Staff Paper Series

STAFF PAPER P72-3 JANUARY 1972

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Staff Paper P72-3 January 1972

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The research on which this paper is based was conducted under the auspices of the University of Minnesota Economic Development Center, The Office of International Agricultural Programs, and the Agricultural Extension Service. It was financed, in part, through grants from the Rockefeller Foundation and the U. S. Agency for International Development.

Staff Papers are published without formal review within the Department of Agricultural and Applied Economics.

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I. Introduction

Effective agricultural planning requires realistic projections of the production and utilization of agricultural products. On the production side, the task for annual crops is fairly easy. The production cycle is annual. Stocks serve primarily as an input to future consumption, not to future production. And the seed component is small and measurable. For livestock, the projection task is not so easy -- particularly when the production cycle is not annual.

Like crops, animal production is a biological process, subject to a variety of unpredictable environmental influences and variables such as drought and disease. But, the potential for increasing production is also affected by the lengthy regeneration interval. It normally requires three to four years between the conception of a large ruminant and that of its progeny. With small ruminants, pigs, and poultry, the time interval is much less. Stage of development, weather, and other factors influence the production interval.

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Two recent studies of agricultural projections* have incorporated supply estimates for large animals. Two techniques were used, the method depending on the data available among countries studied. The first technique projected global estimates of herd offtake using extrapolations of past output trends. The second used estimates which accounted for developments in breeding herds, slaughter by age groups, birth rates, and mortality rates. The latter procedure seems desirable as it permits estimates based on structural changes occurring in (1) function of the animals (beef, dairy, draught, etc.); (2) slaughtering rates and ages; and (3) changes in birth and mortality rates.

The use of flow charts as a conceptual device and accounting tool seems appropriate as both stock and flow variables are involved and changes in these variables can be traced through the system for subsequent time periods. This allows adjustments of previous estimates in the event of large-scale slaughter of animals, disease epidemics or poor weather conditions resulting in abnormal mortality and birth rates.

Flow charts are also useful aids in data collection as the stock and flow variables plus the biological and technical parameters

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* Organization for Economic Co-operation and Development, Agricultural Projections for 1975 and 1985: Europe, North America, Japan, Oceania (Paris, 1968).

United Nations, Food and Agriculture Organization. Provisional Indicative World Plan for Agricultural Development, Vol. 1, (C69/4), August 1969.

are clearly identified. Thus, important subsets of the livestock population and the parameters which are expected to change under agricultural development are set forth.

In this paper, the charts are prepared without reference to any particular geographic region or planning exercise. Put in different words, numbers are used only for illustration. Individuals involved in agricultural development planning will need to modify them to fit particular agricultural situations.

II. Flowcharts for Livestock Supply Projections

The flow chart produces estimates of the production component in the supply-utilization identity often used in commodity projections:

$$P = C + L + X + \Delta S$$

where P = production of the commodity

C = consumption of the commodity

L = losses and stocks for reproduction

X = net export

ΔS = change in stocks.

In this identity, production is set against total use for each commodity. In a developing economy it may not be easy to coordinate supply and demand trends for livestock. One should identify factors which determine herd size, age structure, sex structure, and production. Ideally, one should begin with total herd size and composition in a base period.

Information must be available or assumptions made about fertility rates, slaughter rates, birth rates, yields and mortality rates. Of course, these will vary by period and by species.

The procedure suggested is a series of flow charts depicting stock variables linked over time by the flow variables (losses from death, slaughter, herd additions). The technique is illustrated by constructing a flow chart for cattle.

Composition of the herd:

At the beginning of the base period, females in the herd consist of cows for reproduction, heifers born last period, and heifers born two periods past. The heifers become reproductive females during their third year. Some of the heifers between two and three years of age are slaughtered because they are deemed unfit to reproduce.

The males are composed of adult bulls for reproduction and young bulls and steers in three age categories: less than two years; two-three years; and three-four years. The males retained for breeding purposes become active at four years of age. Some of the males between the ages of three and four are selected for breeding purposes. All the rest of this category are slaughtered.

This classification represents a production pattern typical of many less developed countries. The goal of the development plan is an increase of total production by building up the national herd, increasing turnover of the existing herd, or both. The present calving and culling rates are an immediate limitation on the rate at which cattle numbers might be expanded. These rates often only maintain the current herd size. Restraining the sale of females other than those unfit for reproduction coupled with the culling of males at an advanced age are among the instruments for increasing the size of breeding herds.

