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Development of an investment model for the smallholder cattle sector in the Western Amazon. I. Preliminaries

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Sumário

Development of an investment model for the smallholder cattle sector in the Western Amazon. I. Preliminaries

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Resumo

Poucos são os trabalhos publicados que avaliam aspectos econômicos da pecuária na Amazônia. A maioria deles é pessimista quanto a viabilidade desta atividade dos pontos de vista ambiental e econômico. Entretanto a pecuária é atividade de importância crescente na Amazônia e, particularmente, no estado de Rondônia, que tem assistido a um rápido incremento no seu rebanho bovino nos últimos anos. Assim, é importante conhecer esta atividade e o impacto de tecnologias na mesma e na renda do produtor, mas considerando o desempenho total da unidade de produção e não apenas de uma atividade específica.

Deste modo, a Empresa Brasileira de Pesquisa Agropecuária - Embrapa Rondônia, em parceria com a Universidade de Manitoba, Canadá e o Instituto Internacional para Pesquisa em Políticas Alimentares (Ifpri), idealizou um trabalho com o objetivo de fazer a análise de investimento em pequenas propriedades da Amazônia Ocidental nas quais a principal atividade é a pecuária leiteira. Inicialmente o modelo foi desenvolvido para as condições de Ouro Preto do Oeste, Rondônia, mas facilmente pode ser adaptado para as diferentes realidades da região amazônica.

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A análise consiste na comparação do desempenho financeiro da unidade de produção com e sem a introdução de novas tecnologias num horizonte de vinte anos.

Esta publicação explica o funcionamento deste modelo com seus usos e limitações. Descreve-se a coleta de dados feita para alimentar o modelo. Esta análise pressupõe diversos coeficientes técnicos para a pecuária de leite, que se encontram nesta publicação. O bom funcionamento do modelo depende de conhecimento da evolução do rebanho no período analisado. Um submodelo de crescimento do rebanho foi criado e é explicado.

Abstract

Livestock production systems in the Western Brazilian Amazon currently occupy more cleared land than any other system, and recent data from Rondonia suggest that area in pasture and herd size will continue to grow. Ironically, very little is known about the overall financial returns to these systems, or the heterogeneity of these systems, or perhaps most important, the potential for improving their financial or environmental performance. Most past studies have highlighted the environmental damage linked to these systems and the very poor financial returns to them — but these studies were generally based on incomplete information and/or flawed methodologies.

To fill this critical research gap, and to do so in ways that informed technology development and policy action, Embrapa-Rondonia mounted a collaborative research project with the University of Manitoba and the International Food Policy Research Institute (IFPRI). Several types of livestock production systems were identified, and a whole-farm model complete with technical production parameters (subject to change via farmer investments and/or technological innovations by Embrapa) and key economic parameters was developed, with a time horizon of 20 years. The model captures the multiple products of livestock production systems — beef, calves, milk — and allows for modifications to herd and pasture management strategies, with the former being captured in a submodel focusing on herd dynamics. The model was calibrated for the case of mixed livestock production systems of Ouro Preto do Oeste.

This paper describes in detail the model, the data collection activities linked to its specification and validation, and reports the baseline results and sensitivity analyses undertaken to assess the impact on model results of changes in key model and external parameters. Future work with this model will focus on assessing the financial impacts of different farmer investment strategies and management practices. Environmental issues such as deforestation and carbon sequestration can also be addressed by this model.

1. Model Overview

The Amazon cattle sector is frequently thought to be economic only when extraneous factors are considered. Surprisingly, until recently the actual evidence base has been quite scant, limited to two studies conducted in the mid-1980s which reached pessimistic conclusions about the underlying logic of large-scale cattle production in the Eastern Amazon (Browder, 1988; Hecht et al., 1988). More recent data suggest that this conclusion might be incorrect because profitable cattle production systems have emerged (Mattos & Uhl, 1994). A recent study (Faminow et al., 1997) provides a new underlying economic basis for the dramatic expansion of the Amazon cattle herd based upon demand growth, suggesting that rapidly growing regional consumption provided the fundamental market impetus. None of the studies on the economic returns to cattle production use data from the Western Amazon. The primary objective of this study is to address this limitation by developing an investment model for the smallholder cattle sector in Acre and Rondônia.

This section provides an overview of the basic structure for the investment model, including a description of the primary components, and describes the data gathering process. Because the model was patterned closely on the procedures recommended by Gittinger (1982), readers are referred to that book for additional detail and justification. This first section describes the basic structure of the entire investment model. Following that, in section 2 the data collection methods are presented and insection 3 base data for the investment analysis are discussed. A herd projection model has been developed as a separate, but integrated, component of the investment model.

Sections 1 to 3 are quite general, designed to provide an overview of modeling procedure and methods. The use of the herd growth model for making projections is described in section 4, along with several sample projections. The herd growth model is primarily intended to generate herd structure, growth and production information for use in the investment model. However, used alone the herd growth model also provides insights such as off-take levels and herd productivity.

1.1. Type of models

Two interlinked sub-models are utilized in the construction of the investment model for smallholder cattle production in the Western Amazon. First, a non-stochastic cattle herd growth model was developed to simulate herd structure, growth, sales and purchases for a pattern herd over an extended time period. Beginning with a predetermined number of breeding cows, herd parameters such as birth rates, death losses and herd management policies (such as culling rates) are applied and inventories prepared for different animal classes in each year. Balancing sales and purchases can be made in response to available carrying capacity. This non-stochastic cattle herd growth model is described in more detail later in this paper.

