): E.W.F. Peterson, A. Pelach Paniker, H.M. Riley, V.L. Sorenson. "Spain's Entry into the European Community. Effects on the Feed Grain and Livestock Sector." April 1983, Foreign Agricultural Econ. Rep 180, ERS, USDA.

Column(2): NRC # 3 Nutrient Requirements of Dairy Cattle. 1978. Table 4.

Data on prices and costs, which refer to the period 1979-1980, come from several sources too: The diagnostic study of the Agencia de Desarrollo Ganadero, Jaime Llovera's article, and statistical yearbooks produced by the Spanish Ministry of Agriculture and the report produced by E.W.F. Peterson, A. Pelack Paniker et al ("Spain's Entry into the European Community. Effects on the Feed Grain and Livestock Sectors.") for the USDA.

For the short-term experiments reported in sections 14.2. and 14.3. next, we assumed a 8 hectares dairy farm with 1.28

hectares of cropland and the rest of pasture planted with the mixture of species reported in Table 13-9. Since data on the value of farmland of different values were not available we did not include farmland in the computation of the net worth statement. We also assume that total liabilities amount to 80% of total assets (parameter OMEGA in Table A2-4). We consider two sets of prices for milk and concentrate These two sets of prices attempt to represent the market situation facing the farmer under the In-EEC or Out-EEC scenarios developed by E.W.F. Peterson , A. Pelach Paniker et al. in their analysis. The market situation since these last two authors did their analysis has changed quite drastically due to changes in the Spanish exchange rate with respect to other EEC countries currencies which makes any inference based on these assumptions no longer relevant. The two scenarios are retained, however, since we do not have other alternative scenarios available and because our main goal is to show how the model operates under varying setups.

For the farm growth analysis reported in section 14.3. we study three farm sizes: 8, 12 and 16 hectares, with 1.28 ha of cropland, 1.72 ha of artificial pasture and the rest bushland to be developed during the farm growth process. In Chapter 2 we saw (Table 2-7) that the average farm in Galicia had also about half an hectare of irrigated pasture (about 6% of total hectareage). We excluded this typè of land resource in our analysis since we were not able, for lack of information, to develop seasonal yield curves for irrigated land. The small size of the irrigated area makes the omission, in our opinion, tolerable. However, this aspect of the model should be remedied since irrigation may constitute the most desirable avenue for further farm expansion. We also assume that labor requirements will be met by the farmer and his family and that the basic investment, except for those strictly related to the number of hectares or cows, is the same for all three farm sizes.

Investments for farm development are financed with loans taken under Agencia de Desarrollo Agraria conditions, that is, a 3 year grace period, 12 year loan lenght, 80% financing of total investment, and 13% interest rates. We further assume that purchases of dairy cows after the first year are financed with 3 year loans with a rate of interest of 17% . Annual loans at 20% cover any cash-flow deficit during the development process. We account for inflation, which we may assume will be 10% annually, by deflating the monetary interest rate. This means that the real interest rates considered in the analysis will be 3%, 7% and 10% for long-, medium-, and short-term loans respectively. We also assume a minimum cOnsumption withdrawal of 150,000 pts per year (about $ 1,000, if we use an exchange rate of $1 = 150 pts).

Farmland value is excluded from the computation of the net worth statement because we do not have information on the values of the different types of land. This omission will certainly result in a major underestimation of the profitability of the investment since the upgrading process of bushland will result in a conversion of land with low value into land with high value and this gain in the market value of the land assets will not show up in the value of the project at the end of the planning period. Thus it might happen that investments that would not be profitable had we only considered the stream of annual returns they yield, would be very profitable had we accounted, in addition of that stream of returns, for the increase of assets during the project. As we will see later (section 14.4) the profitability of the investment, even omitting the appreciation of the land base, is very high. However, data on land values should be collected and fed into the model in order to assess growth strategies under more stringent output and input prices and credit conditions.

14.2. Short-Term Management Experiments.

In this section, we first (subsection 14.2.1) report on the calving scheduling experiment, second (subsection 14.2.2.) we examine alternative forage storage policies, and third (subsection 14.2.3.) we report results of the feeding rule experiment.

14.2.1. Calving Scheduling Experiment.

Deciding when to breed the cows may have a major impact on profitability of the farm. As noted several times before, the short-term management problem of the dairy farmer in Galicia is matching feed requirements, which depend on the production/reproduction cycle of the herd, to feed supply which depends on the seasonal pattern of grass production and on the forage storage policy adopted by the farmer. Accordingly a two-step experiment was designed. In the first step, two alternative calving seasons are considered: (a) Births taking place in winter, that is from mid January to mid February; (b) Births occurring during the fall, from mid October to mid November. In case (a) the average birth time fell in the third week of January, approximatively, in case (b) the average birth time fell in the third week of October. The second step consists in choosing, once we have decided on the best calving season, the best average birth time within that season.

The model was run under method (a) conditions (described together with method (b) conditions in Chapter 10, subsection 10.1.1. and Figure 10-2), that is biological priority was milk production and the feeding rule was to feed a ration with NRC recommended ME and CP concentration. Brown & Chandler dry matter intake equation was also activated (KSWT8 = 2) and the cows received 12Kg DM per head during the dry period (DMIDRY = 12).

We will assess the experiments on the basis of the same set of state and output variables selected in our validation analysis (Table 13-5, shows the variable definitions). The results of the analysis can be seen in Table 14-2, below.

The model is set to run with winter or fall births by the switch KSWTPRG taking the value 1 or 2 respectively. Comments on the results in Table 14-2 follow:

(i) Row 8. The level of equity is higher in case (b) than in case (a). The reason for that is that the size of the dairy herd at end of year is, due to the different birthing schedule, larger in case (b) than in case (a)

(ii) Rows 10 & 11. Net Farm Income is slightly higher for case (b) than for case (a). However the converse is true for the cash flow residual earned by the farmer which is 14% higher for case (a).

(iii) Rows 12 & 18. Herd yield average and total milk production are higher in case (b) than in case (a). This is explained by the fact that case (a) is made up of a single lactation cycle with a stable herd structure and case (b) is made up of approximately 2/3 of a lactation cycle and 1/3 of another with the herd structure changing between cycles.

(iv) Rows 13 to 16. All these criteria show a definite superiority for case (a). Returns above variable cost per cow are higher and all cost measures are lower for case (a) as compared to case (b).

Equity is higher in case (b) than in case (a) due to the lag in the calving schedule between the two cases. In case (a), at the end of the year when accounting is made, the size of the herd is at the lowest level it can reach since cows that failed to get pregnant were sold at the end of lactation and replacement heifers will be acquired the following year. In case (b) at the end of the year, the cows that failed to get pregnant are still in full lactation, so the size of the herd is at its highest level. Had accounting been made at the end of the lactation cycle in both cases the level of equity would have been very similar.

Table 14-2

Results of the Calving Scheduling Experiment. Step 1.

Output Variable *	KSWTPRG = 1 Winter Births (a)	KSWTPRG = 2 Fall Births (b)
1. WHTLC(6) (B-Y)	635.	574.
2. WHTLC(6) (E-Y)	632.	559.
3. SILGSUR (B-Y)	15000.	15000.
4. SILGSUR (E-Y)	13942.	15909.
5. GRSSURP (E-Y)	187.	187.
6. TCOWCPR	33889.	31469.
7. TTCOWCW	23601.	23362.
8. EQUITY	1907820.	2244073.
9. FEEDPR	569341.	528678.
10. FINET	426781.	439901.
11. FFEXPSV	585279.	501985.
12. RHYMLK	5161.	5263.
13. RAVCPC	67448.	64166.
14. AVCMLK	7.054	7.835
15. AFCMLK	8.027	8.868
16. ACMLK	15.081	16.703
17. FFPKM	2.437	2.676
18. TMLKPRD	82579.	84212.
19. DMCPLC	5120.	5227.
20. CCPLC	1475.	1460.
21. FCPLC	3644.	3766.
22. GCPLC	1685.	1729.
23. SCPLC	1959.	2038.
24. TLCOWS	16.	16.
25. TYMILK(6)	6000.	6000.

Assumptions: KSWT3 = 1, KSWT8 = 2, DMIDRY = 12.

* Definition of Output Variables to be found in Table 13-5

In summary, the results from the experiment seem to indicate that scheduling births during the winter season will result in enhanced profitability of the farm.

In the second step of the experiment season two mean pregnancy times were selected for the winter calving season: (a) NTPRG = 17, this implied births taking place in mid February; (b) NTPRG = 13, which resulted in births occurring at mid January.

There is a major reason why we should expect significant changes in performance in this experiment. The heaviest consumption of concentrates takes place in the period between parturition time and the onset of grazing, since this is the time at which energy requirements for milk production are highest. During this period the cows are fed a mixture of concentrate and silage. This latter having a rather low ME and CP content. By changing the time cows are bred, which will determine consequently calving time (see Figure 9-1), we reduce or increase the length of this critical period, which is shorter for case (a) than case (b), and consequently the consumption of concentrates.

Two experimental runs were made under method (a) conditions (i.e., biological priority is milk production) and the model was allowed to run for 3 years so that we would see how the stocking rate would eventually adjust.

The results of the experiment are presented in Table 14-3.

Our comments and interpretation follow:

(i) Rows 3 & 4. Silage carryover remains stable during the three year period for both runs. However this stability is obtained with a declining stocking rate in the 3rd year (row 24).

(ii) Rows 6, 7, 9 & 20. Although total concentrate purchase is higher overall, in case (a) than in case (b), this is because the stocking rate in case (a) is higher than in case (b) during the 3rd year. Concentrate consumption per cow (row 20) is lower in case (a) than (b).

(iii) Row 8. Net worth is higher in case (a) than in (b). Again, this is due to the fact that the stocking rate is higher in case (a) at the end of the 3rd year.

(iv) Rows 10 & 11. Farm net income and cash flow are, for the same reasons mentioned above, higher for case (a) than case (b).

(v) Rows 12 & 18. Total milk production is higher in case (a) than (b), especially during the 3rd year. Rolling herd yield milk average is similar in both cases except during the 3rd year for which it is higher in case (b) than in (a). The reason for this is that the smaller herd in case (b) has a higher average age than in case (a) (we know that mean age of the herd is, ceteris paribus, positively related to rolling herd milk yield average).

(vi) Rows 13 to 16. Returns above variable cost per cow are similar in both cases except for the 3rd year when they are substantially higher in case (b) than in case (a). This is related to the higher average age of the cow in case (b) that we mentioned above. The average cost of milk production is lower, during the 3 years, and for the same reasons, in case (b) than in case (a). However the average fixed cost is lower in case (a) and this makes the total average cost of milk production lower in case (a) than in case (b).

Table 14-3

Results of Calving Scheduling Experiments.
Step 2. NTPRG = 17.

Output Variable *	Year 1	Year 2	Year 3
1. WHTLC(6) (B-Y)	635.	615.	615.
2. WHTLC(6) (E-Y)	615.	615.	612.
3. SILGSUR (B-Y)	15000.	18254.	14833.
4. SILGSUR (E-Y)	18254.	14833.	15550.
5. GRSSURP (E-Y)	635.	437.	437.
6. TCONCPR	32361.	31486.	29728.
7. TTCONCW	22463.	20743.	19339.
8. EQUITY	1799805.	1681893.	1597206.
9. FEEDPR	543665.	528969.	499434.
10. FINET	324149.	493076.	263831.
11. FFEXPSV	523463.	508084.	424181.
12. RHYMLK	5260.	5078.	5076.
13. RAVCPC	67823.	66886.	68764.
14. AVCMLK	7.220	6.830	6.640
15. AFCMLK	8.309	8.565	8.893
16. ACMLK	15.529	15.395	15.533
17. FFPKM	3.513	3.672	3.675
18. TMLKPRD	78906.	76173.	71071.
19. DMCPLC	5168.	5095.	5125.
20. CCPLC	1498.	1383.	1381.
21. FCPLC	3670.	3712.	3743.
22. GCPLC	1897.	1958.	1964.
23. SCPLC	1773.	1755.	1780.
24. TLCOWS	15.	15.	14.
25. TYMLKLC(6)	6000.	6000.	6000.

Assumption: KSWT3 = 1, DMIDRY = 12.

* Definitions of Output Variables to be found in Table 13-5

Table 14-3a

Results of Calving Scheduling Experiments.
Step 2. NTPRG = 13.

Output Variable *	Year 1	Year 2	Year 3
1. WHTLC(6) (B-Y).	635.	639.	637.
2. WHTLC(6) (E-Y)	639.	637.	637.
3. SILGSUR (B-Y)	15000.	18050.	12833.
4. SILGSUR (E-Y)	18050.	12833.	16065.
5. GRSSURP (E-Y)	437.	437.	437.
6. TCONCPR	31762.	32472.	28976.
7. TTCONCW	22080.	20877.	18358.
8. EQUITY	1833709.	1715327.	1548151.
9. FEEDPR	533596.	545530.	486797.
10. FINET	368154.	485165.	163870.
11. FFEXPSV	533564.	504711.	410723.
12. RHYMLK	5260.	5078.	5184.
13. RAVCPC	68497.	66661.	73018.
14. AVCMLK	7.092	6.874	6.149
15. AFCMLK	8.309	8.619	9.438
16. ACMLK	15.401	15.493	15.587
17. FFPKM	3.574	3.649	3.671
18. TMLKPRD	78906.	76173.	67398.
19. DMCPLC	5159.	5139.	5222.
20. CCPLC	1472.	1392.	1412.
21. FCPLC	3687.	3748.	3810.
22. GCPLC	2026.	2045.	2082.
23. SCPLC	1661.	1702.	1728.
24. TLCOWS	15.	15.	13.
25. TYMLKLC(6)	6000.	6000.	6000.

Assumptions: KSWT3 = 1, DMIDRY = 12.

*Definitions of Output Variables to be found in Table 13-5

In summary, we may conclude that as the average birth time approachs the onset of grazing thereby shortening that first critical feeding period, enhanced returns for the farmer will result.

14.2.2. Forage Storage Rule Experiment.

Our next experiment focuses on a search, by no means exhaustive, for the best forage storage program. By storage program we mean the proportion of land withdraw for silage production during the three silage periods that the model considers. Five runs were made with the silage proportion ranging from .45 to .65 and the model was again allowed to run for three years which allowed the stocking rate to adjust. As in the last experiment the model was run under method (a) (milk production, is the biological priority) conditions.