Herd build-up:

The breeding herd is projected from one period to the next according to the following biological and technical parameters:

Birth rate - It is defined as the number of calves born each year per 100 cows in the breeding herd. One should note that the calving interval varies according to the state of husbandry, technology, and natural environment. The common calving interval is not in phase with a calendar year planning period. It is a function of the seasonally fluctuating level of nutrition provided by natural grasslands and local husbandry practices. In less developed countries it commonly varies from 13 to 24 months. One must be aware that a birth rate may change during the planning period as agriculture develops. It is assumed that in any given year the calves are half female and half male.

Loss rates - This is defined as the number of animals that die for each 100 animals in the herd. The loss rate is a function of husbandry practices, drought and disease. It is alterable through improved husbandry. Two loss classes are used, one for the new born and one for the rest of the herd, since it is generally higher for the new born.

Both are expected to vary from one period to the next. In total, nine loss rates are identified, one for each subclass of cattle.

Slaughter rates - Among heifers, young bulls and steers, slaughter arises from herd culls and for meat production. Slaughter heifers are selected from the 2-3 years category. Only those regarded as improper for reproduction are culled. Males are slaughtered at the age of 3-4 years. It is assumed there is no slaughter of heifers before the age of 2 and none among males before the age of 3.

All cows and adult bulls are culled and replaced on grounds of infirmity or herd improvement. The slaughter rate then depends partially on the policy of renovation of the herd. Four slaughtering rates are identified. Different rates are likely from one period to the next.

Projections:

Cattle projections are outlined in the flow chart. Symbols and abbreviations are defined in Table 1.

Each of the small boxes represents a variable to be accounted for in the cattle projections. Stock variables, those showing the composition of the herd at the beginning of each period, are grouped together at the top of the chart. The flow variables are losses, slaughter, and additions to the herd and are grouped at the bottom of the chart. Intraperiod movements between the stock and flow variables are indicated with heavy lines. Interperiod movements between the stock categories and between the stock and flow movements are indicated by thin lines. The box in the diagram representing each variable is identified with a subscripted letter. The superscript identifies the time period to which the variable belongs.

The production of new-born animals in any period represents an addition to the herd at the beginning of the next period. In this system, slaughter in any period is synonomous with consumption. Exports and imports are assumed non-existent.

Twenty-three variables are identified in each period of the livestock flow chart. Tables 2 and 3 show the values of each of the variables as functions of the appropriate parameters and, when applicable, of the value of the relevant variables in the preceding time period.

Table 2 shows the computational procedure for two periods in a cattle projection. The herd at the beginning of period I is listed as items (1) through (7). Initial values are indicated by an asterisk (*). Herd additions of females and males are items (9) and (10) respectively. Total births, item (8) are divided equally between females and males. The losses are calculated by multiplying each component of the breeding herd and the additions to the herd by the corresponding mortality rates. They are represented by items (11) through (19). Slaughter is denoted by items (20) through (23). It is calculated by multiplying the appropriate slaughtering rate times each category after subtracting the mortalities.

The breeding herd in the second period is represented by items (1) through (7) under period II, Table 2. This is the initial breeding herd plus the period I additions, minus the period I losses and slaughterings. In more detailed terms, period II cows (F_3^2) are the period I cows (F_3^1) less the mortalities and slaughter, plus the period I females (F_2^1) less their mortalities. The heifers consist of 1-2 year old females (F_1^2) which are female calves of period I (F_0^1) less their mortalities, plus 2-3 year old heifers (F_2^2) [which are the 1-2 year old heifers of period I (F_1^1) less their period I mortalities]. Procedures for the bull portion of the period II herd are similar. Adult bulls are the (M_4^1) retained from Period I plus the (M_3^1) retained from period I. Males (M_1^2), (M_2^2), and (M_3^2) are the corresponding males from period I (M_0^1), (M_1^1), and (M_2^1), less the mortalities in each group.

Table 3 outlines the general case of 'n' periods. It is, of course, obtained by using the same computational procedure as Table 2.

III. Modifications by Type and Use

As mentioned previously, the flow chart accounting framework will give realistic results only if the stock and flow variables along with the technical and biological parameters are adjusted to fit national, regional, or local conditions. The adjustment process centers on the animal type (cattle, hogs, etc.) and the animal's primary function (meat, milk, etc.). Some possible adjustments in flow chart construction by animal type and function are presented in Table 4.