Second, the cattle herd model feeds into a financial model of smallholder farms in the Western Amazon. The basic format of the financial model is a set of budgets to represent activities for pattern farms selected to represent alternative production systems. This budgeting process is conducted on a "whole-farm" basis to represent a system of activities (including livestock, annual crops and perennials) and allow for inter-linkages between different activities. However, because the focus of this study is the cattle sector (primarily dairy production by smallholder farms), extensive focus is placed on activities relating to cattle. This working paper outlines the main components of the investment model in general terms. Full development of the investment model, including analysis of the financial benefits to investment in an improved cattle management system, is discussed in a companion working paper (Faminow et al., 1997). The base conditions for the herd growth model developed here, and used in the companion paper, are for Ouro Preto D'Oeste, a municipality located in central Rondônia.

This site was selected because it is broadly representative of a "mature" colonization project in the Western Amazon and may serve as a guide for conditions that will evolve in newer frontier colonization sites such as Theobroma and Pedro Peixoto, which have been used as benchmark survey sites (Witcover et al., 1996).

The benefits of potential investments for smallholders in the Western Amazon can be studied by developing budgets for resource use, inputs and returns under alternative farming systems, which can include modifications to existing productive systems (such as new technology) and the addition/deletion of specific activities (such as an agro-forestry component). For example, the costs and benefits to a herd improvement investment (e.g., breeding stock, health management, etc.) can be considered. This investment could involve changes to the budgets because of cash investments (e.g., a breeding bull with improved genetic traits), changes in the use of farm resources (e.g., additional farm household labor use for health management) and changed farm revenues (e.g., higher milk production). The net benefits to investments are generally measured in terms of the discounted net present worth of the investment. The analysis is structured to calculate the *incremental* net benefits; that is, the change in net benefits to the farm family resulting from the "with investment" case, relative to the "without investment" case. Thus, all valuation is automatically in terms of opportunity costs.

1.2. Components of the investment model

The investment model involves a series of interlinked spreadsheets whose principal elements are shown in Table 1.

TABLE 1 - Principal elements of the farm investment analysis

Category	Element
1. farm resources	a. land use b. labor use c. distribution by farm operation d. distribution by month
2. farm production	a. crop and pasture production b. livestock herd and production c. production values
3. farm inputs	a. investment b. operative expenditures c. incremental working capital
4. farm budget	a. with project b. without project
5. herd growth model	

1.3. Uses and limitations of the investment model

The model can be used to describe the structure of different farming systems in the study region by using alternative pattern farms. The general process is to generate the budgets and conduct analyzes of changes to the farming systems identified for the pattern farms. Although the traditional use is to study the potential net benefits from a farm investment, it is also possible to use the model to simulate other changes (such as policies) which affect farm resources, investments, operating expenditures and revenues. Resources can also be evaluated from a social perspective by comparing the private farm benefits from an investment to changes in environmental values (monetary or imputed).

Sensitivity analysis is one of the important components of the use of the model. One of the critical problems associated with farm budget/investment analysis is that point estimates of critical parameters can significantly influence the interpretation of results. In order to be effective, the sensitivity of the investment analysis needs to be thoroughly investigated. However, because the model does not have an objective function the use of standard economic optimization techniques is not possible.

An exhaustive search of alternatives might reveal an "optimum," but this is a task better left to techniques such as mathematical programming. However, the investment model provides an important first step for the development of a model capable of finding optimal solutions because it provides most of the data necessary for model specification.

It is also possible to extend the model and link natural resource and broader social land-use issues to the evaluation of pasture development and cattle production. This could occur from both micro and macro perspectives. First, from a micro perspective the returns from less intensive use of the land (e.g., extractive, sustainable forestry, etc.) can be regarded as an opportunity cost of more intensive uses (e.g., pasture development, clear-cut forestry, etc.). Second, in principle the implication of non-site specific resource and environmental issues (e.g., social value of carbon sequestering, biodiversity) can be evaluated. If reliable estimates of broad environmental values become available it would be possible to evaluate the tradeoffs and complements in private and social net benefits from agricultural development in this model.

2. Data collection

This section describes the data collection process. When building an investment model statistical surveys are generally not used because the objective is to analyze the economics of alternative production systems not model the "average" farm (Gittinger, 1982). The survey instrument being utilized to study "benchmark sites" does provide some critical information (e.g., data sufficient to develop basic herd profiles) but it does not allow for the distinguishing of more subtle information on alternative production sub-systems or the calculation of detailed budgets (Witcover et al., 1996). Normally extensive, in-depth interviews with producers, technicians, and other specialists are conducted in order to collect the necessary technical parameters. These interviews are not generally easily integrated into a formal questionnaire format or statistical sampling procedures. Nonetheless, care must be taken to ensure that the "stylized" systems are broadly representative and comparison with data drawn from the statistically representative sample is warranted. There are five basic steps to data collection.

traditional systems used by small farmers in tropical countries (Nicholson et al., 1994).

Step 1: Identify primary production systems and herd parameters for cattle production. Dual-purpose systems with a strong orientation to milk production are dominant for small farmers. Two alternative smallholder sub-systems in Ouro Preto D'Oeste (hereafter, Ouro Preto) have been identified: (1) mature cattle orientation and (2) emerging cattle orientation. The system identification phase utilized interviews of cattle production specialists (principally Embrapa Rondônia and Empresa de Assistência Técnica e Extensão Rural - EMATER-RO) as the initial data source, augmented by field proving with a small sample of farmers.

Step 2: Extensive interviews with a sample of farmers to identify technical coefficients for measures of input and resource use on farms. The objective of this exercise was to develop base information which, when combined with price information, will form the primary information for farm budgets. Interviews were conducted with farmers in the Ouro Preto município during the week of July 29 - August 2, 1996. Interviews were selected with the assistance of EMATER, the Associação dos Criadores, and the Sindicato Rural. Team members then visited each farm (along with a representative of the organization that assisted in arranging the interview) and interviewed the household member responsible for farm operations. Other family members active in the farm operations were invited to participate as well and in some cases contributed substantially to the interview. In the selection of farms an effort was made to focus on small producers (those with one lot of 100 hectares or less) and to choose a range of producers that were broadly representative of small farms in the region. Thus, this process can be regarded as a "judgement survey." In order to check whether the sites selected by cooperating agencies were roughly representative the team also interviewed several farmers which were selected by driving along a rural "linha". Farmers along this line were selected as follows: (1) one on the very accessible part near the city of Ouro Preto; (2) a second near the end of the line and the division with another município; and (3) a third at about the mid-point between the two initial locations.