We can see in Table 14-4 the results of the experiments which we now discuss:

(i) Row 2. Total concentrate consumption by cows increases, slighty, as the silage proportion increases. The increase in concentrate consumption per cow is steeper as the silage proportion increases (row 3).

(ii) Row 4. The stocking rate decreases during the third year as the silage proportion increases. One exception to that tendency is run (2) where the stocking rate increases the second year and then falls the 3rd year to the level of run (1)

(iii) Row 6. Total milk production decreases as the silage proportion increases. An exception is again run (2) which yields the highest total milk production for the three years.

(iv) Row 7. Net worth decreases with increases in the silage proportion. This fall in equity at end of 3rd year is related to the lower stocking rate achieved with higher silage proportions.

(v) Row 8. Cash flow declines quite substantially with increases in the silage proportion. The reason for that decline is double: (a) lower stocking rates with increasing silage proportion; (b) higher operating costs with increasing silage proportion.

(vi) Row 9. For the reasons outlined in (v) average total cost of milk production increases with higher silage proportions.

In summary, we may conclude that for a 8 ha farm with the given structure of land assets, withdrawing 45% of pastureland for silage production during the three silage season seems to be a reasonable course of action.

The results obtained in this experiment must be subjected to a double qualification. First, we saw that the best results were achieved for the value of the silage proportion parameter (PRPAT#) equal to the lowest bound of the range selected for the experiment. This suggest that perhaps lower values of the parameter may have resulted in still better performance. Second, we maintained in the experiments the same silage proportion for the three silage cutting periods. Again, setting the silage proportion at different levels, which the model allows, for the three silage cutting periods may result in enhanced performance.

Table 14-4

Forage Storage Program Experiment

Output Variable *	Year	(1) .45	(2) .50	(3) .55	(4) .60	(5) .65
		Proportion of Pasture Conserved for Silage (PRPAT#)				
1.	1	18672.	17733.	17206.	16752.	16205.
SILGSUR(E-Y)	2	13951.	8790.	11686.	10707.	13802.
	3	13493.	10120.	14492.	12970.	15508.
2.	1	22017.	22879.	23021.	23154.	23277.
TTCONCW	2	20730.	21713.	21127.	21260.	21383.
	3	18751.	20373.	18548.	18660.	18775.
3.	1	1468.	1525.	1535.	1544.	1552.
CCPLC	2	1382.	1357.	1408.	1417.	1426.
	3	1339.	1455.	1427.	1436.	1444.
4.	1	15.	15.	15.	15.	15.
TLCOWS	2	15.	16.	15.	15.	15.
	3	14.	14.	13.	13.	13.
5.	1	5260.	5260.	5260.	5260.	5260.
RHYMLK	2	5078.	4990.	5078.	5078.	5078.
	3	5076.	5121.	5184.	5184.	5184.
6.	1	78906.	78906.	78906.	78906.	78906.
TMLKPRD	2	76173.	79846.	76173.	76173.	76173.
	3	71071.	71694.	67398.	67398.	67398.
7.EQUITY	1	1666330.	1578871.	1585035.	1585019.	1585019.
8.	1	543675.	515508.	503618.	491952.	480555.
FFEXPSV	2	517298.	559768.	489225.	477171.	465417.
	3	453634.	411575.	397328.	385653.	374247.
9.	1	15.283	15.640	15.790	15.938	16.083
ACMLK	2	15.338	14.985	15.703	15.861	16.015
	3	15.187	15.545	15.796	15.969	16.138

Assumptions: KSWT3 = 1, KSWT8 = 8.

* Definitions of Output Variable to be found in Table 13-5

14.2.3. Feeding Rule Experiment.

Our next series of experiments constitute an assessment of four types of feeding rules and for each feeding rule we also search for the best combination of forage and concentrate to feed the cows. Let us recall that we divided the year into several distinct feeding periods according to the availability of the different types of forage (silage or grass) and the biological status of the cows. The first period goes from parturition to the beginning of the first grazing season, the second period goes the length of the first grazing season, the third period goes from the end of the first grazing season to the beginning of the second grazing season. The fourth and last period goes from the beginning of the second grazing season to the next parturition time the following year. Let's now describe the four feeding rules that we evaluated in our experiments:

(I) Fixed concentrate amount feeding rule. This rule consists in feeding fixed amounts of concentrate to each cow, regardless of lactation number and weight, during each feeding period, the rest of the ration being forage.

(II) Proportional feeding rule. Under this rule cows are fed a ration made up of concentrate and forage in a fixed proportion, although different for each feeding period, of dry matter intake. Again the rations thus defined will be given to cows regardeless of their lactation number.

(III) Fixed milk/concentrate ratio feeding rule. Under this rule cows are fed concentrates according to their milk yield during the lactation curve. The milk/concentrate ratios are constant during every feeding period but are changed between feeding periods.

(IV) Recommended ME concentration feeding rule. Under this rule cows are fed rations containing a given proportion (fixed during the year) of the NRC recommended concentration of ME on ration. Following this rule cows are given rations with an energy content that fits their production and biological status over the production cycle. However, they may get more or less energy according to whether they are fed rations containing more than or less than 100% of the NRC recommended concentration of ME in the ration.

In all of the four series of experiments outlined above we run the model for three years in order for the stocking rate to settle down. We judged the feeding rule and the particular input combination that were best for each feeding rule on the basis of the present value of the investment as it was defined in equation (12.90).

More detail for each of the experiments outlined follows:

(I) We made two sets of nine trials with the values for the concentrate amounts fed to cows during each feeding season that are shown in Table 14-5 below. The results are shown in Table 14-6. The best feeding combination among those tested is, as we can observe in Table 14-6, the 7th trial of experiment Ib. The best concentrate feeding combination is then 6., 4.1, 1, and 0. kg of concentrate per cow during each of the four feeding periods that we described at the beginning of this subsection.

Table 14-5

Characteristics of First Feeding Rule Experiment.

	CINPLC1 (I) Concent.fed 1st season		CINPLC2 (I) Concent.fed 2nd season		CINPLC3 (I) Concent.fed 3rd season		CINPLC0 (I) Concent.fed 4th season	
Trial #	Ia	Ib	Ia	Ib	Ia	Ib	Ia	Ib
	(kg DM/cow)							
1	3.	3.	2.4	2.3	1.	1.	0.	0.
2	3.5	3.5	2.8	2.6	1.	1.	0.	0.
3	4.	4.	3.2	2.9	1.	1.	0.	0.
4	4.5	4.5	3.6	3.2	1.	1.	0.	0.
5	5.	5.	4.0	3.5	1.	1.	0.	0.
6	5.5	5.5	4.4	3.8	1.	1.	0.	0.
7	6.	6.	4.8	4.1	1.	1.	0.	0.
8	6.5	6.5	5.2	4.3	1.	1.	0.	0.
9	7.	7.	5.6	4.6	1.	1.	0.	0.

Table 14-6

Results of First Feeding Rule Experiment

	Present Value of Investment	
Trial #	Ia	Ib
	(000 pts)	
1	2249.7	2250.7
2	2251.5	2252.5
3	2228.3	2242.2
4	2230.4	2245.7
5	2233.2	2248.9
6	2256.5	2284.8
7	2246.7	2285.6
8	2253.3	2278.6
9	2234.1	2274.8

Table 14.7 shows the performance of the model corresponding to the conditions set for the seventh trial of run Ib. We can make the following observations:

(i) With the proposed feeding rule cows increase their dry matter intake and become heavier (rows 17 and 1). Since the amounts of concentrate per cow are fixed throughout the year the consumption of forage increases. This produces two results: (a) the stocking rate decreases (row 11); (b) there arise during the year forage (especially silage) deficits which are bridged with increased use of concentrates (row 18).

(ii) For the reasons outlined above we note that the model increased purchases of concentrates (rows 2, 3, and 7) and shows declining net worth, farm net income and cash flow (rows 6, 8 and 9) from the first to the third year.

(iii) Rolling herd milk yield average (row 12) increases for two reasons: An increased consumption of concentrates and a herd with a higher average age.

Table 14-7

First Feeding rule (Trial Ib-7) Detailed Results

Variable *	Year 1	Year 2	Year 3
1. WHTLC(6) (E-Y)	634.	649.	673.
2. TCONCPR	20125.	23267.	25280.
3. TTCONCW	13392.	15548.	17220.
4. TYMILK(6)	4962.	5142.	5341.
5. SILGSUR (E-Y)	9252.	5438.	9254.
6. EQUITY (000 pts)	1868.1	1775.3	1698.8
7. FEEDPR (000 pts)	338.1	390.9	424.7
8. FINET (000 pts)	356.3	345.5	186.4
9. FFEXPSV (000 pts)	526.7	434.0	365.5
10. TMLKPRD	67676.	64046.	60755.
11. TLCOWS	15.	14.	13.
12. RHYMLK	4512.	4575.	4673.
13. RAVCPC (000 pts)	68.0	65.6	66.5
14. AVCMLK	5.167	5.804	6.050
15. AFCMLK	9.699	10.077	10.213
16. ACMLK	14.866	15.881	16.263
17. DMCPLC	5135.	5168.	5264.
18. CCPLC	893.	1111.	1325.

PRESWTH = 2285.6 (000 pts)

Assumptions: Interest Rates = .12, .17, .20
Discount Rate (RI) = .12
Milk Price = 19.3 (pts/kg)
Concentrate Price = 16.8 (pts/kg)

* Definitions of Output Variables to be found in Table 13-5

In summary, we can see that feeding the cows without taking into account their particular characteristics results in a likely wasteful consumption of concentrates that are converted into body weight which probably results in lower returns than would otherwise be obtained.

(II) This experiment consisted of two sets of 8 trials whose values for the variables (CPCINL#) are shown in Table 14-8 below. As we see in Table 14-9 the 3rd trial of the experiment IIa yields the best results. This corresponds to the feeding regime 42., 22., 0., 0. for the four feeding seasons, meaning a 42% of the daily dry matter intake in season 1 is made up of concentrates, 22% of daily dry matter intake in season 2 is made up of concentrate, etc.

Table 14-8

Characteristics of Second Feeding Rule Experiment

Trial #	CPCINL1 % of Concent.fed 1st season		CPCINL2 % of Concent.fed 2nd season		CPCINL3 % of Concent.fed 3rd season		CPCINL0 % of Concent.fed 4th season	
	IIa	IIb	IIa	IIb	IIa	IIb	IIa	IIb
1	34.	34.	18.	18.	0.	15.	0.	0.
2	38.	38.	20.	20.	0.	15.	0.	0.
3	42.	42.	22.	32.	0.	15.	0.	0.
4	46.	46.	24.	24.	0.	15.	0.	0.
5	50.	50.	26.	26.	0.	15.	0.	0.
6	54.	54.	28.	28.	0.	15.	0.	0.
7.	58.	58.	30.	30.	0.	15.	0.	0.
8.	62.	62.	32.	32.	0.	15.	0.	0.

Table 14-9

Results of Second Feeding Rule Experiment

Trial #	Present Value of Investment IIa	IIb
	-------- (000 pts)	--------
1	2272.9	2179.4
2	2274.7	2170.7
3	2276.4	2172.8
4	2266.1	2174.9
5	2267.9	2177.1
6	2269.7	2167.9
7	2271.5	2170.1
8	2273.3	2172.2

In Table 14-10 we can see in more detail the results produced by the best trial run of the experiment. Let's briefly comment those results:

(i) The model behaves very similarly to experiment I. Cows become heavier (row 1), consequently increasing their dry matter intake (row 17) from the 1st to the second year. The same two results, basically for the same reasons en sue here too.

(ii) The stocking rate declines further in this experiment (row 11) during the 3rd year

(iii) Once the model settles down in the 3rd year we have a consumption of concentrates twice as high as the 1st year. This fact coupled with the fall in the stocking rate results in a 32% fall in cash flow between the 1st and 3rd year.

(iv) Both experiments I and II yield basically the same present value of investment making it difficult to decide between them. In any case, the same criticism leveled against the feeding rule I can be made of feeding rule II.

Table 14-10

Detailed Results of Best Run of Second Feeding Rule

Variable *	Year 1	Year 2	Year 3
1. WHTLC(6) (E-Y)	630.	658.	674.
2. TCONCPR	14412.	22750.	19953.
3. TTCONCW	7814.	14438.	12477.
4. TYMILK(6)	4705.	5240.	5163.
5. SILGSUR (E-Y)	5030.	5522.	10019.
6. EQUITY (000 pts)	--	--	--
7. FEEDPR (000 pts)	242.1	382.2	335.2
8. FINET (000 pts)	375.9	227.1	154.9
9. FFEXPSV (000 pts)	550.3	389.1	370.1
10. TMLKPRD	64177.	61314.	55013.
11. TLCOWS	15.	13.	12.
12. RHYMLK	4278.	4716.	4584.
13. RAVCPC (000 pts)	69.6	66.3	69.2
14. AVCMLK	4.029	6.120	5.238
15. AFCMLK	10.228	10.332	10.971
16. ACMLK	14.257	16.453	16.209
17. DMCPLC	5112.	5234.	5270.
18. CCPLC	521.	1111.	1040.

PRESWTH = 2276.4 (000 pts)

Assumptions: Interest Rates = .12, .17, .20
Discount Rate (RI) = .12
Milk Price = 19.3 (pts/kg)
Concentrate Price = 16.8 (pts/kg)

* Definitions of Output Variables to be found in Table 13-5

(III) This third experiment consisted of a set of 9 trials. The experimental design can be seen in Table 14-11. Under this feeding rule cows are given concentrate as a function of their milk production. The milk/concentrate ratio is changed every feeding season since the forage available in each feeding season is of different quality. In Table 14-12 we can see that the ninth trial of the experiment yields the highest value of the performance variable. The best concentrate combination indicates that cows should be given 1 kg of concentrate for every 2.3 kg of milk in the first season, 1 kg of concentrate for every 3.0 of milk in the 2nd season, etc.

In Table 14-13 we can take a more detailed look at the best run of experiment III. According to that table we can make the following observations.

(i) Cows get very heavy (row 1), more so than in the two experiments before. Since dry matter intake depends on weight of animals we see dry matter intake increasing very much between the 1st and the 3 rd year (row 17).

(ii) This feeding rule imposes a heavy consumption of concentrate per cow (row 18) which frees enough forage for the stocking rate to rise (row 11).