Table 4. Guidelines for Flow Chart Construction by Animal Type and Function.

Animal Type	Function	Guidelines for Flow Chart Construction
Beef Cattle	Draught	Higher % of old steers, small % of breeding stock
Beef Cattle	Veal Production	Breeding cows are a large proportion of total herd
Beef Cattle	Capital Accumulation or Prestige	High proportion of non-productive animals more bulls than are needed
Water Buffalo	Draught	Same as beef cattle used for draught
Cattle, Buffalo	Milk Production	Adjustment of breeding period, feed conversion efficiency parameter may be needed
Sheep	Wool and Meat	Non-productive males may be retained for wool production purposes
Goats	Wool, meat milk	Non-productive animals retained for wool, kids slaughtered
Pigs and Poultry	Meat Meat, eggs	Feed conversion efficiency measure may be needed in each case

This procedure serves only as a guideline. Experience with local conditions, and, if necessary, preliminary livestock population sampling will be the crucial inputs for construction of a realistic model.

Simplifications may often be necessary owing to the detailed data required for construction of a complete flow chart as performed in Tables I, II, and III. For example, global estimates of mortality rates may have to suffice.

IV. Summary

This paper presents a framework for projecting, period by period, the important variables of livestock production. It is meant to help prevent two sources of livestock planning errors: (a) simple extrapolations of livestock numbers; and (b) failure to distinguish between stock variables and flow variables. Flow charts are used to show the linkage between flow variables (production, herd additions, losses) of one production period and those of subsequent periods. A breeding herd for a base period is defined. It is projected from one period to the next according to the relevant parameters including breeding interval, birth rate, mortality rate, and slaughtering rate.

The procedure is general. It may be applied to a particular geographic region or used in a planning exercise after defining and fixing the technical and biological parameters that fit the specific agricultural environment.

Table 1. Flow Chart Abbreviations and Symbols

	Period 1	Period 2	Period n
A. Stock Variables			
Adult Cows	F_3^1	F_3^2	F_3^n
Females born last period	F_1^1	F_1^2	F_1^n
Females born 2 periods past	F_2^1	F_2^2	F_2^n
Adult Bulls	M_4^1	M_4^2	M_4^n
Males born last period	M_1^1	M_1^2	M_1^n
Males born 2 periods past	M_2^1	M_2^2	M_2^n
Males born 3 periods past	M_3^1	M_3^2	M_3^n
B. Flow Variables			
Total births	B^1	B^2	B^n
Female births	F_o^1	F_o^2	F_o^n
Male births	M_o^1	M_o^2	M_o^n
Losses Adult Cows	L_1^1	L_1^2	L_1^n
Losses, F_1	L_2^1	L_2^2	L_2^n
Losses F_2	L_3^1	L_3^2	L_3^n
Losses, Adult Bulls	L_4^1	L_4^2	L_4^n
Losses, M_1	L_5^1	L_5^2	L_5^n
Losses, M_2	L_6^1	L_6^2	L_6^n
Losses, M_3	L_7^1	L_7^2	L_7^n

(continued)

(continued)	Period 1	2	n
Losses, F_o	L_8^1	L_8^2	L_8^n
Losses, M_o	L_9^1	L_9^2	L_9^n
Slaughter, F_3	S_1^1	S_1^2	S_1^n
Slaughter, F_2	S_2^1	S_2^2	S_2^n
Slaughter, M_4	S_3^1	S_3^2	S_3^n
Slaughter, M_3	S_4^1	S_4^2	S_4^n

C. Rates

Birth rate	b^1	b^2	b^n
Newborn loss rate	l_1^1	l_1^2	l_1^n
Adult loss rate	l_2^1	l_2^2	l_2^n
Slaughtering rate, F_2	s_2^1	s_2^2	s_2^n
Slaughtering rate, F_3	s_3^1	s_3^2	s_3^n
Slaughtering rate, M_3	s_4^1	s_4^2	s_4^n
Slaughtering rate, M_4	s_5^1	s_5^2	s_5^n