Step 3: Focus group meeting. At the conclusion of the field trip in July-August, the research team organized a focus group meeting where data collected during the field interviews were summarized and presented.

Participants included representatives of the following organizations: EMATER-RO, Embrapa Rondônia, Sindicato Rural (Patronal), Sindicato dos Trabalhadores Rurais, Associação dos Produtos Alternativos, Aroopam, and Parmalat. Following a presentation and discussion of summary findings the participants were split into two groups for detailed discussion and review of: (1) herd coefficients/parameters and (2) principal investment costs for cattle production.

Step 4: Collect price information. A variety of sources was used, but the general strategy will be to survey regional suppliers for prices of locally-purchased inputs (e.g., hardware stores) and products (e.g., packing plants), augmented with public information sources (e.g., prices from EMATER). In some cases farmer records and/or recall was used to confirm price/cost data. The most accurate results come from combining the quantitative input and resource use data collected in step 2 with price data collected from retail and wholesale firms in the region.

Step 5: Replicate procedures in Acre and link base information collected under steps 1-4 above to systematic data collected in the benchmark surveys of smallholders in Pedro Peixoto and Theobroma. Preliminary results will be presented to representatives of farmers, producer groups and government institutions in the study sites and the models re-calibrated to correct errors.

3. Base Data for Investment Analysis

This section provides an overview of the base data needed to develop farm budgets. The farm budgets are designed to reflect the financial aspects of the production systems utilized in the pattern farms. Although micro-data are important and the farm activities must be represented in sufficient detail to permit realistic evaluation of the financial benefits and costs from farm activities, not every minute activity needs to (or should) be included. Judgement is necessary to prevent the model from becoming so detailed as to be cumbersome for analysis.

3.1. Cropping patterns

Cropping patterns establish the boundaries of the investment analysis by specifying the inputs and outputs from the pattern farm.

Once a cropping pattern is established it is possible to determine farm resource use (land and labor), production, input uses and revenues. The cropping patterns should represent the typical activities of farms in the region. When there are many production alternatives in a region then the number of pattern farms that must be analyzed will be large. However, when most producers in a region devote most of their farm resources to a single activity then the basic cropping patterns will be that activity. However, empirical evidence from Central Rondônia suggests that there can be substantial differences within and between groups of farms, according to factors such as scale of operations and type of technology utilized (Léna, 1991).

Establishment of cropping patterns is the first step in the analysis because the cropping pattern determines the other components of the farm budgets. Once the cropping patterns are determined farm land use is next established. The total area of a pattern farm is normally divided into the alternative uses such as pasture, annual crops, perennial crops, forest, etc. In the case of Ouro Preto, pasture for dairy production is the dominant land-use for smallholders.

Usable interviews were conducted with ten cattle producers in the Ouro Preto município. Four of them owned one 100 hectare lot, two had smaller lots (85 and 62.5 hectares, respectively) and the remaining four had larger properties (range 120 - 300 hectares). In all cases farm acreage was primarily devoted to cattle pastures. On average, 85 percent of the farm area (range 48 - 100%) was reported as having been deforested, although most reported that some of the pastures were in capoeira. In the region there are also a fairly small number of large-scale beef operations. But they reflect only a tiny proportion of the farms with cattle and a very small share of the total cattle in the region. We did not interview any beef cattle producers.

When asked, all but one respondent regarded their farm as a specialized dairy operation. The production system is oriented to milk production as the main source of cash income, but utilizing zebu-dairy crossbred cattle. Several producers commented that they normally utilized a zebu bull to provide beef-producing characteristics to male calves (plus natural resistance to tropical conditions). None of the farms would be considered a specialized dairy farm of the type found in the south of Brazil or in developed countries. Respondents reported that all male calves were sold to specialized beef producers before they reached one year of age. Female calves were retained for herd replacement and growth.

Several of the large producers reported that they selected heifers for final inclusion in the breeding herd on the basis of milk-production potential. But this is the exception rather than the rule. Most producers retain all heifers for inclusion in the breeding herd and only cull them if they fail to produce a calf after several breeding cycles.

The concept of a stable full-development herd may not properly reflect this management system. In some cases cattle herds appeared to be growing past the carrying capacity of the land base for the farm. The pastures on some farms with high stocking rates appeared over-grazed. This may reflect a "learning curve" where producers are experimenting with stocking rates to maximize the production from the pasture. Or it may reflect other objectives of the farm family such as wealth growth.

When asked about the durability of pastures, respondents gave differing results. Several showed pastures that had been in production for periods up to 20 years, but when pressed indicated that one (or more) times the pasture had been "recovered". One common pasture creation process seems to be the following. In the initial years after establishment of the farm, pastures are established after one or two crops of a rice/maize/beans/manioc rotation. But with time, once the cattle herd is providing a cash flow to sustain the family there is a tendency to minimize or eliminate annual crop production and convert forest directly to pasture. The "first-generation" pastures were not well suited to soil conditions, susceptible to attacks from spittlebugs and not managed for sustainable production (grazing intensity, rotation, burning, etc.). Many of these pastures degraded to very low stocking rates and eventually were abandoned to secondary forest growth or re-cleared and re-planted with more suitable forage varieties. Respondents reported that with proper pasture establishment (see below), regular weeding and proper grazing intensity it was not necessary (or desirable) to burn pastures regularly. However, burning is a common management tool in the region, and most respondents reported the need to hire temporary workers to cut back grass from fences to protect them from burn damage so it seems that no-burn pasture management might still be a theoretical concept (but not a practiced one) in the region.