(iii) Despite the higher stocking rate, when we compare experiment III to experiments I and II, and the higher milk production, overall returns (row 8, 9, 13) are lower for this experiment than for the two others. Seemingly too much concentrate is given. In simple production economics terms we can say that the marginal value product of the concentrate is lower than its cost making it profitable to reduce its use. However the trial which is best is the one making the heaviest use of concentrate. This indicates that the problem resides in the particular allocation of concentrate during the year implied by this particular feeding rule.

In summary, when we compare this feeding rule with the two previous ones we find it inferior despite the fact that it results in higher stocking rates and higher milk production.

Table 14-11

Characteristics of Third Feeding Rule Experiment
(Kilograms of Milk per Kilograms of Concentrate)

Trial #	1st season	2nd season	3rd season	4th season
1	3.1	3.8	3.	7.
2	3.	3.7	3.	7.
3	2.9	3.6	3.	7.
4	2.8	3.5	3.	7.
5	2.7	3.4	3.	7.
6	2.6	3.3	3.	7.
7	2.5	3.2	3.	7.
8	2.4	3.1	3.	7.
9	2.3	3.0	3.	7.

Table 14-12

Results of Third Feeding Rule Experiment

Trial #	Present Value of Investment
	(000 pts)
1	2082.6
2	2088.1
3	2093.0
4	2090.0
5	2123.0
6	2124.9
7	2122.4
8	2120.5
9	2141.9

Table 14-13

Detailed Results of Best Run of Third Feeding Rule

Variable *	Year 1	Year 2	Year 3
1. WHTLC(6) (E-Y)	690.	721.	744.
2. TCONCPR	35430.	37502.	34177.
3. TTCONCW	25200.	25216.	22717.
4. TYMILK(6)	5620.	5556.	5555.
5. SILGSUR (E-Y)	17571.	13301.	12355.
6. EQUITY (000 pts)	1905.9	1790.3	1638.1
7. FEEDPR (000 pts)	595.2	630.0	574.2
8. FINET (000 pts)	286.1	517.7	129.1
9. FFEXPSV (000 pts)	421.9	443.5	345.1
10. TMLKPRS	74297.	74221.	66476.
11. TLCOWS	15.	16.	14.
12. RHYMLK	4953.	4639.	4748.
13. RAVCPC (000 pts)	61.1	59.4	65.9
14. AVCMLK	7.837	7.219	6.412
15. AFCMLK	8.840	9.064	9.933
16. ACMLK	16.677	16.283	16.345
17. DMCPLC	5252.	5303.	5499.
18. CCPLC	1680.	1576.	1623.

PRESWTH = 2141.9

Assumptions:
Interest Rates = .12, .17, .20
Discount Rate (RI) = .12
Milk Price = 19.3 (pts/kg)
Concentrate Price = 16.8 (pts/kg)

* Definitions of Output Variables to be found in Table 13-5

(IV) In our last feeding rule experiment we take, as a baseline the NRC recommended concentration of ME in the ration which is a function of weight and milk yield. Table 14-14 below reproduces a portion of Table-3 of the NRC document.

Table 14-14

Recommended Nutrient Content of Rations for Dairy Cattle

	Lactating Cows Rations					
Nutrients (Concentration in the Feed Dry Matter	Cow Wt(kg)	Daily Milk Yield (kg)				Dry Pregnant Cows
	< 400	< 8	8-13	13-18	>18	
	500	<11	11-17	17-23	>23	
	600	<14	14-21	21-29	>29	
	> 700	<18	18-26	26-35	>35	
Metabolic Energy (Mcal/Kg DM)		2.36	2.53	2.71	2.89	2.23

Source: National Research Council. Nutrient Requirements of Dairy Cattle, 1978.

In this experiment, consequently, cows recieve during the year rations with a concentration of ME that takes into consideration their weight and milk yield on a week by week basis.

Consumption of concentrate changes under this feeding rule by giving the cows rations with a concentration of ME ranging from 115 to 85% of the NRC recommended values. In this experiment we made extensive and intensive searches which are shown in Table 14-15.

In our extensive search we find that the best results appeared on the interval 105-90. This led us to make a finer search within that interval. the results of the intensive search can be seen in Table 14-16.

As it appears in Table 14-16 giving cows a ration with 96% of the NRC recommended concentration of ME yields the best results.

Table 14-15

Characteristics of Fourth Feeding Rule Experiment. Percentage of NRC Recommended Concentration of ME on Ration (%)

Trial #	Extensive Search	Intensive Search
1	115.	104.
2	110.	102.
3	105.	100.
4	100.	98.
5	95.	96.
6	90.	94.
7	85.	92.

Table 14-16

Results of Fourth Feeding Rule Experiment

Trial #	Present Value of Investment
	(000 pts)
1	2279.8
2	2325.8
3	2353.0
4	2371.0
5	2435.4
6	2424.9
7	2374.4

In Table 14-17 we can see in more detail the characteristics of the best feeding regime under the (IV) feeding rule. Comments on that Table follow:

(i) The feeding rule results in stable weights for the cows during the three year period (row 1). No wasteful increases in weight occur. Dry matter intake per cow remains stable (row 10) during the run (row 17).

(ii) Total milk production and stocking rate decline (row 11) from the 1st to the 3rd year. Total milk production during the three years is higher than in the best of the three previous experiments (I).

(iii) Concentrate purchases during the 3 years are similar in experiments (I) and (IV) (row 2, 3 and 7). Concentrate consumption per lactating cow follows in case (IV) a more stable pattern than in case (I). This indicates that no silage deficit arises during the year that must be resolved with unplanned purchases of concentrates.

(iv) The present value of the investment is 6.5% higher in experiment (IV) than in experiment (I). Farm net income (row 8), cash flow (row 9) and returns above variable cost per cow (row 13) are substantially higher in case (IV) than in case (I).

(v) This higher returns of experiment (IV) come not only from a higher milk production extracted from a similar dairy herd (row 12, rolling milk yield averages) but also because this higher output is produced more efficiently. This increased efficiency can be observed in the evolution of the cost concepts (rows 13, 14, 15) and the returns above variable cost per cow (row 13) in both cases.

Table 14-17

Detailed Results of Best Run of Fourth Feeding Rule Experiment.

Variable *	Year 1	Year 2	Year 3
1. WHTLC(6) (E-Y)	644.	647.	646.
2. TCONCPR	23470.	21745.	22741.
3. TTCONCW	16201.	14423.	15486.
4. TYMILK(6)	5555.	5554.	5554.
5. SILGSUR(E-Y)	12071.	7669.	11021.
6. EQUITY (000 pts)	1872.5	1767.8	1673.7
7. FEEDPR (000 pts)	394.3	365.3	382.1
8. FINET (000 pts)	423.8	421.9	226.5
9. FFEXPSV (000 pts)	590.0	522.8	422.2
10. TMLKPRD	73912.	67778.	62567.
11. TLCOWS	15.	14.	13.
12. RHYMLK	4927.	4841.	4813.
13. RAVCPC (000 pts)	72.3	71.9	70.9
14. AVCMLK	5.503	5.237	5.527
15. AFCMLK	8.881	9.530	9.903
16. ACMLK	14.385	14.766	15.430
17. DMCPLC	5135.	5103.	5093.
18. CCPLC	1080.	1030.	1191.

PRESWTH = 2435.4

Assumptions: Interest Rate = .12, .17, .20
Discount Rate (RI) = .12
Milk Price = 19.3 (pts/kg)
Concentrate Price = 16.8 (pts/kg)

* Definitions of Output Variable to be found in Table 13-5

In summary, we may conclude that the best feeding rule is the one based in the NRC recommanded concentration of ME on the ration which takes account of the status of the cow on a weekly basis. The best concentrate use for the given set of prices can be found by supplying the cows rations with varying proportions of the NRC recommended concentration of ME as we did in experiment (IV).

14.3. Price Change Impact Analysis.

In this section we examine in more detail the set of seven trials making up experiment (IV) in the previous section (subsection 14.2.3). We will discuss the different behavior of the model under the seven alternative trial conditions and we will see that we need to consider more than one year when looking for the best level of concentrate use.

We also discuss in this section the results of an experiment which enables us to see how the best concentrate use changes with prices. This experiment consists in rerunning experiment (IV) with a new set of prices that comes from the Spain in/out EEC scenarios developed by Peterson and Pelach et al. [60] that we have already mentioned.

Deciding on the best feeding regime requires the model to be run for more than one year. As we can see in Table 14-18 if we were to decide on the basis of a one year run we would undoubtedly decide for the lowest proportion (92%), since it yields the highest cashflow (row 7, 1st year) of all the alternatives and it does it by making the most efficient (the lesser) use of concentrate (rows 2 and 8, 1st year). Deciding on the basis of a single year run, however, would be a mistake. Any feeding regime will determine besides the financial results for the year the value of a set of state variables at the end of the year that will strongly influence changes in the farm the following year. Some of the important state variables whose end-of-year values will affect next year performance are: (a) Cow weight and dry matter intake per cow, and (b) Concentrate consumption that will affect the consumption of forage per cow and hence the stocking rate the following year.

Table 14-18

Detailed Results for Experiment IV

Variable *	Year	(1) 104	(2) 102	(3) 100	(4) 98	(5) 96	(6) 94	(7) 92
1. TMLKPRD	1	75715.	75583.	75382.	74762.	73912.	72543.	70579.
	2	75996.	75787.	72344.	72152.	67778.	66507.	61140.
	3	68022.	67724.	63597.	63239.	62567.	61516.	55986.
2. AVCMLK	1	7.801	7.385	6.766	6.130	5.503	4.906	4.310
	2	6.475	5.966	5.831	5.435	5.237	5.258	5.558
	3	5.354	5.217	4.610	5.254	5.527	5.522	4.764
3. AFCMLK	1	8.670	8.685	8.708	8.780	8.881	9.049	9.301
	2	8.857	8.861	9.108	9.120	9.530	9.702	10.362
	3	9.705	9.717	10.053	10.091	9.903	10.056	10.732
4. ACMLK	1	16.470	16.070	15.474	14.910	14.385	13.954	13.610
	2	15.332	14.827	14.939	14.550	14.766	14.960	15.920
	3	15.058	14.934	14.663	15.344	15.430	15.578	15.496
5. TLCOWS	1	15.	15.	15.	15.	15.	15.	15.
	2	16.	16.	15.	15.	14.	14.	13.
	3	14.	14.	13.	13.	13.	13.	12.
6. RHYMLK	1	5048.	5039.	5025.	4984.	4927.	4836.	4705.
	2	4750.	4737.	4823.	4810.	4841.	4750.	4703.
	3	4859.	4837.	4892.	4865.	4813.	4732.	4665.
7. FFEXPSV	1	440.9	470.8	515.1	554.9	590.0	614.5	628.3
	2	521.5	557.4	532.6	558.6	522.8	503.5	421.2
	3	437.0	442.1	458.6	412.7	422.2	408.0	410.3
8. CCPLC	1	1772.	1637.	1455.	1266.	1080.	900.	722.
	2	1566.	1402.	1322.	1198.	1030.	975.	922.
	3	1508.	1403.	1229.	1255.	1191.	1080.	844.
9. Average FFEXPSV		466.5	490.1	502.1	508.7	511.7	508.7	486.3

* Definitions of Output Variables to be found in Table 13-5

In order to decide on the best concentration proportion we need an average measure of the three years like the present value of the investment that we used. Looking at any particular year and only the cash flow indicator (row 7) we see that the best proportion (96%) does not rank, among the seven alternatives, the highest in any of the three years. When we average out the cash flow value during the three years (row 9) in a measure similar to the present value of investment we see the 5th alternative (96%) scoring the highest.

We also see in Table 14-18 how the alternatives making the heaviest use of concentrate result in higher stocking rates and higher total milk production. These, however, are reached at an excessive cost. We can say that for alternatives (1) to (4), at the given set of prices, the marginal value product (MVP) of concentrates is lower than their price making it profitable to reduce its use. Conversely, alternatives (6) and (7) make not enough use of concentrates. The MVP of concentrates being, roughly, higher than its price.

Finally we should note the delayed effects that some policies have on the performance of the system and hence how seemingly good 1st year policies influence the behavior and performance of the system the following years in a less than optimal way. The ability to capture these intertemporal connections and delayed affects improves decision-making and is one of the mayor contributions well designed simulation models can make.

Let us now comment on our price change impact analysis. We used the same set of alternatives we consider in experiment (IV) above. The results judged on the basis of the present value of investment can be seen in Table 14-19.

We see in Table 14-19 that the best concentration proportion is now (94%) which implies a reduced use of concentrates as production economics would lead us to predict. Concentrate consumption per cow is reduced 20% the first year, about 6% the second year, and more than 10% the third year, when compared with results in Table 14-17 (row 18).

We also see in Table 14-19 that the adjusted feeding regime results in leaner cows (row 1) producing about 100 kg of milk less per cow (row 12) than in the best regime of experiment (IV).

The concentrate consumption adjustment is not able to prevent slight increases in both the average variable cost and the average fixed cost (rows 14 and 15), caused by the increase in the input price, which result in higher total average cost of milk (row 16). These increases in the cost measures compounded with the fall in the output price result in substantially lower returns above variable cost per cow (row 13) and a fall of about 38% in the three year cash flow average.

Table 14-19

Results of Price Impact Experiment

Trial #	Percentage of Recommended Concentration of ME on Ration	Present Value of Investment
	(%)	(000 pts)
1	104.	1871.4
2	102.	1927.8
3	100.	1978.9
4	98.	2004.2
5	96.	2087.7
6	94.	2088.6
7	92.	2066.2

Table 14-20

Detailed Results of Price Impact Experiment

Variable *	Year 1	Year 2	Year 3
1. WHTLC(6) (E-Y)	635.	631.	624.
2. TCONCPR	20246.	21060.	21929.
3. TTCONCW	13494.	13653.	14040.
4. TYMILK(6)	5428.	5427.	5427.
5. SILGSUR (E-Y)	9615.	6258.	10643.
6. EQUITY (000 pts)	1866.9	1759.5	1664.1
7. FEEDPR (000 pts)	374.6	389.6	405.7
8. FINET (000 pts)	295.8	261.6	79.3
9. FFEXPSV (000 pts)	467.6	364.6	275.4
10. TMLKPRD	72543.	66507.	61516.
11. TLCOWS	15.	14.	13.
12. RHYMLK	4836.	4750.	4732.
13. RAVCPC (000 pts)	64.1	60.6	59.6
14. AVCMLK	5.380	5.797	6.128
15. AFCMLK	9.049	9.702	10.056
16. ACMLK	14.429	15.498	16.184
17. DMCPLC	5119.	5068.	5047.
18. CCPLC	900.	975.	1080.