FLOW CHART FOR CATTLE

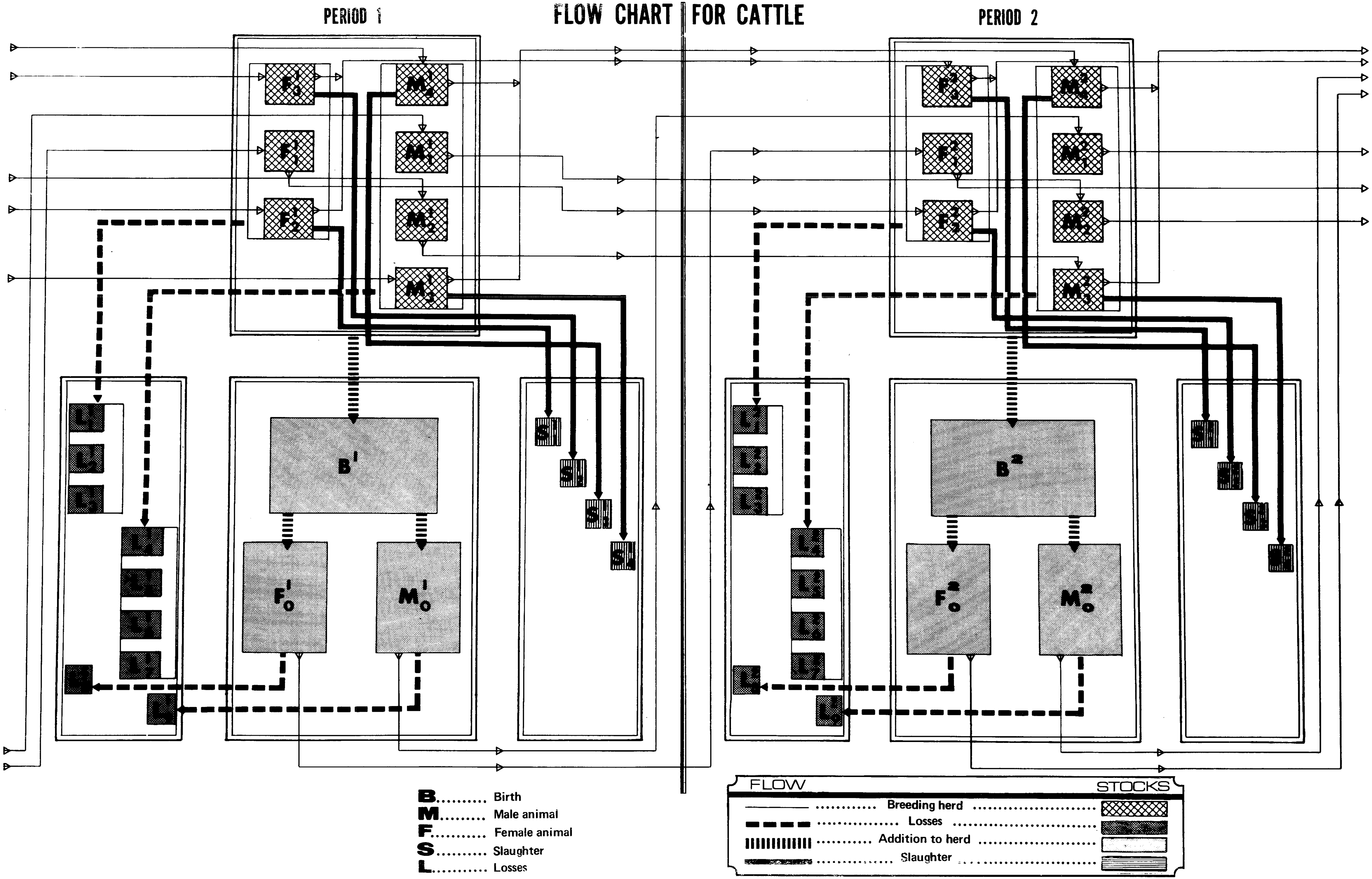

Table 2: CATTLE PROJECTIONS, PERIOD 1 and 2

Period 1

1. $F_3^1 = F_3^{1*}$
2. $F_1^1 = F_1^{1*}$
3. $F_2^1 = F_2^{1*}$
4. $M_4^1 = M_4^{1*}$
5. $M_1^1 = M_1^{1*}$
6. $M_2^1 = M_2^{1*}$
7. $M_3^1 = M_3^{1*}$
8. $B^1 = b^1 F_3^1$
9. $F_0^1 = 1/2B^1$
10. $M_0^1 = 1/2B^1$
11. $L_1^1 = 1_2^1 F_3^1$
12. $L_2^1 = 1_2^1 F_1^1$
13. $L_3^1 = 1_2^1 F_2^1$
14. $L_4^1 = 1_2^1 M_4^1$
15. $L_5^1 = 1_2^1 M_1^1$
16. $L_6^1 = 1_2^1 M_2^1$
17. $L_7^1 = 1_2^1 M_3^1$
18. $L_8^1 = 1/2\ 1_1^1 B^1$
19. $L_9^1 = 1/2\ 1_1^1 B^1$
20. $S_1^1 = s_3^1 (F_3^1 - L_2^1)$
21. $S_2^1 = s_2^1 (F_2^1 - L_3^1)$
22. $S_3^1 = s_5^1 (M_4^1 - L_4^1)$
23. $S_4^1 = s_4^1 (M_3^1 - L_7^1)$

Table 2: CATTLE PROJECTIONS, PERIODS 1 and 2 (continued)

Period 2

1. $F_3^2 = F_3^1 - (L_1^1 + S_1^1) + F_2^1 - (L_3^1 + S_2^1)$
2. $F_1^2 = F_0^1 - L_8^1$
3. $F_2^2 = F_1^1 - L_3^1$
4. $M_4^2 = M_4^1 - (L_4^1 + S_3^1) + M_3^1 - (L_7^1 + S_4^1)$
5. $M_1^2 = M_0^1 - L_9^1$
6. $M_2^2 = M_1^1 - L_5^1$
7. $M_3^2 = M_2^1 - L_6^1$
8. $B^2 = b^2 F_3^2$
9. $F_0^2 = 1/2B^2$
10. $M_0^2 = 1/2B^2$
11. $L_1^2 = 1_2^2 F_3^2$
12. $L_2^2 = 1_2^2 F_1^2$
13. $L_3^2 = 1_2^2 F_2^2$