Our assessment is that dairy farms can be classified into two general size classifications: large and small size (Table 2). The division line between the two groups is 100 hectares in total farm size, the original Instituto Nacional de Colonização e Reforma Agrária (INCRA) allotment used in the Ouro Preto colonization project.

Although there was a great deal of heterogeneity among the smaller producers, it is reasonable to classify them into two sub-components. Emerging dairy farms are those early in the transformation from annual and perennial crop production. Herd size is generally smaller and they have a relatively large proportion of land that is in degraded pasture or capoeira that has not yet been recovered. Herd production indices are generally very low. Mature dairy farms are those that are in advanced stages of development in the sense that the owner has been a dairy producer on the farm for an extended time (often 20 years or more) and the herd has grown to utilize virtually all of the available carrying capacity. These mature operations are more intensively managed and have higher productivity levels than emerging dairy farms. Given that mature operations are bumping up on a land constraint there are three options for these producers: (1) stabilize herd size and focus managerial efforts and investment upon improving herd and pasture production indices; (2) buy additional land to allow herd growth and/or (3) cash out on the farm, utilizing the cattle herd for financial objectives such as to establish a cash base for retirement or to reward departing family members for their contribution to farm success. We identified and characterized these two sub-systems independently, based upon field interviews and in-depth discussions with a broad range of technical specialists and farm organizations. But it should be noted that they correspond quite closely to an earlier evaluation and seem to confirm conclusions reached by a joint EMATER-RO and Embrapa Rondônia team (EMBRATER, 1987). Table 2 summarizes the characteristics of these patterns farms using this format.

TABLE 2 - Farm patterns based upon field visit to Ouro Preto do Oeste, July/August 1996.

	Large size	small size	
		emerging	mature
herd (hd.)			
lactating cows	90	15	45
dry cows	60	15	40
Calves	128	17	65
heifers 1-2 yrs	64	9	31
heifers 2-3 yrs	63	8	29
steers 1-2 yrs	0	0	0
Bulls	8	1	4
Total	413	65	214
farm area (ha)			
total farm	250	100	100
Area pasture	150	60	85
paddock size	4-20	4-30	3-15
no. paddocks (no.)	14	3	6
herd statistics			
milk production (liter/day/cow)	6	3	4
days lactation (days)	240	180	210
calving rate (%)	90	72	80
death rate - calves (%)	5	20	5
death rate - adults (%)	1	4	3
cull rate - cows (%)	12.5	-	12.5
cull rate - bulls (%)	30	20	25
calving interval (mo.)[1]	13.2	15.4	14.4
Management			
herd separated	Yes	no	yes
controlled breeding	Yes	no	no
milkings per day	2	1	1
calves separated from cow	Yes	no	no
Selection of cows	Yes	no	no
Supplemental feeding	Yes	no	no
Pasture burned	No	yes	yes
herd health management	Comp	part	com
Stocking rate (AU/ ha)[2]	2.0	0.8	1.7

[1] Calculated from calving percentage as CI = 12 x (100 - Calving%)/ 100) + 1). For example, the calculation for a small beginning farm is CI = 12 x (100 - 72)/ 100) + 1) = 12 x 1.28 = 15.4 months

[2] Calculated using the animal unit conversions described in a latter section with the herd inventory numbers above in this table.

3.2. Labor requirements

The allocation of household labor is also an important aspect of farm resource use. For some crops labor might be the binding constraint. Even if adequate family labor is available on a year-round basis high labor demands for some activities in specific time periods might be a limiting factor on production. For example, the amount of land that can be cleared each year during the dry season in Rondônia and Acre is limited by the availability of family labor on farms, especially when farms have low levels of capitalization. Evidence from the Ouro Preto region (Léna, 1991) suggests that economic growth of colonists is directly linked to the amount of family labor that is available.

In addition to family labor farms might employ hired labor in their operations. This might be necessary in periods of the year when the labor demands exceed the availability of household labor. It also becomes a factor on farms when adult males decide to leave the farm to establish their own farms or become engaged in off-farm work. However, care must be taken to ensure that hired laborers are, in fact, available. Labor availability (on-farm) will be determined by the family structure data for the test sites (Léna, 1991; Witcover et al., 1996).

3.3. Farm production

Farm production is calculated by tabulating production per hectare and multiplying by the number of hectares allocated to each crop in the pattern farms. For crops, production is yield multiplied by area. Pasture production is measured in terms of carrying capacity; the number of animal units that can be stocked for each hectare multiplied by the total amount of pasture. The calculation of farm production is one calculation that can create misleading results if not done carefully. Normally, agricultural production varies considerably from year to year as a result of natural conditions and management decisions (guided by economic incentives). Thus, evaluation of the farm budgets based upon average production figures might be very misleading. Mean productivity data will be utilized as a base, but subjected to sensitivity analysis.

Livestock production is determined using a herd model for inventory, purchases and sales as described below. In addition to revenues and expenses from the cattle herd the value of other products is included (e.g., milk production). The model calculations include sales of discarded animals such as culled bulls and cows.

3.4. Input uses: investment and operating

Input use is divided into two components, investments and operating expenditures. For smallholder farms the types of investments include land improvement (e.g., recovery of degraded pasture), construction (e.g., building corrals and fences), equipment (e.g., purchase of an elephant grass processing machine) and livestock (e.g., purchase of a bull with improved genetic potential). Investments are valued at constant costs and are budgeted for the years in which they occur. No allowance is made for depreciation. Instead, when the end of the useful life of investments is reached salvageable items are sold and additional investment necessary to replace the worn-out investment is charged to the budget. Livestock which are sold due to replacement by investment in 'improved' stock are treated as negative investments and not as benefits to the farm operation. Operating expenditures for farm operations are separated by crop and livestock. Specific costs of maintaining livestock (e.g., vaccines, medicines) and pasture (e.g., annual weeding) are included.