PRESWTH = 2088.6

Assumptions:
- Interest Rates = .12, .17, .20
- Discount Rate (RI) = .12
- Milk Price = 17.75 (pts/kg)
- Concentrate Price = 18.5 (pts kg)

* Definitions of Output Variables to be found in Table 13-5

Going to a lower level of concentrate consumption does not improve results significantly over keeping the 96% concentration we had found in experiment (IV). As we can see in Table 14-19 the difference in outcome between the 96% and the 94% concentrations is indeed minimal when measured on the basis of the present value of investment. This indicates that changes of concentrate price in the 10% order will not result in major shifts in concentrate use or in the profitability of the farm business. On the other hand, reductions in the price of milk of the 5 to 10% order will significantly reduce farm returns.

14.4. Farm Growth Analysis

In this section we discuss three farm growth processes which are financed under the Agencia de Desarrollo Ganadero (ADG) conditions. Let's again restate those conditions:

- 80% of total investment financed
- 3 year grace period
- 12 year loan length
- 13% interest rate

We consider three farm sizes: 8, 12 and 16 hectares. Only 3 hectares of those farms are developed (1.72 is artificial pasture, 1.28 is cropland), and the farm sustains 5 dairy cows, 2 heifers and 2 growing calves. The remaining area of the farm is undeveloped and the growth strategy consists in upgrading these portion of the land, acquiring new equipment and installations, and buying a few more dairy cows.

Only 80 percent of total initial investment is financed under ADG conditions. The farmer is supposed to contribute the remaining 20 percent or the farm business must be able to produce funds enough to solve any cash flow deficit that would arise. We assume that the farmer does not have this 20 percent of investment available and that he resorts to annual loans in order to solve any cash flow deficit.

In our farm growth analysis we will judge the profitability of the investment on the basis of the internal rate of return (IRR) concept. As we know the IRR of an investment is that discount rate that equates the discounted value of benefits and costs over the life of the investment. In an alternative definition, the IRR is that discount rate that makes the sum of the discounted net benefits of the investment over the life of the investment equal to zero.

In order to find the stream of net benefits generated by the investment we have to deduct from the stream of cash flows generated by the developping farm business (our variable FFEXPSV) the returns earned by the inputs (labor, capital, land, management) owned by the farmer in absence of the investment, which would be earned by the farmer whether or not the investment is implemented. In this sense, as we mentioned in Chapter 12, these returns represent the opportunity cost of the inputs already owned by the farmer which should not be attributed to the new investment.

We have no data on the returns to inputs earned by traditional 5 to 6 cows farms in Galicia. We can get around this problem, however, by assuming two extreme values within which the stream of the cash flows of the undeveloped farm would fall. Substracting those two streams of values from the stream of cash flows generated by the developed farm will yield the stream of returns attributable to the investment under those hypothesis. Two IRR will result, consequently, from this computation, which should bound the actual IRR after financing the investment.

We assume that the minimun value for the stream of returns without the investment is about 125,000 pts. The maximum value is about 200,000 pts. This upper bound has been found in the following way. For the year 1979 (to which the set of prices and costs considered in our analysis correspond) we observe that in the strata of Galicia dairy farm ,- reported in the Red Contable Agraria Nacional (RCAN) (National Agricultural Accounting Network), published by the Ministry of Agriculture of Spain in 1979 [64]-, of less than 5 hectares (mean surface 4 hectares and 9.6 lactating cows) the average farm generates about 40,000 pts of net benefit per cow. Considering our initial farm size (3 hectares, 5 cows) we arrive at our 200,000 pts value. This represents an upper bound also because the sample of farms whose accounts are collected in the RCAN are better managed, better equiped and more profitable than typical in the region and their performance is by no means comparable to that of the more traditional farms. We also assume that grass utilization by the herd (our parameter TN3) is only 90% of the grass available.

Table 14-21 shows the set of performance indicators, besides the IRR, which serve us to see the pattern of change in the farm business during the life of the investment. In the upper part of the table we can see for every year the cash flow accounts, rows 1 to 14. In the bottom part we show a set of financial and physical indicators whose changes indicate the nature of the farm growth process.

Table 14-22, 14-24, 14-26, show for the three farm sizes, the unadjusted and adjusted streams of net returns as well as the two bounding IRR's. Tables 14-23, 14-25, 14-27, show changes in the farm business over the life of the investment with two additional assumptions: (1) of a minimum cash withdrawal for consumption purposes of 150000 pts per year is made by the farmer from the farm business, (2) that cash flow deficits are covered by taking an annual loan.

Table 14-21

Definitions of Output Variables Used in the Assessment of Growth Experiments.

Variable	Variable Definition
Sources of Funds	
1. CSHRCP	Cash receipts
2. CKNGI	Net capital gains income
3. TSLOAN	Initial loan
4. XNILOAN	New intermediate loan
5. OWNFNDS	Own funds
6. TCASHIN	Total cash in (1+2+3+4+5)
Uses of Funds	
7. CSHFEXP	Farm cash expenditures
8. FFINCTG	Farm family income target
9. TIINVST	Initial investment
10. ACCBSTP	Breeding stock investment
11. RPYLOAN	Loan repayment
12. TCSHOUT	Total cash out (7+8+9+10+11)
13. ANLOAN	Annual loan (if 12>6 then 6-12)
14. FFEXPSV	Residual cash flow (if 6>12 then 8+6-12)
15. EQUITY	Equity (000 pts)
16. TMLKPRD	Total milk production (kg)
17. TLCOWS	Total lactating cows
18. AVCMLK	Average variable cost of milk (pts/kg)
19. AFCMLK	Average fixed cost of milk (pts/kg)
20. ACMLK	Total average cost of milk (pts/kg)

We can see in Tables 14-22, 14-24, 14-26 that the profitability of the investment is very high. We know and mentioned it earlier that one condition promoting a viable and successful farm growth process is the existence of unused resources which can be more fully ultilized when other complementary resources are added. In our case we have a farm situation with two main inputs underused: land and labor. It is no wonder then that a reasonable investment plan should yield such high returns.

A qualification must be made here concerning these high IRR's. We assumed that the opportunity cost of labor, capital and land contributed by the farmer was represented by the net returns generated by the undeveloped farm. However, the relevant opportunity cost of labor may not be the one contained in the net returns concept above, but the alternative earning labor may obtain in the non-agricultural sector, which is much higher. Accounting for that alternative shadow price for labor would undoubtedly result in a set of much lower IRR's. Difficult issues concerning the appropriate reservation price for the farm operator and family labor arise here.

On the other hand, we must recall that our equity concept excludes the value of farmland. However, an essential part of the investment plan consists in upgrading the undeveloped land owned by the farmer. This upgrading process converts low-value bushland into high-value pasture land, an appreciation process our accounting neglects. The actual equity at the end of the investment plan life would be much higher had a complete accounting been performed.

Let us now comment on the results shown in Tables 14-23, 14-25 and 14-27.

We see (rows 16 and 17) that the farms achieve their full production potential at the sixth year. Since a major portion of total investment is realized at the beginning of the process and the farmer is assumed unable to fulfill his 20 percent of the initial investment, this gradual potential buildup of the farm puts some financial strains on the farm business.

The first four years constitute a difficult period for the farm business. We see that the 8 and 16 hectares farm cases must resort to short-term loans (row 13) to bridge cash-flow deficits in the first four years. The 12 hectares case will need short-term financing for only the first two years.

The 3 year grace period is quite instrumental in enhancing the feasibility of the growth process. Delaying repayment of the long-term loan until the fourth year allows the first years cash-flow problems to be worked out before the heavy repayment schedule begins (row 11).

The financial strains that we just mentioned show up also in a U shaped pattern of equity during the life of the investment. We can see (row 15) that equity declines until the 4th or 5th year rising then regularly until the 12th year. The decline is deeper for the 12 and 16 hectare cases. The growth of equity during the last half of the investment life is also faster for those two cases.

For the 8 hectare case non-farmland equity decreases slightly (about 8%) between the beginning and the end of the investment. Equity for the 12 hectare case rises by 45%. For the 16 hectare case the growth of equity is about 105%.

At the end of the investment the 8 hectares farm generates a cash-flow that is 256% higher than the minimun consumption withdrawal. The 12 hectare farm generates a cash-flow 458% higher and the 16 hectare farm a cash-flow 597.5% higher.

The average variable cost (row 18) follows, except for the 2nd and 3rd year, a slightly decreasing trend from the 1st to the 12th year. During the 1st half of the investment life average variable costs are higher for the 12 and 16 hectares cases than for the 8 hectare case. This is undoubtedly due to the heavier annual interest charges in the first years supported by the larger farms that enter into the computation of the average variable costs.

Average fixed costs (row 19) decline rapidly during the life of the investment, reaching a value at the 12th year less than half their value at the beginning of the investment period. Total average fixed costs (row 20) follow a pattern similar to that of average fixed costs.

The decline from the 1st to the 12th year is of the order of 40%.

We see also that the value of the average fixed cost at the end of the period for the three farm sizes is about the same. Does this mean that there are no economies of size in the range of farms we chose?. The answer is likely yes, there are. The reason that no economies of size show up in our Tables is because labor has not been costed out in our accounting. Had we done so, applying a minimum wage rate at the labor used in the farms, we could undoubtedly have come out with higher values for the cost concepts for the smaller farms. This is confirmed by the much higher returns to factors of production yielded by the larger farms.

Finally, we can compare the performance of the model with actual data from a sample (19 farms) of the best farms developed by the ADG and which in 1979 were in their 3rd to 5th year of development (C. Rodriguez Epelde, C. Posada Naria and R. Gonzalez Santillana [68]).

As we can see in Table 14-28 it seems that the growth process occurs more rapidly than our model predicts. Yields per cow are slighty higher in the model and milk production per hectare is lower when compared to sample results. The model farm consumes about 25% more concentrate per cow than the sample farms. Gross income per hectare is slighty higher for the sample farms. Overall we can accept that the model performance compares not too unfavorably with actual farm performance.

Table 14-22

Results of the 8 Hectare Farm Growth Experiment

Year	Farm Family Net Benefit with the Investment (FFEXPSV) (1)	Farm Family Net Benefit without the Investment (Assumptions) (2)	(3)	Incremental Net Benefit (4)= (1)-(2)	(5)= (1)-(3)
	(000 pts)				
1	-189.9	125.	200.	-314.9	-389.9
2	329.7	125.	200.	204.7	129.7
3	320.0	125.	200.	195.0	120.0
4	167.8	125.	200.	42.8	-32.0
5	255.9	125.	200.	130.9	55.9
6	351.4	125.	200.	266.4	151.4
7	314.3	125.	200.	189.3	114.3
8	296.4	125.	200.	171.4	96.4
9	359.1	125.	200.	234.1	159.1
10	420.6	125.	200.	295.6	220.6
11	488.8	125.	200.	363.8	288.8
12	534.2	125.	200.	409.2	334.2

EQUITY(12) = 1006.4

Assumptions: XLAND = 8 (hectares)
Milk Price = 19.3 (pts/kg)
Concentrate Price = 16.8 (pts/kg)
ME Concentration Proportion = 96%

(4) Internal Rate of Return: 54.% (From column (4) data)
(5) Internal Rate of Return: 30.1% (From column (5) data)

Table 14-23

Detailed Results of the 8 Hectare Farm Growth Experiment

Variable *	Year 1	2	3	4	5	6	7	8	9	10	11	12
Sources of Funds:												
1. CSHRCP	927.3	894.3	912.2	1051.8	1226.3	1418.7	1366.6	1224.2	1351.4	1513.6	1460.5	1470.7
2. CKNGI	250.4	190.4	183.1	189.2	205.9	249.9	302.1	330.1	250.1	254.3	353.5	276.4
3. TSLOAN	2426.1	--	--	--	--	--	--	--	--	--	--	--
4. XNILOAN	--	--	26.4	171.9	219.6	246.2	139.2	98.8	246.5	212.1	--	373.2
5. OWNFNDS	--	--	--	--	--	--	--	--	--	--	--	--
6. TCASHIN	3603.8	1084.8	1121.7	1413.0	1651.8	1914.8	1807.9	1653.1	1848.0	1980.0	1824.0	2120.3
Uses of Funds:												
7. CSHFEXP	761.2	790.7	795.9	799.8	844.2	908.2	863.5	786.7	811.5	834.2	823.5	790.4
8. FFINCTG	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0
9. TIINVST	3032.6	--	--	--	--	--	--	--	--	--	--	--
10. ACCBSTP	--	--	26.4	171.9	219.6	246.2	139.2	98.8	246.5	212.1	--	373.2
11. RPYLOAN	--	339.9	195.9	324.9	369.3	408.9	491.0	471.2	430.9	513.1	501.8	422.4
12. TCSHOUT	3943.8	1280.7	1168.2	1446.7	1583.1	1713.3	1643.6	1506.7	1638.9	1709.4	1475.2	1736.0
13. ANLOAN	339.9	195.9	46.5	33.6	--	--	--	--	--	--	--	--
14. FFEXPSV	150.0	150.0	150.0	150.0	218.7	351.4	314.3	296.4	359.1	420.6	488.8	534.2
15. EQUITY	1086.4	517.6	368.4	351.0	399.2	465.0	452.7	642.6	825.4	849.8	746.2	1006.4
16. TMLKPRD	43074.	42235.	43347.	50436.	58894.	68179.	65042.	57395.	64811.	72441.	69002.	71043.
17. TLCOWS	10.	9.	9.	11.	13.	15.	14.	13.	15.	16.	15.	16.
18. AVCMLK	7.31	9.58	9.60	8.48	7.98	7.41	6.60	6.04	7.22	6.95	6.06	6.68
19. AFCMLK	11.18	11.39	10.99	8.97	7.82	6.81	7.04	7.41	6.28	5.61	5.66	4.67
20. ACMLK	18.49	20.97	20.59	17.46	15.80	14.22	13.65	13.46	13.50	12.57	11.72	11.35