14. $L_4^2 = 1_2^2 M_4^2$
15. $L_5^2 = 1_2^2 M_1^2$
16. $L_6^2 = 1_2^2 M_2^2$
17. $L_7^2 = 1_2^2 M_3^2$
18. $L_8^2 = 1/2\ 1^2,\ B^2$
19. $L_9^2 = 1/2\ 1^2,\ B^2$
20. $S_1^2 = s_3^2 (F_3^2 - L_1^2)$
21. $S_2^2 = s_2^2 (F_2^2 - L_3^2)$
22. $S_3^2 = s_5^1 (M_4^2 - L_4^2)$
23. $S_4^2 = s_4^2 (M_3^2 - L_7^2)$

Table 3: CATTLE PROJECTIONS, GENERAL CASE PERIOD n

Period n

1. $F_3^n = F_3^{n-1} - (L_1^{n-1} + S_1^{n-1}) + F_2^{n-1} - (L_3^{n-1} + S_2^{n-1})$

2. $F_1^n = F_0^{n-1} - L_8^{n-1}$

3. $F_2^n = F_1^{n-1} - L_3^{n-1}$

4. $M_4^n = M_4^{n-1} - (L_4^{n-1} + S_3^{n-1}) + M_3^{n-1} - (L_7^{n-1} + S_4^{n-1})$

5. $M_1^n = M_0^{n-1} - L_9^{n-1}$

6. $M_2^n = M_1^{n-1} - L_5^{n-1}$

7. $M_3^n = M_2^{n-1} - L_6^{n-1}$

8. $B^n = b^{n-1} F^n{}_3$

9. $F_0^n = 1/2\ B^n$

10. $M_0^n = 1/2\ B^n$

11. $L_1^n = 1_2^n F_3^n$

12. $L_2^n = 1_2^n F_1^n$

13. $L_3^n = 1_2^n F_2^n$

14. $L_4^n = 1_2^n M_4^n$

15. $L_5^n = 1_2^n M_1^n$

16. $L_6^n = 1_2^n M_2^n$

17. $L_7^n = 1_2^n M_3^n$

18. $L_8^n = 1/2\ 1_1^n B^2$

19. $L_9^n = 1/2\ 1_1^n B^2$

20. $S_1^n = s_3^n \quad (F_3^n - L_1^n)$

21. $S_2^n = s_2^n (F_2^n - L_3^n)$

22. $S_3^n = s_5^n (M_4^n - L_4^n)$

23. $S_4^n = s_4^n (M_3^n - L_7^n)$