3.5. Market prices: received and paid

Market prices for agricultural products were taken from weekly price surveys in Ouro Preto which are released by EMATER on a monthly basis. Data were taken for the period July, 1994 through June, 1996. Care must be taken in interpreting these prices because they are based upon a judgement sample and not always collected systematically or even in every month. Apparently, in some months prices are not collected and the report simply uses the price from the previous month. In some cases prices remain constant at even levels for periods of 2-3 months for some products. Still, these prices are probably generally representative of local market conditions and can be used for establishing baseline prices and also for establishing ranges for sensitivity analysis.

Summary price data are shown in Table 3. These are prices received by farmers net of transportation charges to the central market and can be interpreted as typical prices received at the farm gate. For each item (except manioc) the 24-month high, low and mean prices are shown, along with the "recent" price level (prices over the last six to eight months). Cattle prices are reported on a "per animal" basis, except for fattened steers which are priced by arroba. An *arroba* is 15 kilograms carcass-weight. The normal pricing procedure is to take 50%

of the live-weight of a fattened steer as the estimate of carcass yield and calculate price on that basis. For example, a 450 kg. steer sold for slaughter would yield 225 kg. (using the standard 50% calculation) or 15 arrobas. If the price per arroba were $R 14.00, the amount paid to the producer would be $R 210.00. As can be seen, for cattle-related prices, recent levels are all below the mean price. This reflects a general decline of cattle-related prices by 30-50 percent, relative to price levels in the second half of 1994. Milk prices declined from $R 0.20 to $R 0.14 at the end of 1995 and remained at this low level through 1996.

TABLE 3 - Prices received by farmers at Ouro Preto do Oeste[1], Rondônia, in reais.

	high	Low	mean[2]	recent
cattle related				
Fattened steer (arroba)	24.00	13.00	16.83	14.00
Mixed-breed cow (animal)	500.00	280.00	373.13	290.00
Common cow (animal)	310.00	200.00	264.52	200.00
Heifer, 1-3 yrs. (animal)	295.00	130.00	198.91	130.00
Steer, 1-3 yrs. (animal)	230.00	110.00	167.09	120.00
Male calf (animal)	130.00	75.00	100.95	80.00
Female calf (animal)	165.00	80.00	117.98	85.00
milk (litre)	0.20	0.14	0.16	0.14
<u>Crops</u>				
Robusta coffee (60 kg processed sack)	135.00	58.00	91.83	80.00
Common rice (60 kg sack)	9.00	5.00	7.00	7.50
Beans (60 kg sack)	24.50	12.50	18.95	20.00
Corn (60 kg sack)	8.00	4.00	5.28	5.00
Mandioc (tonne)[3]	-	-	-	30.00

[1]Monthly data (July, 1994 through June, 1996) by EMATER-RO are based upon a judgement sample of about 10 producers selling in the Ouro Preto market. Prices for field crops have a deduction of $R 1.00 per sack for a transportation charge, based upon a "typical" shipping distance of 20 kilometres within the municipal region. Technicians from Emater reported that transport cost discounts within the municipal region tend to be based upon volume (number of sacks) and not distance shipped to market. Note that the data collected by Emater are not based upon scientific sampling methods and current price levels are not always reported. Apparently, it is common practice to use the preceding month's price in leu of updated prices.

[2]Mean prices should not be interpreted too strictly because the sampling and price reporting procedures used by Emater are not rigorous.

[3]Spot price (October, 1996) by Embrapa Rondônia technicians in Ouro Preto. Price is f.o.b. farm gate as paid by commercial processors of mandioc flour.

Field crops such as corn, rice and beans are typically sold in 60 kg. sacks. In contrast to cattle-related prices, annual crop prices have been much more stable, with recent prices slightly above the 24-month average. Coffee prices have declined substantially over the time period.

EMATER-RO does not report prices for all types of cattle needed for the budgets. Specifically, missing were prices for culled bulls and culled cows (these are sold for slaughter at a price discount relative to fattened steers), culled heifers, and work oxen. However, discussions with EMATER-RO and Embrapa Rondônia specialists produced methods for calculating the missing prices as shown in Table 4. Normally, culled bulls are sold for slaughter at about a 10% price discount on the steer price, while culled cows are sold for about a 20% discount which reflects their lower meat yield. Thus, for the baseline case prices for culled bulls and cows were calculated at 90 and 80 percent of the fattened steer price, or $R 12.60 and $R 11.20 per arroba, respectively.

Under the herd management systems used by most small dairy producers in the Ouro Preto region heifers are rarely culled, instead almost always retained for herd replacement and growth. However, the design of more intensive production systems requires the use of selective culling of heifers from the breeding herd into beef fattening for eventual slaughter, so the steer (1-3 yrs.) price can be used as a proxy. Because steers display better gains than heifers, the steer price was discounted to $R 150.00 per head.

Work oxen are commonly utilized on farms. Culled work oxen were valued at the same price as culled bulls, with the difference in total value due to weight differences (see Table 4). Steers are utilized as work oxen, so newly purchased work oxen are valued at the price for steers (1-3 years) where the opportunity cost of diverting a steer to farm work is the value of selling it for fattening.

TABLE 4 - Calculation of cattle values not provided by Emater-Ro.

Animal type	Price (reais/arroba)	weight (arroba)	value (reais)
Culled bulls	12.60	24	302.00
Culled cows	11.20	15.6	175.00
Culled heifers	-	-	150.00
Wok oxen	-	-	167.00
Culled work oxen	12.60	19.20	242.00

Input prices were collected in Ouro Preto from local suppliers (Table 5). Normally two local suppliers were visited to check prices of inputs utilized in dairy production. Some of the inputs wear out fairly quickly, so the frequency of purchase are is also shown. In actuality, some of these items are considered investments (e.g.,equipment and tools) while others are included as operating expenditures (e.g., vaccine and medicines).