* Definitions of Output Variables to be found in Table 14-21

Table 14-24

Results of the 12 Hectare Farm Growth Experiment

Year	Farm Family Net Benefit with the Investment (FFEXPSV) (1)	Farm Family Net Benefit without the Investment (Assumptions) (2)	(3)	Incremental Net Benefit (4)= (1)-(2)	(5)= (1)-(3)
	(000 pts)				
1	-261.2	125.	200.	-386.2	-461.2
2	345.2	125.	200.	220.2	145.2
3	437.6	125.	200.	312.6	237.6
4	179.9	125.	200.	54.9	-20.1
5	331.0	125.	200.	206.0	131.0
6	528.5	125.	200.	403.5	328.5
7	421.4	125.	200.	296.4	221.4
8	435.5	125.	200.	310.5	235.5
9	596.5	125.	200.	471.5	396.5
10	522.4	125.	200.	397.4	322.4
11	736.3	125.	200.	611.3	536.6
12	838.3	125.	200.	713.3	638.3

EQUITY(12) = 1710.9

Assumptions: XLAND = 12 (hectares)
Milk Price = 19.3 (pts/kg)
Concentrate Price = 16.8 (pts/kg)
ME Concentration Proportion = 96%

(4) Internal Rate of Return: 63.% (From column (4) data)
(5) Internal Rate of Return: 41.4% (From column (5) data)

Table 14-25

Detailed Results of the 12 Hectare Farm Growth Experiment

Variable *	1	2	3	4	5	6	7	8	9	10	11	12
	Year											
Sources of Funds:												
1. CSHRCP	1226.7	1163.3	1286.9	1455.2	1656.7	2018.5	2009.4	2002.3	2150.3	2258.4	2122.2	2118.
2. CKNGI	302.2	249.6	239.7	246.4	317.0	380.6	436.8	433.3	379.9	336.7	521.6	415.
3. TSLOAN	3063.8	--	--	--	--	--	--	--	--	--	--	--
4. XNILOAN	--	--	156.2	179.8	329.2	706.2	272.8	84.1	261.8	299.6	--	354.
5. OWNFNDS	--	--	--	--	--	--	--	--	--	--	--	--
6. TCASHIN	4592.7	1412.9	1682.8	1881.4	2302.9	3105.3	2719.0	2519.7	2791.9	2894.7	2643.8	2889.
Uses of Funds:												
7. CSHFEXP	1024.2	1110.9	1116.2	1129.1	1190.3	1308.5	1279.3	1224.6	1238.9	1290.7	1261.0	1168.
8. FFINCTG	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150
9. TIINVST	3829.8	--	--	--	--	--	--	--	--	--	--	--
10. ACCBSTP	--	--	156.2	179.8	329.2	706.2	272.8	84.1	261.8	299.6	--	354
11. RPYLOAN	--	411.2	259.2	392.5	452.4	562.2	745.5	776.5	644.8	782.1	646.5	527
12. TCSHOUT	5003.9	1672.1	1681.5	1851.5	2121.9	2726.9	2447.6	2235.2	2345.4	2522.3	2057.5	2200
13. ANLOAN	411.2	259.2	--	--	--	--	--	--	--	--	--	--
14. FFEXPSV	150.0	150.0	151.2	179.9	331.0	528.5	421.4	434.5	596.5	522.4	736.3	838
15. EQUITY	1180.0	473.2	177.9	284.9	214.4	412.5	508.9	568.5	985.2	1203.5	1381.3	1710
16. TMLKPRD	56927.	54761.	61670.	69711.	79596.	97497.	96027.	94149.	103008.	108790.	100308.	101911
17. TLCOWS	14.	12.	13.	15.	18.	23.	22.	22.	22.	23.	22.	22
18. AVCMLK	8.32	11.19	10.11	9.31	8.26	7.36	6.91	6.87	7.19	7.88	6.71	6
19. AFCMLK	10.14	10.72	9.41	7.87	7.02	5.68	6.32	6.09	4.83	4.49	4.88	4
20. ACMLK	18.46	21.92	19.52	17.19	15.28	13.05	13.23	12.96	12.03	12.37	11.59	11

* Definitions of Output Variables to be found in Table 14-21

Table 14-26

Results of the 16 Hectare Farm Growth Experiment

Year	Farm Family Net Benefit with the Investment (FFEXPSV) (1)	Farm Family Net Benefit without the Investment (Assumptions) (2)	(3)	Incremental Net Benefit (4)= (1)-(2)	(5)= (1)-(3)
	(000 pts)				
1	-454.6	125.	200.	-579.6	-654.6
2	317.4	125.	200.	192.4	117.4
3	520.7	125.	200.	395.7	320.7
4	242.2	125.	200.	117.2	42.2
5	446.0	125.	200.	321.0	246.0
6	603.7	125.	200.	478.7	403.7
7	544.0	125.	200.	419.0	344.0
8	604.6	125.	200.	479.6	404.6
9	639.5	125.	200.	514.5	439.5
10	1022.6	125.	200.	897.6	822.6
11	1072.1	125.	200.	947.1	872.1
12	1046.2	125.	200.	921.2	846.2

EQUITY(12) = 2598.2

Assumptions:
- XLAND = 16 (hectares)
- Milk Price = 19.3 (pts/kg)
- Concentrate Price = 16.8 (pts/kg)
- ME Concentration Proportion = 96%

(4) Internal Rate of Return: 53.% (From column (4) data)
(5) Internal Rate of Return: 40.6% (From column (5) data)

Table 14-27

Detailed Results of the 16 Hectares Farm Growth Experiment

Variable *	1	2	3	4	5	6	7	8	9	10	11	12
	Year											
Sources of Funds:												
1. CSHRCP	1376.4	1400.6	1637.9	1857.5	2709.8	2709.8	2806.2	2804.7	2610.6	2510.7	2681.1	2665.2
2. CKNGI	328.1	230.9	291.3	352.6	456.5	434.8	536.2	521.7	502.9	599.5	525.4	545.1
3. TSLOAN	3579.3	--	--	--	--	--	--	--	--	--	--	--
4. XNILOAN	--	--	289.9	307.3	617.4	1010.1	259.9	41.6	34.3	344.5	328.4	98.5
5. OWNFNDS	--	--	--	--	--	--	--	--	--	--	--	--
6. TCASHIN	5283.8	1631.5	2219.1	2517.4	3204.6	4154.6	3602.3	3368.0	3147.8	3454.6	3534.8	3308.8
Uses of Funds:												
7. CSHFEXP	1264.3	1377.5	1461.1	1492.8	1555.9	1738.3	1755.8	1694.9	1639.1	1577.9	1596.6	1530.6
8. FFINCTG	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0
9. TIINVST	4474.1	--	--	--	--	--	--	--	--	--	--	--
10. ACCBSTP	--	--	289.9	307.3	617.4	1010.0	259.9	41.6	34.3	344.5	328.4	98.5
11. RPYLOAN	--	604.6	500.7	676.9	706.3	802.6	1042.6	1026.8	834.9	509.6	537.8	633.4
12. TCSHOUT	5888.4	2132.2	2410.7	2627.0	3029.7	3700.9	3208.3	2913.3	2658.3	2582.0	2612.8	2412.6
13. ANLOAN	604.6	500.7	182.6	109.6	--	--	--	--	--	--	--	--
14. FFEXPSV	150.0	150.0	150.0	150.0	325.1	603.7	544.0	604.6	639.5	1022.6	1072.1	1046.2
15. EQUITY	1267.1	446.0	-.6	-66.5	24.1	331.4	432.0	953.8	1558.9	2092.5	2310.2	2598.2
16. TMLKPRD	63854.	66350.	78782.	89039.	102929.	131778.	133939.	132673.	124636.	119663.	127997.	125945.
17. TLCOWS	16.	15.	17.	20.	24.	31.	31.	28.	26.	28.	29.	28.
18. AVCMLK	10.07	12.86	11.01	9.65	8.10	7.95	7.49	7.55	8.07	7.26	7.68	7.52
19. AFCMLK	10.22	10.06	8.58	7.29	6.31	5.18	5.54	5.04	4.79	4.64	4.41	4.32
20. ACMLK	20.29	22.93	19.60	16.94	14.42	13.13	13.03	12.60	12.86	11.91	12.10	11.85

* Definitions of Output Variables to be found in Table 14-21

Table 14-28

Comparison of Actual with Simulated Growth Results

Performance Indicator	ADG Sample Results(3-5 years)	Model Results 5th Year
Size (hectares)	11.8	12.
Stocking rate (cows/ha)	1.75	1.50
Milk yield (lt/cow)	4182.	4239.
Milk yield (lt/ha)	7237.	6633.
Concentrate consumption per cow (Kg/cow)	881.	1185.
Gross Income (pts/ha)	131668.	129948.

14.5. Final Comments.

The set of experiments that we have shown in this Chapter illustrates the range of applicability of the model. The conclusions should be qualified as to the degree of model validation achieved.

We have shown also at least an example of every one, except for type (c), of the four types of experimentation a simulation model can produce according to A. Wright. Our experiments have been rather coarse and finer searches would probably have yielded improved values for the performance indicators chosen. In absence of a higher degree of model validation achieved there would be no guarantee that the improved values would be closer to the real optimum values than the values obtained in our experiments. This fact together with cost considerations have limited the number of experiments performed, as well as the effort put in on any of them.

Finally, let us recapitulate what we have done in this Chapter. We found that winter births were more, if slightly, profitable than fall births. For the winter calving season, we also found that mean birth times closer to the onset of grazing would save on concentrate consumption and result in higher returns. The most profitable proportion of pastureland to be conserved for silage production was no more than 45 percent. However, this result must be qualified by the fact that we did not explore lower values of the relevant parameter nor did we explore different proportions for the three cutting periods considered in the model. In our evaluation of feeding rules we found that following the NRC recommendations on concentration of ME on ration resulted in the best allocation of concentrate during the production cycle. We also found that under the market environment assumed, rations with a 96% of the NRC recommended concentration of ME yielded the highest returns. Our farm growth analysis showed the high feasibility and profitability of the growth plans under ADG loan conditions of which the 3 year grace period is quite instrumental in solving cash flow problems in the first part of the investment life.

CHAPTER 15

Conclusions and Final Comments

In this last chapter we will first examine the degree in which our research objectives have been fulfilled and restate the conclusions reached at the end of the model experimentation phase. Second, we will examine the limitations and shortcomings of our modelling effort, suggesting ways to remedy them. Third and last we will suggest further lines of research with the model and model expansion possibilities.

15.1. Conclusions.

A dairy/forage simulation model capable of capturing important aspects of real dairy farming systems in the Galician context has been developed. The model reproduces realistically the temporal pattern of forage production coming from the various types of land resources owned by the typical farmer. Quantity and quality of forage is accounted for in a dynamic way. The model also simulates the demographic processes of the dairy herd, keeping track of numbers of animals in the different age cohorts and monitoring the productive-reproductive cycle of the dairy herd, i.e., pregnancy, lactation, open period, and dry period. The model also contains in its nutritional component a rather detailed biological model of the dairy cow, tracing feed disappearance, conversion of feed into energy and conversion of energy into the joint products of a dairy cow, that is, milk, progeny and body tissue. The forage, herd demographics and nutritional components, interface with each other under the influence of managerial decision-making, which is exogenous to the model, through a feed availability, feed use balancing mechanism where feed availability coming from the forage subsystem and feed requirements coming from the herd demographics and nutritional components are reconciled. The last component of the model produces the financial accounts of the farm business generating several financial and technical performance indicators useful in evaluating the performance of the farm business under a variety of resource base conditions, forage and herd management programs, feeding rules, and market environments.

Although the model operates in a realistic way, a totally satisfactory validation has not been achieved, mainly due to the lack of critical data. The model is sensitive to several parameters: (a) The annual milk yield potential; (b) The nutritional quality of the grass grazed by the cows; and (c) The degree of grass utilization by cows when grazing.

The conclusions reached with the model must then be qualified by the degree of validation achieved.

Many types of analysis, both short-term and long-term, can be conducted with the model. We have selected a set of them which illustrate uses for the model and provide information on the growth processes which are being promoted by the agricultural decision-making establishment in order to raise the overall level of efficiency of the galician dairy industry.

Again comments on the experiments follow:

1. In the scheduling of calving dates we found that winter births resulted in higher returns than fall births. For the winter births season we also found that average birth times closer to the beginning of the first grazing period should save on concentrate consumption and thus result in higher returns.

2. The very limited forage storage program experiment yielded, for the 8 hectares farm with the given land structure, higher returns for the policy consisting in making three silage cuts throughout the year on no more than 45 percent of the pastureland available. As we said earlier, this result must be qualified by the fact that the best value of the control variable was equal to the lowest bound of the range of values explored, raising the possibility that lower values would have resulted in

better performance. Also, the same silage proportion was maintained through the experiment for the three silage periods considered. Again releasing that constraint may have resulted in enhanced returns.

3. Four feeding rules were assessed. The best one consists in following the NRC recommendations on concentration of ME on rations fed to cow.

4. For the best of the feeding rules we found that supplying 96 percent of the NRC recommended concentration of ME on rations fed resulted in the best allocation of concentrate throughout the year for a three-year study period, under the market environment defined by Peterson, Pelach Paniker et al [60] out-of-EEC (1979) scenario. The best proportion fell to 94 percent of recommended ME concentration under the in-EEC (1979) market environment scenario which projected a decline in the price of milk and rise in the price of concentrates of 8 percent and 11 percent respectively. The best short term adjustment to that change of prices is reducing the consumption of concentrate, thus raising its MVP, and consequently increasing the consumption of forage per cow. In the medium term, however, this short-term adjustment may result in a decline of the stocking rate, illustrating the interconnection between the feeding policy and the stocking rate variable that we announced in chaper 2.

5. Three growth processess corresponding to three farm sizes were studied and an assessment of the Agencia de Desarrollo Ganadero credit program was made. The upgrading and modernizing investments for the three farm sizes were highly profitable when measured by the IRR under the hypothesis considered. Assuming that the farmer would not be able to contribute 20% of his financial needs a cash-flow deficit appeared in the first two or four (according to the farm sizes) years of the growth process, due to the gradual nature of the forage production build up process in the reclamed land. Omitting farmland value, equity will rise considerably in the larger farms (12 and 16 hectares) but will remain stable in the smaller farm. Also, when compared to actual growth processes the model generates a slower rate of growth. This rate of growth is, however, comparable to the average performance of the best managed dairy farms undergoing the modernization process which are monitored and by the Agencia de Desarrollo Ganadero (Table 14-28).

Several issues arise from the growth experiments. Some have to do with the relevance of the assumptions about the market environment under which the conclusions were reached. These assumptions refer to : (a) a stable relationship between output and input prices, and (b) the treatment of inflation, by adjusting with the rate of inflation the monetary interest rates.