TABLE 5 - Prices of purchased inputs for operating expenditures

Items	units	Price (reais)	use rate
Medicines and vaccines			
Hoof and mouth	dose	0.50	2/ year
Brucellosis	dose	0.35	1/ life (cows)
Carbunculo	dose	0.17	1/year
Rabies	dose	0.22	1/year
Paratifo	flask (25 doses)	3.50	-
Parasites	flask (40 doses)	12.60	2/ year
Minerals			
Common salt	25 kg bag	12.60	on demmand
mineral salt	30 kg bag	15.00	50 g/ day (young), 70 g/day (adult)
Dairying equipment			
Vaccination pistol	-	69.50	3 years
Maintenance	-	10.00	per year
Saddle	-	50.00	3 years
Maintenance	-	20.00	2/ year
Bridle	-	50.00	1.5 year
Foot-secure rope	meter	0.45	1 year
milking pail	-	20.00	1 year
Plastic milk bottle	-	49.00	2 years
Lasso	12 meters	15.00	1 year
Feed for horse (12 kg corn/ month)	kg	0.09	-
Riding horse	-	500.00	6 years
Farming equipment			
hoe	-	5.60	1 year
machete	-	3.00	1 year
chain saw	-	700.00	1 year
Axe	-	18.00	2 years

4. Cattle herd model

A key component when developing a farm investment model for livestock production is the specification of a model for making herd projections. Because herd growth occurs from biological processes it takes time and will not usually fit neatly within the accounting framework that forms the base of investment analysis. In the case of cattle for beef production, conception through to when a grass fattened steer is ready for slaughter will normally take five or more years in the Amazon. It is necessary to evaluate the effect of herd composition, purchases and sales on the financial performance of farms in order to understand the economic incentives faced by farmers in the Amazon.

Particularly important is the need to understand the influence of herd production parameters on herd growth patterns and develop a deeper understanding of how changes to technical production parameters affect the herd growth trajectory and ultimately are transmitted into herd productivity measures such as off-take rates of milk and beef.

Cattle herd growth models are specifically designed to track herd growth and structure based upon an initial set of parameters and production system design. The evolution from one herd structure to another usually reflects changes in the underlying herd parameters and/or system. The change from one herd equilibrium, based upon initial conditions, to a new equilibrium, that is based upon the new herd parameters, provides a way to evaluate the future feed requirements, handling facilities, investments and productivity of the herd. Initial herd parameters are usually selected to reflect a pattern herd, generally designed to emulate existing farm structure. The movement to a new equilibrium provides a method in which to simulate alternatives and, especially, evaluate the impact of technological or institutional interventions.

The cattle herd model was developed in *Corel Quattropro 7.0* format. The discussion below utilizes terms from Quattropro like "notebooks" and "pages". Readers can refer to the relevant Quattropro manual for more information. The primary spreadsheet is a herd projection model which contains a set of interlinked accounts, where technical coefficients for the herd are applied to the different categories of cattle in the herd. This herd projection model allows the tracking of herd development from an initial herd condition through to a "full development" condition. Linked to this spreadsheet (but on a subsequent page of the "notebook") is a summary page which allows the researcher to keep track of different herd growth simulations. Each component of the cattle herd model is discussed in more detail below. It should be pointed out that this model utilizes the capacity of Quattropro to link calculations whenever possible, but is not fully automatic. In tracing through herd development a decision to buy or sell animals in herd balancing operations must be made for each year of the model in order to calculate herd conditions for the subsequent year. In making this annual choice there is considerable potential for gaining insights into the types of decisions that a producer would need to make over time as the herd developed, and the alternatives that would be faced. But, a cost of this design is that computing power is not fully utilized.

The herd growth sub-model is organized as follows. Column A contains row headings while data are entered (or shown) in columns C, D, F - Z, and AB of the spreadsheet. In columns C and D can be found data for the initial herd conditions, first calculated for a 1000-cow herd and then for a 100-farm herd as discussed in Gittinger (1982). The effects of changes in herd management are traced through a 20-year time path in columns F - Y. In most simulated cases the herd will stabilize at the full-development level well before the end of the 20-year period so some of the columns might be unnecessary. However, in order to trace explosive herd growth from continual pasture expansion it will be illustrative to use all the available columns. The full-development 1000-cow herd case which is necessary to initiate the calculation procedure is shown in column Z. Finally, for convenience, row headings are repeated in column AB.

Data are imputed by row. Rows 1-19 are reserved for technical herd parameters, which must be entered for each year in the program for the column as described above. It is here that the technical effects of a program to change herd management through interventions in herd health, nutrition, genetics or management would be entered. Rows 20-26 are reserved for opening stock numbers necessary for calculation of the initial and full development herds. In rows 27-28 a male calf sale rule is entered. This was included in order to reflect the typical smallholder system where all male calves are sold but leave flexibility so that later on the benefits of retaining male calves for establishing a steer fattening component of the farm operation can be studied (by changing this rule and then tracing through the herd development). Considerable space was left in the form of blank lines between rows 1-50 for the addition of additional information without the need to change the row numbers below. Rows 51-153 contain the actual herd projections. Base coefficients from rows 1-50 are linked into the calculations as appropriate, limiting the number of keystrokes that are necessary.

4.1. Structure and use

The herd projection model closely follows the structure described in detail by Gittinger (1982). A brief summary of the calculation structure is given below, but primary focus is on the changes from the Gittinger example that were necessary to adjust the model to reflect the farming structure for smallholder dairy producers in the Western Amazon. Because of this readers interested in most calculation details will want to refer to Gittinger (1982).

The basic idea is to link resource availability (i.e., pasture carrying capacity) to herd development through the use of *technical coefficients* that summarize key biological production parameters. Technical coefficients include: calving rate, mortality rates for different classes of cattle, culling rates, carrying capacity, and pasture area. Although technical coefficients reflect natural or biological conditions they can be influenced by farm decisions; in fact, the improvement of herd management practices to better herd technical coefficients is an important component of agricultural development programs. The technical coefficients for the example developed in this section are shown in Table 6. These are the parameters used in the base model developed for Ouro Preto in the companion working paper (Faminow et al., 1997). In order to attain higher levels of production, an improvement in herd genetics is necessary. In order to accomplish a rapid improvement in overall herd genetics by eliminating inferior gene stock, the base model assumes that all bulls and 30% of breeding cows are culled (and replaced) in the first year of the investment project.

TABLE 6 - Technical coefficients for example

item	coefficient
Calving rate	50%
calf mortality	10%
Adult mortality	5%
Culling rate, bulls	16%
Culling rate, oxen	not available
Culling rate, cows	11%
culling rates, heifers	0%
Carrying capacity per hectare	0.8 AU/ ha[1]

[1] as discussed below, carrying capacity changes over the development period

The herd projection commences with a stable herd, with an initial inventory of bulls, breeding cows, calves, heifers, steers and work oxen which then can change during the year depending upon calving rates, death losses, culling rates, and herd purchases/sales. The idea of a stable herd is that at the end of the year net additions to the herd through biological reproduction and herd purchases from outside are balanced by herd losses from deaths, culling and sales. Thus, opening and closing stocks will be the same in a stable herd. Normally, farmers would have a herd that uses up the available carrying capacity of the farm pasture. Sales and purchases, outside of those that reflect culling operations, are balancing operations to ensure that the herd size is stable. Because natural herd production in most conditions would cause herd growth, the usual case is that there are balancing sales of heifers that are not needed to be transferred into the herd breeding stock. The stable herd concept has been used to develop technical recommendations for dairy producers in Rondônia (EMBRATER, 1987) but the overall explosive growth in the cattle herd (Costa et al., 1996.) suggests that area and pasture expansion has been continuous and a stable herd equilibrium has not been realized in practice.

For large ranches a herd projection can be done for each individual case. However, with small farms it is difficult to build a model without having fractional animals. In order to avoid this complication a standard practice, and the one followed here, is to build the model for a 100-farm herd. An example of a herd projection is shown in the appendix to this report. The discussion of model calculations in this section all refer to that example.

Design of the herd projection begins with computing the stable herd at full development in the last column (Z). In cases where herd size per farm exceeds the normal service capacity of a bull (commonly 25 to 35 cows) the number of bulls needed would grow. In line 63 the number of bulls required to service the breeding cows in the herd is calculated. In cases where herd growth causes the number of bulls in the herd to be lower than required, the number of additional bulls that should be purchased is entered in line 64. Beginning with the opening stock of bulls, death losses and culls are calculated using the technical coefficients given above (note that these can differ across project years) which are then subtracted from the opening stock. Replacement purchases for the herd will balance the losses (sum of deaths and culls) and for a growing herd, when the cow-to-bull ratio exceeds the maximum allowed level, new bulls are entered in "purchases for purchased heifers." For breeding cows we start with an opening stock of 1000 cows, selected to give an easy base from which to establish herd size without consideration of total carrying capacity (in column Y this herd size will be adjusted to the carrying capacity).

Deaths and culls are subtracted and replacements added (heifer transfers) to form the closing stock. For the full development case the herd will be stable and replacements will just match losses, but during a phase of herd expansion additional retention of heifers will occur and the breeding cow inventory will grow. This is discussed in detail below because the decision to retain heifers is one of the critical decisions that must be taken by farm managers, a decision which is simulated in the model.

Births are calculated using the calving rate and separated into male and female calves. This is done because of the different roles that they play within the dominant smallholder farming system. Many small producers sell the male calves after they are weaned for the cattle fattening sector, while female calves are retained for breeding cow replacement. In improved systems retention is selective, with only those heifers with most genetic potential entering the breeding cow herd and rapid culling with poor performance. In the "rustic" systems utilized by most smallholders virtually all heifers are retained and enter into the breeding cow category, despite their potential and/or performance. As a result, farm herds tend to grow continuously. Separating the accounts allows different treatment to occur. It also facilitates the analysis of the benefits of adding a cattle fattening operation, if desired at a later date. Note also, that the herd model with minor adaption could be used to simulate a cow-calf operation (cria-recria). The model shown in the appendix assumes that all male calves are sold at the end of the year so they never show up in the actual closing herd inventory. Female calves progress through the herd as heifers, 1-2 years old and 2-3 years old, with death losses each year and possible culling in the third year. It is assumed that they are bred during their third year and produce offspring at the average calving rate for the herd. At the end of that year they are transferred to the breeding cow inventory. For simplicity, this example has assumed there are no work oxen.

The 1000-cow herd must now be adjusted to reflect the available carrying capacity at full development. This is calculated at the bottom of the spreadsheet in row 153 and is based upon the number of hectares of pasture in each year multiplied by the carrying capacity of that pasture. Because carrying capacity is not an exact calculation, a band for herd size plus or minus 10% of the carrying capacity is normally allowed. This is a rough rule of thumb to allow for normal variation and not a hard and fast rule. The model is developed assuming one animal unit for each animal (excluding calves).

As discussed below, this might be different than the carrying capacity of farms given the usual animal unit equivalencies used by Embrapa. Animal unit equivalencies are present later in this report. Adjustment is done by taking the ratio of the carrying capacity number in column Y (row 153) to the actual closing stock in column Z (row 151) and multiplying this ratio by 1000 cows, after adjusting both for the number of bulls and oxen. For example, the carrying capacity in year 20 is 11,250, the actual closing stock in the 1000-cow full development herd is 1698 and there are 40 bulls and no oxen. In year 20 there are 276 bulls. The number of cows for the full development 100-farm herd would be calculated as follows:

Number of cows = ((11250 - 276 - 0)/(1698 - 40 - 0)) * 1000 = 6619.