Other issues have to do with the micro versus the macro performance of the ADG program and with its distributional implications. As we saw, under the ADG loan conditions and the inflation rate assumption, the profitability of the investment is so high, that the loan conditions can be said to contain a subsidy. However, the funds and resources (technical assistance agents) available for the program on an annual basis are limited with only a handful of farmers being served every year. This means that the generous loan conditions will limit the extent of the program by reducing the yield of loans to the credit institution and so its ability to reach more farmers every year, in this way reducing the speed of the industry transformation process. The good performance of the program from the point of view of the individual farmer participating in the program may well be in detriment of the overall, aggregate, objectives of the program, which presumably are to reach as many farms as possible in the shortest period of time with the resources available. Examination of such aggregate issues would require a macro model and analysis to which the dairy/forage simulation model could contribute valuable information.

15.2. Limitations and Flaws of the Model.

As in any simulation study lack of basic knowledge about the simulated system and lack of data about critical parameters result in an incomplete model whose shortcomings must be recognized since they will constitute the starting points for further research efforts.

In this section we list some of the most obvious of those shortcomings.

1. Although the nutritional quality, ME and CP mainly, of the grass grazed changes during the year, the model assumes an average, unchanging, value for these two parameters.

2. The grass growth curve of irrigated pasture has not been defined.

3. The modeling of seasonal change in nutritional quality of silage available is crude.

4. There are no complete yield-fertilizer response functions in the model. Only a single point is known on those functions.

5. There are no storage activities and processes accounted for in the model in the sense that storage alternatives other than silage have not been investigated.

6. The forage component does not contain a detailed model of grass growth. Only seasonal growth aspects and nutritional quality of grass are considered. Changes in the quality of the grass dead and alive during the year, and its utilization by grazing animals is not accounted

for.

7. The parameter (TN3) setting the percentage of grass utilized by the cow has been given an untested value. The sensitivity analysis reveals that farm business performance is quite sensitive to that unreliable parameter.

8. For the herd demographics submodel birth rates of cows and heifers should be tested against real data.

9. The probabilistic mechanism determining cow removals from death, disease or poor productive and reproductive performance, should be checked against real data. An endogenous disinvestment component is needed.

10. The model considers a calving period of 1 year which may not be a realistic assumption. Some flexibility should be built into the model in this aspect.

11. The mechanism setting the number of female calves that should be kept for replacement purposes is probably too rigid. More flexibility should be incorporated into that mechanism. The decision to keep females for milk production instead of selling them for meat or to other dairymen should be made endogenous.

12. The process of shifting biological priority between milk production and weight maintenance has not been satisfactorily modelled. The interaction between milk

production and body weight during the critical period around the peak of the lactation curve is not well accounted for.

13. The nutritional component only considers two basic nutritional requirements of the animals: energy and protein. Other potentially limiting constraints set by crude fiber, minerals, vitamins, and other constituents of the rations fed are assumed to be not bounding.

14. Some loose ends remain in the modeling of dry matter intake by lactating cows. Some of the determinants of the dry matter intake, fat and crude fiber percent in ration, are not well modelled.

15. The annual milk yield potential parameter, SYMILK, to which model performance is highly sensitive has been given an untested value. The model has been run with a value for SYMILK which is essentially, although based on some real data, a guesstimate.

16. The annual milk yield potential of new cows entering the herd during the growth process is does not change. There is evidence that heifers entering the herd have an improving average genetic ability for milk production. This means that cows in a given lactation cohort would produce a little more, on the average, than the cows in the previous lactation did. This would raise total output production and herd milk yield average during the growth

process over what the model predicts.

17. The efficiency in the utilization of ME for different purposes, i.e., milk production, weight maintenance, weight gain, is coarsely modelled. An average, unchanging, value is assumed.

18. The nutritional requirements of very young calves during the first weeks after birth are modelled in an unduly simplistic manner.

19. The constituents of milk such as fat, protein, etc. are not taken into account in the model. For instance, milk fat appears in the dry matter intake equation but the eventual connection has not been made. The changes of these constituent during the lactation cycle should be modelled and linked to the dry matter intake equation (see point 14 above).

20. The dry matter intake equation may be affected by seasonality factors omitted from our model. If these proved to be important they should be incorporated into the model.

21. The scaling parameter (TN1) of the dry matter intake equation has been given a value based only in a crude sensitivity analysis. The model is quite sensitive to this parameter which indicates that checking against real data is needed.

22. Dry matter intake has been assumed, against some evidence to the contrary, to be independent of the energy content of the ration. The nature of this dependency between dry matter intake and energy content of the ration should be fully established.

23. There remains the overall problem of checking model results, as produced in the NUTIMP subroutine, against actual farm or experimental station data.

24. The equipement assets of the farm are not linked to a temporal profile of labor requirements during the year making it impossible to assess equipment investment alternatives.

25. Labor needs and labor availability during the year are not modelled. For the range of farm sizes considered in the growth analysis the questionable assumption is made that the farm family will supply all labor needed in the farm. Data on labor needs and availability is needed to determine the amount of labor to hire, if needed, during the year.

26. Another questionable assumption is that the farmer owns all necessary equipement for all farm activities. No machinery is ever hired, purchased or sold. An endogenous investment disinvestment mechanism that accounts for disposal or acquisition of capital goods (cattle, machinery, etc) should be a priority in the expansion of

the model.

27. The per kilo costs of producing grass and silage are not computed, for a variety of reasons, in the model. The opportunity costs of producing silage in each silage period should be defined for a best forage storage program to be determined.

28. Revenues from milk sales are independent of the quality of the milk produced, since the composition of milk has not been modelled in detail. This should be remedied since accession into the European Community will mean that milk price will be very much influenced by milk quality which, apart from the normal change in the constituents of milk during the lactation cycle, depends essentially upon sanitation and breed type.

29. Farmland value and the process of land value appreciation through the upgrading process have been omitted from the model. Data on land values should be collected and fed into the model in order for a complete assessment of the investment to be made. This would interact with the endogenous investment/disinvestment component which is an expansion priority of the model.

30. The imputation of returns to factors of production, i.e., to land, capital, operator and family labor and management, has not been performed. Opportunity cost principles should guide this partition of returns.

31. Very few other sources of credit available to the farmer are modelled. Wider choice, if existent, should be built into the model and related to the eventual investment disinvestment and opportunity cost components.

32. Alternative ways of adjusting for inflation should be considered.

33. Breeding stock investment-disinvestment decisions depend upon the forage production of the land base, the feeding policy (thus on input and output prices) and the consumption of dry matter per cow which depends on herd age composition. The realism, or economic rationality, of this mechanism should be further investigated. Decisions to keep or sell or add to the herd should be made dependent upon the economic returns accruing from any of the alternatives. Milk, beef, and concentrate prices should be involved in the investment-disinvestment decision.

34. The model is run in a deterministic mode. Randomness in yields and in the biological performance of dairy animals is omitted. Consequently, no policies to manage risk, e.g. understocking, can be investigated.

The list of shortcomings of the model could be extended ad infinitum since it is not possible to completely simulate a complex bioeconomic system like a dairy farm. In any case, the list we have offered above touches all those points deserving further research and validation efforts. A shorter list of shortcomings and remedies for them, stating their relative priority is discussed in the next section.

15.3. Model Expansion Possibilities and Further Lines of Research.

As we have said at the end of the last section all controversial aspects of the model listed there should be remedied. However, efforts destined to remedy model shortcomings should be allocated according to some priority order.

The economic aspects of the model that require further priority attention are in order, the modelling of an endogeneous component explaining investment-disinvestment decisions relating to herd expansion or contraction, machinery acquisition or disposal, and land acquisition or disposal (hence off-farm migration), a complete accounting of opportunity costs of outputs produced on the farm and a sound partition, following opportunity cost principles, of returns among the factors of production.

Further improvement of the technical aspects of the model would require bringing into the research more agronomic and dairy science knowledge, i.e., agronomists and dairy scientists, so that the agronomic and biological deficiencies of the model would be more soundly dealt with.

The two priority aspects of the model where the agronomists and dairy scientists input would yield high payoffs in terms of improved model validation are:

1. A more detailed model of grass growth explaining, among other phenomena, the interaction of grass and grazing animals during the grazing season.

2. Development of a model component explaining the seemingly shifting priority between milk production and weight maintenance during the first weeks of lactation and the ability of the cow to mobilize fat tissue to bridge energy deficit situations. Differences among individual cows in the same lactation as to performance should also recieve attention.

Other aspects of the model that require further expansion are:

3. Determination of the grass growth curve of irrigated pasture.

4. Complete specification of the yield-fertilizer response functions.

5. Definition of labor needs temporal profile as a function of equipment endowment, herd size, land base structure and size, and cropping program. Development of a mechanism matching labor requirements to labor supplied by the farm family and eventual surplus or deficits. The eventuality

of off-farm work for the smaller farms should be explored and accounted for in the model since this will affect the opportunity cost accounting for the farm.

6. Incorporate randomness in those facets of the model where it is essential, i.e., forage and crop production, cows biological performance, marketing risks.

As we mentioned in the model validation chapter (chapter 13), a way to validate the model is to create in the experimental station a farmlet reproducing the same initial conditions and management policies that could be fed into the model. Model results would then be compared with the data generated by the real system and verification testing could be performed. Fine-tuning of many model parameters would also result from this procedure. Another and likely more promising avenue for model validation would be to check model operation against actual farm operation in order to validate and fine-tune the model against actual farm data.

Once the model has been satisfactorily validated, that is the deficiencies we have listed have been removed, and the model expanded along the lines described above, a whole set of improved analysis could be conducted on it. The mode of operation of the model is the classical budgeting procedure: Alternatives are defined, investments, prices, costs and management policies are fed into the model and economic implications of every alternative are computed and then compared on the basis of a common denominator.

The following types of analysis can be conducted on the model:

1. We have seen that the best feeding policy, which in the model is operationalized through the parameter AZ(I), is dependent upon the prices of milk and concentrate. The analysis should be made for different milk and concentrate prices to scan the possible range of price variations. Regression analyses should be performed on those observations. The resulting function, with the feeding policy parameter, AZ(I), as a dependent variable and the price of milk and of concentrate as the independent variables, could then be incorporated into the model thus endogenizing the feeding policy optimization procedure.

2. A whole new set of problems appear when we take into account the unavoidable uncertainties surrounding the dairy farming systems. The extend of imperfect knowledge faced by the farmers must be investigated first and then appropriate policies for dealing with lack of knowledge must be developed. These policies may involve learning, information systems and such insurance schemes as understocking, additional grain purchases, small scale irrigation schemes, chance taking, etc. Accesion into the EEC will create new unknowns for Spanish farmers. Adjusting to such imperfection in knowledge, especially

marketing risks, will alter the economic consequences of the growth process which should be reexamined. Learning as well as the expected utility hypothesis should be incorporated into the analysis of decision making under uncertainty.

3. For the smaller farms an important problem consists in deciding whether to invest in expensive cropping machinery that considering their small farms could be underused, or having part of their machine work performed by outsiders under a custom work system.

4. Further expansion or eventual contraction of the farm business after the vertical growth strategy has been implemented, or after accesion into the EEC has been achieved, may take three form: (i) Renting (in or out) of pasture land on medium-term conditions; (ii) Purchase or sale of land. (iii) Irrigation of the owned pasture. These three avenues for farm expansion (the first two for farm contraction) have different learning, financial, insurance, chance taking, and growth implications that may be examined with the model. The determination of which types of farms contract and which expand constitute a research prioritie.

5. For every farm size the best asset organization, i.e., housing system, feeding and milking machinery, tractor size and cropping machinery, etc, must be investigated.

This investigation would naturally lead to a consequent analysis of economies of size for Galician dairy farms and the Galician dairy industry and to an assessment of the farm expansion-contraction processes mentioned above.

6. Interregional, intersectoral, and international analysis of comparative advantage and efficiency will require the development of cost data which can be obtained from the model.

7. The model could be used to assess, at the farm level, macropolicies directed at the dairy farm sector or at the agricultural sector in general such as, price policies, taxation policies, credit policies, etc. For instance, seasonal price policies which may result in shifting the cycle of the dairy herd, may be investigated.

In summary, the model, once completely developed and satisfactorily validated, promises to be of use in a wide variety of farm management analysis of farms with different land size and land structure. The model is especially well suited for performing an exhaustive exploration of the production function of the dairy farm business, uncovering aspects of performance poorly known and orienting research towards areas of the business where more knowledge would yield the highest payoffs in terms of enhanced efficiency and returns. The model is also able to assess growth processes under a variety of assumptions concerning, initial asset organization, investment alternatives, credit conditions and marketing environment. Finally, the model could be used as a component of macromodels addressing industry-wide issues.

APPENDICES

APPENDIX 1

APPENDIX 1

SWITCHS

ALL SUBR

(i)	KSWTPRG = 1	DSPRG1 = .275 Winter births	
	= 2	DSPRG2 = .04 Fall births	

Parturition takes place at different time

SUBR DHERD

(ii)	KSWT2 = 0	Herd stabilizer	is CLVGRW	
	= 1	,,	,, HFGRWT	
	= 2	,,	,, COWGRW	

SUBR NUTIMP

(iii)	KSWT3 = 1	CMERLC(I) is equal	to Recommended	
	= 2	,, ,,	to input	

SUB NUTIMP

(iv)	KSWT4 = 1	DMI is inputed proportion of WHTLC
	= 2	,, is input
(v)	KSWT5 = 1	NEme computed according to equation
	= 2	NEme ,, ,, to table NRC guidelines
		Keep KSWT5 = 1
(vi)	KSWT6 = 1	Protein computed by factorial method
	= 2	,, ,, by NRC tables

Keep always KSWT6 = 2

(vii) KSWTDRY = 1 DMILC is inputed proportion of WHTLC

= 2 ,, is input

During DRY PERIOD

SUB NUTIMP

(viii) KSWT7 = 1 CMERH is equal to Recommended

= 2 ,, is input

(ix) KSWT8 = 1 DMI__MX(I) is defined as proportion (according to NRC table) of WHT__(I)

= 2 DMI__MX(I) is defined according to equations, Keep KSWT8 = 2 when KSWT3 = 2

SUB DHERD

(x) KSWT9 = 1 HEIFNPG are sold at NTPRG

= 2 HEIFNPG are retained in Herd

SUB NUTIMP

(xi) KSWT11 = 1 Concentrates elasticity factor FCPC(I) shut off

= 2 Concentrates elasticity factor FCPC(I) on

Keep KSWT11 = 1

SUB FEEDACC

(xii) KTPRINT = 2 Print a subset of all data possible in FEEDACC

= 1 Print all

SUB FEEDAC

(xiii)	KSWT12 = 1	Having KSWT3 = 2, it allows for directly defining diets by fixing amounts of concentrates fed to cows at different periods
	= 2	Having KSWT3 = 2, it allows for directly defining diets by fixing percentage of concentrate on diets to cows
(xiv)	KDETPRT = 1	Print DT by DT data of all subroutines
	= 2	Print only end-of-year financial summary results

SUB PLTAINV

(xv)	KINVST = 1	No new investment process takes place
	= 2	A whole new investment program starts

SUB PLTAINV

(xvi)	KSWT13 = 1	Farmland value is not included in longterm assets computation
	= 2	Farmland value is included

SUB FINACC

(xvii)	KSWT14 = 1	Farm family living expenditures and savings is computed as a residual
	= 2	FFEXPSV is set equal to target, an annual loan will be taken if a deficit of cash arises

MAIN

(xviii)	KSIMRUN = 1	SYMILK and other sensitivity analysis are made
	= 2	No sensitivity testing

APPENDIX 2

APPENDIX 2

TABLE A2-1

Simulated Pattern of Change of Total Crude Protein Requirement of Lactating Cows.

Week	gr CP/day TCPLC(6)	Week	gr CP/day TCPLC(6)
1	686.	26	2082.
2	644.	27	2028.
3	1031.	28	2501.
4	2011.	29	1943.
5	2254.	30	1885.
6	2419.	31	1876.
7	2536.	32	1767.
8	2622.	33	1707.
9	2685.	34	1647.
10	2730.	35	1587.
11	2755.	36	1526.
12	2767.	37	1464.
13	2770.	38	1581.
14	2836.	39	1529.
15	2827.	40	1472.
16	2813.	41	1236.
17	2795.	42	1176.
18	2404.	43	1114.
19	2382.	44	1047.
20	2397.	45	901.
21	2326.	46	864.
22	2291.	47	827.
23	2255.	48	787.
24	2218.	49	745.
25	2180.	50	700.

TABLE A2-2

Simulated Pattern of Change of Concentration of ME and CP of Silage during the Year.

Week	Mcal/kg DM CMESILG	gr CP/kg DM CPTSILG	Week	Mcal/kg Dm CMESILG	gr CP/kg Dm CPTSILG
1	2.187	74.053	26	2.304	97.577
2	2.187	74.053	27	2.320	101.120
3	2.187	74.053	28	2.307	98.733
4	2.187	74.053	29	2.293	96.346
5	2.187	74.053	30	2.282	94.859
6	2.187	74.053	31	2.270	93.371
7	2.187	74.053	32	2.258	91.884
8	2.187	74.053	33	2.247	90.396
9	2.187	74.053	34	2.235	88.908
10	2.187	74.053	35	2.224	87.421
11	2.187	74.053	36	2.212	85.933
12	2.187	74.053	37	2.201	84.446
13	2.187	74.053	38	2.189	82.958
14	2.310	97.000	39	2.260	82.327
15	2.310	97.000	40	2.252	81.344
16	2.310	97.000	41	2.244	80.360
17	2.310	97.000	42	2.259	84.403
18	2.310	97.000	43	2.250	82.824
19	2.310	97.000	44	2.240	81.225
20	2.376	110.548	45	2.230	79.636
21	2.376	110.548	46	2.221	78.519
22	2.345	102.765	47	2.213	77.403
23	2.335	101.468	48	2.204	76.286
24	2.324	100.171	49	2.195	75.170
25	2.314	98.874	50	2.187	74.053

TABLE A2-3

Simulated Patterns of Change of Weights of Growing Calves, Heifers and Lactating Cows during the Year.

Week	WHTGCL	WHTGH	WHTLC(6)	WeeK	WHTGCL	WHTGH	WHTLC(6)
1	311.	551.	631.(5)	26	177.	425.	596.
2	316.	554.	631.(5)	27	183.	432.	597.
3	46.	316.	570.	28	189.	439.	598.
4	49.	319.	570.	29	195.	445.	599.
5	53.	322.	570.	30	200.	452.	600.
6	60.	325.	570.	31	206.	459.	601.
7	66.	329.	570.	32	211.	466.	602.
8	73.	332.	570.	33	216.	473.	603.
9	79.	335.	570.	34	221.	480.	604.
10	86.	338.	570.	35	227.	487.	606.
11	92.	341.	571.	36	232.	495.	607.
12	99.	344.	572.	37	238.	502.	609.
13	106.	347.	573.	38	243.	510.	611.
14	111.	353.	576.	39	248.	517.	612.
15	116.	359.	580.	40	254.	525.	614.
16	121.	364.	584.	41	259.	533.	616.
17	126.	370.	589.	42	264.	541.	619.
18	132.	376.	589.	43	269.	549.	621.
19	138.	382.	589.	44	275.	556.	625.
20	144.	388.	590.	45	280.	564.	627.
21	149.	394.	590.	46	285.	572.	628.
22	156.	400.	591.	47	290.	580.	630.
23	161.	406.	592.	48	296.	587.	631.
24	166.	413.	594.	49	301.	595.	631.
25	172.	419.	595.	50	306.	603.	631.
				1	311.	608.	631.
				2	316.	612.	631.
				3	46.	316.	571.(7)

APPENDIX 3

APPENDIX 3

TABLE A3-1

Values of Parameters of Subroutines DHERD and NUTIMP.

Parameter	Definition	Value
BRH	Birth rate of heifers	.7
BRC	Birth rate of cows	.85
PLRCL	Death rate of growing calves	.03
PLRH	Death rate of heifers	.03
FM	Fat matter content of milk (%)	3.5
GHDMIPR	Proportion of dry matter intake of growing heifers to body weight	.024
PGRATE	Growth rate of products of conception	.0106
GZAL	Grazing allowance	.20
WHTGCL	Starting value of growing calves weight (kg)	306.
WHTGH	Starting value of heifers weight (kg)	547.
WHTLC(1)	Starting value of weight of cows in 1st lactation (kg)	536.
WHTLC(2)	Starting value of weight of cows in 2nd lactation (kg)	562.
WHTLC(3)	Starting value of weight of cows in 3rd lactation (kg)	581.
WHTLC(4)	Starting value of weight of cows in 4th lactation (kg)	609.
WHTLC(5)	Starting value of weight of cows in 5th lactation (kg)	626.
WHTLC(6)	Starting value of weight of cows in 6th lactation (kg)	635.
WHTLC(7)	Starting value of weight of cows in 7th lactation (kg)	632.
NGEST	Length of gestation period (DT'S)	38.
NLACT	Length of lactation period (DT'S)	41.
NTPREG1	Time to pregnancy (in DT'S)	17.
TN1	Scaling factor of dry matter intake equation	1.05
DWGNGH	Desired rate of growth of heifers (kg/day)	.5
DWGNGCL	Desired rate of growth of growing calves (kg/day)	.9
FATMT	Kilograms of fat produced by day (average)	.79
CFPC	Crude fiber per cent in dry matter intake	16.66

TABLE A3-2

Values of Parameters of Subroutine FORAGE

Parameter	Definition	Value
NTCLS1	Time to chose for 1st silage (DT'S)	14.
NTCUT1	Time to cut 1st silage (DT'S)	20.
NTCLS2	Time to close for 2nd silage (DT'S)	21.
NTCUT2	Time to cut 2nd silage (DT'S)	27.
NTCLS3	Time to close for 3rd silage (DT'S)	37.
NTCUT3	Time to cut 3rd silage (DT'S)	42.
NTOTHV	Time to harvest winter cereal crop (DT'S)	14.
NTCNHV	Time to harvest corn crop (DT'S)	39.
NTSFS	Time to activate 1st yield delay (DT'S)	6.
WTSSS	Time to activate 2nd yield delay (DT'S)	30.
DEL1	Mean time of 1st yield delay (DT'S)	13.
DEL2	Mean time of 2nd yield delay (DT'S)	9.
GSYLD1(1)	Grass yield in pasture in 1st year of development during 1st growth season (kg DM/ha)	2800.
GSYLD1(2)	Grass yield in pasture in 2nd year of development during 1st growth season (kg DM/ha)	3600.
GSYLD1(3)	Grass field in pasture in 3rd year of development during 1st growth season (kg DM/ha)	4400.
GSYLD1(4)	Grass yield in pasture in 4th year of development during 1st growth season (kg DM/ha)	5200.
GSYLD2(1)	Grass yield in pasture in 1st year of development during 2nd growth season (kg DM/ha)	700.
GSYLD2(2)	Grass yield in pasture in 2nd year of development during 2nd growth season (kg DM/ha)	900.
GSYLD2(3)	Grass yield in pasture in 3rd year of development during 2nd growth season (kg DM/ha)	1100.
GSYLD2(4)	Grass yield in pasture in 4th year of development during 2nd growth season (kg DM/ha)	1300.
GSYAT1	Grass yield in artificial pasture, 1st season, (kg DM/ha)	6800.
GSYAT2	Grass yield in artificial pasture, 2nd season, (kg DM/ha)	1700.
FNTAT1	Nitrogen application to pasture, 1st season, (kg N/ha)	70.
FNTAT2	Nitrogen application to pasture,	

	2nd season, (kg N/ha)	30.
FKPSTPH	Potassium application to pasture, (kg K/ha)	60.
FPPSTPH	Phosphorus application to pasture, (kg Ph/ha)	100.
OTYLD	Yields of winter cereal crop (kg DM/ha)	7970.
CRNYLD	Yields of corn crop (kg DM/ha)	10510.
FTOT	Nitrogen application to winter cereal crop (kg N/ha)	180.
FTCRN	Nitrogen application to corn crop (kg N/ha)	180.
CMEOTH	Content on metabolic energy of winter cereal (Mcal/kg DM)	2.31
CMEGSIN	Content on metabolic energy of grass grazed (Mcal/kg DM)	2.412
CMECRN	Content on metabolic energy of grass grazed (Mcal/kg DM)	2.42
CPTGSIN	Content on crude protein of grass grazed (gr CP/kg DM)	180.
CPTOTH	Content on crude protein of winter cereal (gr CP/kg DM)	97.
CPTCRN	Content on crude protein of corn (gr CP/kg DM)	84.
TN3	Grass utilization by herd (%)	90.
AVSILG	Starting available silage (kg DM)	15000.

TABLE A3-3

Values of Parameters of Subroutine FEEDACC

Parameter	Definition	Value
NTSGRZ1	Time to start 1st grazing season (DT'S)	12.
NTEGRZ1	Time to end 1st grazing season (DT'S)	25.
NTSGRZ2	Time to start 2nd grazing season (DT'S)	34.
NTEGRZ2	Time to end 2nd grazing season (DT'S)	44.
CNCMEC#	Content of metabolic energy in concentrate (Mcal/Kg DM)	3.28
GCPKCN	Content of crude protein in concentrate (gr CP/kg DM)	187.

TABLE A3-4

Values of Parameters of Subroutine PLTAINV

Parameter	Definition	Value
OMEGA	Percent of initial investment loan financed	.80
GAMMA	Percent of initial loan in long-term conditions	1.
DCSTPS	Development cost of pasture (pts/ha)	55000.
CSTIRR	Irrigation investment cost (pts/ha)	0.
PRFNC	Fencing costs (pts/Km)	110000.
PRWTP	Water points investment cost (pts/unit)	20000.
PRSTLLS	Cost of stalls (pts/unit)	15000.
PRSTBL	Cost of stable (pts/unit)	100000.
PRHLRM	Cost of health installations (pts/unit)	45000.
PRSILPF	Cost of silo-platform (pts/m)	600.
PRMWELL	Cost of manure well (pts/m)	750.
PRPARM	Cost of milking parlor (pts/unit)	200000.
PCOWLT1	Price of a pregnant cow in first lactation	95000.
PCOWNP1	Price of a nonpregnant cow in first lactation (pts)	90000.
PCOWLT2	Price of a pregnant cow in second lactation (pts) –	93000.
PCOWWP2	Price of a nonpregnant cow in second lactation (pts)	88000.
PKCOW	Price of beef meat (pts/kg lwt)	80.
PRMILK	Price of milk (pts/lt)	19.3
PKGCL	Price of veal meat (pts/kg lwt)	165.35
PRCONC	Price of concentrate (pts/kg)	16.8
TXPST	Tax on pastureland (pts/ha)	1000.
TXCRPL	Tax on cropland (pts/ha)	1000.
RTILOAN	Intermediate-term interest rate	.13
RTLLOAN	Long-term interest rate	.17
RTALOAN	Annual interest rate	.20
PHFPRG	Price of pregnant heifers (pts)	60000.
PHFNPG	Price of nonpregnant heifers (pts)	60000.
PKHEIF	Price of beef meat (pts/kg)	136.55
PGCL	Price of growing calve 1 weel old (pts)	16000.
PRNFERT	Price of nitrogen fertilizer (pts/kg)	11.29
PRKFERT	Price of potasium fertilizer (pts/kg)	11.77
PRPFERT	Price of phosphorus fertilizer (pts/kg)	6.88

TABLE A3-5

Values of Parameters of Subroutine FINACC

Parameter	Definition	Value
EQDEPR	Percent of equipment depreciated annually	.083
DPRIMP	Percent of improvments ,, ,,	.02
DEPRBAO	Percent of buildings & others ,, ,,	.05
DPRHRD	Percent of dairy herd ,, ,,	.12
GRACEI	Grace period on intermediate loans (years)	0.
DRLOANI	Duration of intermediate loans (years)	3.
GRACEL	Grace period of long-term loans (years)	0.
DRLOANL	Duration of long-term loan (years)	12.
PCCONT	Contingency percent on total operating costs	.05
PCBAO	Percent of investment in building & others spent annually in repairs and maintenance	.02

BIBLIOGRAPHY

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1. Abkin, Michael H. Policy Making for Economic Development: A Systems Simulation of the Agricultural Economy of Southern Nigeria. Staff paper series 74-4. East Lansing, MI., Department of Agricultural Economics, MSU, 1972.

2. Agencia de Desarrollo Ganadero. "Controles en Explotaciones de Vacuno Lechero del Norte y Galicia. Analisis de los Resultados 1977-1981." Boletin No.15, Ministerio de Agricultura, Pesca y Alimentacion, Madrid, Septiembre, 1982.

3. Agra Europe, Special Report No.6. "The Agricultural Implications of EEC Enlargement, Part III: Spain." Agra Europe (London) Ltd. Agroup House, 16, Landsdale Gardens, Turnbridge Wells, Kent TN1 JPD, United Kingdom.

4. Anderson, J.R.. "Simulation: Methodology and Application in Agricultural Economics." Review of Marketing and Agricultural Economics, 43: 3-55, 1974.

5. Bartola, Alexandro. "A Dynamic Model of the Italian Cattle and Beef Sector." European Review of Agricultural Economics.

6. Bath, D.L. and Loren F. Bennett. "Development of a Dairy Feeding Model for Maximizing Income above Feed Cost with Access by Remote Computer Terminals." Journal of Dairy Science, 63: 1379-1389, 1980.

7. Black, J.Roy and J. Hlubik. "Basics of Computerized linear Programs for Ration Formulation." Journal of Dairy Science, 63: 1366-1378, 1980.

8. Broster, W.H. and G. Alderman. "Nutrient Requirements of the High Yielding Cow." Livestock Production Science, 4: 263-275, 1977.

9. Brown, C.A., P.T. Chandler, and J.B. Holter. "Development of Predictive Equations for Milk Yield and Dry Matter Intake in Lactating Cows." Journal of Dairy Science, 60: 1739-1754, 1977.

10. Brown, Maxwell L.. Farm Budgets. World Bank Staff Occassional Papers, # 29. John Hopkins University Press, 1979.

11.Bywater, A.C. and J.B. Dent. "Simulation of the Intake and Partition of Nutrients by the Dairy Cow: Part I." Agricultural Systems, pp 245-260, 1976.

12.Bywater, A.C.. "Simulation of the Intake and Partition of Nutrients by Dairy Cow: Part II. Agricultural Systems, pp 261-279, 1976.

13.Candler, W. and W. Cartwright. "Estimation of Performance Functions for Budgeting and Simulation Studies." American Journal of Agricultural Economics, 51: 159-169, February, 1969.

14.Cebrian del Moral, M.. "La Hierba como Alimento para los Rumiantes." El Campo, No.86, Abril-Junio, 1982.

15.Coffey, J. and W. Toussaint. "Some Economic Aspects of Free Choice Feeding of Dairy Cows." Journal of Farm Economics, 45: 1213-1218, December, 1956.

16.Colino, Jose. "Galicia y la P.C.A." Agriculture y Sociedad, No.16, Julio-Septiembre, Madrid, 1980.

17.Colino, Jose. "El Modelo Espanol de Desarrollo Ganadero y la Competitividad de las Producciones Carnicas del Sector Vacuno." Investigaciones Economicas, No.18, Mayo-Agosto, 1982.

18.Colino, Jose. "La Ganaderia Bovina Gallega ante la CEE." Revista de Estudios Agro-Sociales, No.116, Julio-Septiembre, 1981.

19.CRIDA - 01. Memoria 1978. Centro Regional de Investigacion y Desarrollo Agrario # 1. La Coruna.

20.CRIDA - 01. Memoria 1979. ,, ,,

21.CRIDA - 01. Memoria 1980. ,, ,,

22.CRIDA - 01. Memoria 1981. ,, ,,

23.Dean, G.W., D.L. Bath and S. Olayide. "Computer Program For Maximizing Income above Feed Cost from Dairy Cattle." Journal of Dairy Science, 52: 1008-1016, 1969.

24.Dent, J.B. and J.R. Anderson. Systems Analysis in Agricultural Management. John Wiley & Sons, Australasia PTY LTD, 1971.

25.Diaz Patier, E.. "Relacion de Algunhas Caracteristicas Socio-economicas coa Adopcion de Practicas Novas por

Labregos da Meseta Interior Galega." Revista Galega de Estudios Agrarios, 2, 1979.

26. Diaz Patier, E.. "La Ganaderia Espanola ante la Integration en la CEE." Revista de Estudios Agro-Sociales, No.116, Julio-Septiembre, 1981.

27. Diaz Patier, E. and F. Sineiro Garcia. "Factores que Limitan la Utilizacion de las Tierras a Monte. Estudio de una Zona de la Meseta Interior Gallega." Communicaciones I.N.I.A., Serie: Economia y Sociologia Agrarias, No.7, 1979.

28. Diaz Patier, E. and F. Sineiro Garcia. "Factores que Limitan la Utilizacion de las Tierras a Monte. II. Analisis de Ocho Municipios en Diferentes Zonas de Galicia." Communicaciones I.N.I.A., Serie: Economia y Sociologia Agrarias, No.11, 1981.

29. Eisgruber, L.M. and G.E. Lee. "A Systems Approach to Studying the Growth of the Farm Firm." In, Systems Analysis in Agricultural Management. J.R. Anderson and J.B. Dent. Ed. John Wiley & Sons, Australasia PTY LTD, 1971.

30. Gonzalez de Chaves Fernandez, A.. "El Uso de la Simulacion para el Estudio de un Sistema Extensivo de Produccion Animal." Communicaciones INIA, Serie: Economia y Sociologia Agraria, No.9, 1981.

31. Gonzalez Santillana, R. and A. Gonzalez Arraez. "Produccion de Leche Basada en Pasto." El Campo, No.86, Abril-Junio, 1982.

32. Gonzalez Santillana, R., A. Gonsalez Arraez and M. de los Angeles Barrecheguren. Effecto de la Suplementacion con Concentrado sobre la Produccion y Calidad de Leche de Vacas en Pastoreo, con Partos Agrupados a la Salida del Invierno. CRIDA - 01, la Coruna, 1981.

33. Harsh S.B., L.J. Connor and G.D. Schwab. Managing the Farm Business. Prentice-Hall, Inc., Englewood Cliffs, N.J. 07632, 1981.

34. Heady, E.O., J. Madden, N. Jacobson and A. Freeman. "Milk Production Functions Incorporating Variables for Cow Characteristics and Environment." Journal of Farm Economics, 46: 1-19, February 1964.

35. Heidhues, T.. "Change: A Permanent Phenomenon." European Review of Agricultural Economics, Vol.3, 3(2/3), 1972.

36. Hlubik, J.. An Economic Evaluation and Replacement Model for the Lactating Dairy Cow Including Biological Components. M.S. Thesis, Michigan State University, 1979.

37. Hoover, L., P. Kelley, G. Ward, A. Feyerherm and R. Chodda. "Economic Relationships of Hay and Concentrate Consumption to Milk Production." American Journal of Agricultural Economics, 49: 64-78, February, 1967.

38. Hottel, B.J. and B.L. Gardner. "The Rate of Return to Investment in Agriculture and Measuring Net Farm Income." American Journal of Agricultural Economics, 65: 553-557, August, 1983.

39. Irwin, J.. "Discussion: Firm Growth Research Opportunities and Techniques." Journal of Farm Economics, 48: 1532-1535, December, 1966.

40. Jaske, Michael R. "System Simulation Modeling of a Beef Cattle Enterprise to Investigate Management Decision Making Strategies." Ph.D. Dissertation, Michigan State University, 1976.

41. Johnson, Glenn L. and G.E. Rossmiller. "Improving Agricultural Decision Making: A Conceptual Framework." In Agricultural Sector Planning. G.E. Rossmiller. Ed. Agricultural Sector Analysis and Simulation Projects, Depart. of Agr. Econ., Michigan State University, East Lansing, Michigan, 1978.

42. Johnson, S.R. and G.C. Rausser. "Systems Analysis and Simulation: A Survey of Applications in Agricultural and Resource Economics." In A survey of Agricultural Economics Literature. Vol.2, Ed. L.R. Martin, University of Minnesota Press, Minneapolis, 1977.

43. Kellog, D.W., N. Scott Urguhart and A.J. Ortega. "Estimating Holstein Lactation Curves with a Gamma Curve." Journal of Dairy Science, 60: 1308-1315, 1977.

44. Lloveras Vilamanya, J.. "Comparacion Productivo-Economica de las Rotaciones de Cultivos y Praderas para la Produccion de Leche en Galicia." I Xornadas Agrarias Galegas, Santiago de Compostela, 1983.

45. LLoveras Vilamanya, J.. Personal Communication, 1984.

46. LLoveras Vilamanya, J.. "Cultivos y Rotaciones de Cultivos." El Campo, No.86, Abril-Junio, 1982.

47. Lovering J. and J.A. McIsaac. "A Forage-Milk Production

Model." Journal of Dairy Science, 64: 798-806, 1981.

48.Manestch, T.J.. "Theory and Practice of Model Building and Simulation." In Agricultural Sector Planning, Ed. G.E. Rossmiller, Michigan State University, East Lansing, Michigan, 1978.

49.Manestch, Thomas J. et al. A Generalyzed Simulation Approach to Agricultural Sector Analysis, with Special Reference to Nigeria. East Lansing, Mi., Michigan State University, November 30, 1971.

50.Manestch, T.J. and Park, G.L. Systems Analysis and Simulation with Applications to Socio-Economic Systems. Parts I and II. East Lansing, MI., Department of Electrical Engineering and Systems Science, Michigan State University, 1974.

51.Manestch, T.J., A.A. Ramos, and S.L. Lenchner. "Computer Simulation Analysis of the Program for Modernizing Cotton Production in Northeast Brazil." Department of Electrical Engineering and Systems Science, Michigan State University, 1968.

52.Ministerio de Agricultura. Programa de Desarrollo Ganadero Nacional (Ganaderia Ligada a la Tierra). Direccion General de la Produccion Agraria. Madrid, Enero, 1980.

53.Ministerio de Agricultura. Anuario de Estadistica Agraria 1978. Ministerio de Agricultura, Pesca y Alimentacion, 1978.

54.Moreno Gonzalez, J.. "Investigaciones sobre Tecnologia del Maiz Grano y Forrajero en las Explotaciones Agricolas." El Campo, No.86, Abril-Junio, 1982.

55.National Research Council. Nutrient Requirements of Dairy Cattle. Fifth revised edition, 1978.

56.Naylor, T.H., J.L. Balintfy, D.S. Burdick and K. Chu. Computer Simulation Techniques. John Wiley, New York, 1966.

57.Paris, Q., F. Malossini, A. Pilla, and A. Romita. "A Note in Milk Production Functions." American Journal of Agricultural Economics, 52: 594-598.

58.Pelach Paniker, A.. "Impacts on Selected Feedgrain and Livestock Enterprises of Spain's Accession to the European Economic Community." M.S. Dissertation, Michigan State University, 1981.

59.Peterson, E.W.F.. "Adjustment of the Spanish Feedgrain and Livestock Sectors Following Accession to the European Community." Ph.D. Dissertation, Michigan State University, 1981.

60.Peterson, E.W.F., A.Pelach Paniker, H.M. Riley and V.L. Sorenson. Spain 's Entry into the European Community. Effects on the Feed Grain and Livestock Sectors. U.S.D.A. ERS, Foreign Agricultural Economic Report 180, April, 1983.

61.Petit, M.. "Relationships Among Various Aspects of Agricultural Change." European Review of Agricultural Economics, Vol.3, 3(2/3), 1976.

62.Pineiro Andion, J.. "Los Prados." El Campo, No.86, Abril-Junio, 1982.

63.Posada, A.. "A Simulation Analysis of Policies for the Northern Columbias Beef Cattle Industry." Ph.D. Dissertation, Michigan State University, 1974.

64.Red Contable Agraria Nacional. Resultados Empresariales 1979. Ministerio de Agricultura, Pesca y Alimentacion, Madrid, 1979.

65.Red Contable Agraria Nacional. Resultados Empresariales 1980. Ministerio de Agricultura, Pesca y Alimentacion, Madrid, 1978.

66.Redman, J.C.. "Economic Aspects of Feeding for Milk Production." Journal of Farm Economics, 34: 333-345, August, 1952.

67.Renborg, U.. "Growth of the Agricultural Firm: Problems & Theories". Review of Marketing and Agricultural Economics, 38: 51-101, 1970.

68.Rodriguez Epelde, C., C. Posada Naria and R. Gonzales Santillana. "La Produccion de Leche en Galicia." Mimeo, 1982.

69.Rodriguez, M., R.-Zuniga, T. Ruiz-Huerta Carbonell, and R. Soria Gutierrez. El Desarrollo Ganadero Espanol: El Sector Vacuno. Departamento de Economia Agraria del C.S.I.C., 1979.

70.Rossmiller, G.E. et al. Agricultural Sector Planning: A General Systems Simulation Approach. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan, 1978.

71. Schaeffer, L.R., C.E. Minder, I. McMillan and E.B. Burnside. "Nonlinear Techniques for Predicting 305 Day Lactation Production of Holstein and Jerseys." Journal of Dairy Science, 60: 1636-1644, 1977.

72. Sineiro Garcia, F.. "Aspectos del Uso Ganadero del Monte para la Produccion de Carne." Mimeo, CRIDA - 01, la Coruna.

73. Sineiro Garcia, F.. "Tecnicas de Transformacion del Monte en Pasto." Communicacion Presentada al III Seminario INIA/SEA sobre Pastos, Forrages y Produccion Animal, Mabegondo (La Coruna), Noviembre, 1977.

74. Skees, J.R.. "A Multiple Farm Simulation Model of the Impact of Income Tax and Commodity Policies on the Opportunities for Growth of Varied Size Corn/Soybean Farms." Ph.D. Dissertation, Michigan State University, 1981.

75. Stewart, H.M., E.B. Burnside, J.W. Wilton and W.C. Pfeiffer. "A Dynamic Programming Approach to Culling Decisions in Commercial Dairy Herd." Journal Dairy Science, 60: 602-617, 1976.

76. USDA/ESCS. Compendium of Agricultural Statistics: Spain. Foreign Agricultural Economic Report, March, 1980.

77. Walker, O. and J. Martin. "Firm Growth Research Opportunities and techniques." Journal of Farm Economics, 48, December, 1966.

78. Wood, P.D.P.. "Algebraic Models of the Lactation Curves for Milk, Fat and Protein Production, with Estimates of Seasonal Variation." Animal Production, 22: 35-40, 1976.

79. Wright, A.. "Farming Systems, Models, and Simulation." In Systems Analysis in Agricultural Management. J.R. Anderson and J.B. Dent. Ed. John Wiley & Sons, Australasia PTY LTD, 1971.

80. Zusman, P. and A. Amiad. "Simulation: A Tool for Farm Planning under Conditions of Weather Uncertainty." Journal of Farm Economics, 49: 574-594, August, 1965.