Calculation of the number of breeding cows for the 100-farm herd is done automatically. However, because the spreadsheet program carries fractions, but they are hidden, the actual number of breeding cows in the model (see appendix) is slightly different at 6,624.

Exactly the same process is followed for the initial herd at the beginning of the spreadsheet (columns C and D). First the 1000-cow herd inventory is developed using the initial technical coefficients. Then the 100-farm inventory is developed. In this case there are 1000 breeding cows for the stable initial herd and an actual closing inventory of 1472 animals, roughly 15 animals per farm. The 100-farm herd has 3872 breeding cows.

Calculation of the herd dynamics requires a series of sequential decisions and calculations. Most of the process is automatic, due to the built-in set of calculations. The initial step is to develop the scenario for herd development. In most cases this will come about through changes to technical coefficients (such as a program to improve herd genetics and management) or carrying capacity (improvements in pasture quality, supplementary feeding or pasture expansion). The example shown in the appendix assumes that carrying capacity increases from pasture improvement, as described below. Proceeding from an initial set of technical coefficients, new parameters can be entered and the herd projection made. Closing stocks in one year are transferred to the following year as opening stocks. This is done automatically as a pre-set cell address in the Quattropro spreadsheet. When a technical parameter is changed, causing a closing stock for one year to be adjusted, the change is made automatically because they are linked through cell addresses. The same is true for most of the herd calculations.

From the number of breeding cows the calving rate will determine the number of calves born in a year. For example, the illustrative model developed in this section for a stable 100-farm herd begins with an inventory of 3872 breeding cows and a calving rate of 50%. Thus, there would be 1936 calves born that year, 968 male calves and 968 female calves. However, with death losses the actual number of calves that are in the inventory at the end of the year would be smaller. This is the number that are transferred to the next category. The base model assumes a death loss of 10% so of the 968 female calves born only 871 would still be in the herd at the end of the year to be transferred into the category, heifers (1-2 years). Mortality losses on these 871 heifers (at the adult rate of 5%) reduces their number at the end of the second year to 828, which are transferred into the category, heifers (2-3 years). The same mortality percentage would apply for heifers (2-3 years) so at the end of the year there will be 786 heifers ready to be transferred into the breeding cow inventory as needed. In a stable herd all are not usually needed to replace culls and death losses from the breeding cow herd so the surplus heifers (2-3 years) available at the end of the year would be sold. In the base case death losses to the breeding cow inventory are 194 (5%) and culls are 426 (11%) so only 620 of the available heifers would need to be rotated into the breeding cow inventory in order to maintain a stable herd. The same type of calculations would need to be made for male calves, steers and work oxen. These calculations will depend on the farm production system as well as the technical herd coefficients.

Most calculations are automatic, but there are two decisions that must be taken for each year of the projection. The first key decision takes place in rows 97-100. In row 97 the difference between preliminary closing (row 140) and carrying capacity (row 153) is reported. In year 1 there is overstocking (1095 approximate AU animal units). Although available carrying capacity is being exceeded the basis to increase herd size comes from the fact that pasture is in the process of being prepared and will soon be available (see discussion below). The analyst must decide whether to sell or purchase heifers. On average only half of the calves are female and roughly 4 years will pass until the female offspring of a retained heifer will herself produce a calf and can be used for milk production, and then only at the herd's average calving rate.

Thus, beef off-take calculations that ignore the contribution of milk production for cash sales and on-farm consumption (Hecht, 1993) If carrying capacity was not being met, a purchase of heifers could be made to bring the herd up to capacity if the financial capability of the farm allowed it (i.e., sufficient cash or credit was available). Alternatively, if there is insufficient carrying capacity for the preliminary closing stock, the analyst can elect to sell the surplus. Otherwise, some arrangement might be made to expand carrying capacity such as renting pasture, providing supplementary feed or buying pasture. Alternatively, stocking rates might be increased past the maximum levels for sustained pasture productivity, leading to subsequent pasture degradation. Normally, transfers to cows will just replace breeding cow losses in the case of a stable herd but contribute to herd growth in the case of a herd development projection. The general rule used in the projections for the smallholder dairy to retain all heifers effectively means that the closing stock for heifers 2-3 years old is transferred to the breeding cow inventory through row 100, "transfers to cows." Flexibility for purchases or sales is built into the decision in rows 98 (sales) and 99 (purchases), but the underlying assumption in this example is that farmers expand their herd through internal heifer retention only. Because carrying capacity is never met over the herd development process, no sales of heifers are ever entered. But, as will be shown below, under alternative pasture development assumptions and technical herd coefficients it is possible that herd growth will catch up to and surpass pasture carrying capacity.

A second key decision point occurs in each year of the projection. Herd growth from retaining female calves (or purchasing heifers) that causes the number of breeding cows to increase also causes the number of bulls required for breeding coverage to increase. For example, in year 4 (see appendix), the number of breeding cows has increased to 3948, which require 158 bulls, at 25 cows per bull (see line 63). There are only 155 bulls in the herd so 3 additional bulls must be purchased, which is entered in line 64.

Thus, herd growth can come from four sources: (1) retaining more heifers (2-3 years) for introduction into the breeding cow inventory; (2) purchasing stock (heifers and cows); (3) improving the technical coefficients of the herd and (4) purchasing bulls to service increases in breeding cow numbers. Retaining heifers for breeding involves minimizes cash outlays (the other two require additional cash on hand or farm credit) and is a widely used method for small farmers in the Amazon. But it is also the slowest way to herd growth. The heifers must be bred and then there is a 9-month gestation period until the calf is born. The same is true for fattened steers. Five years pass between the time when a heifer is retained until a fattened steer is ready for sale (close to 1 year for the gestation and birth and 4 years for fattening). Thus, rapid initial herd growth requires that farms purchase stock and, through the cumulative effect, can lead to rapid growth in later years. The adoption of improved herd management practices also has a slow impact upon herd growth. First, the improvement of technical coefficients through programs such as improvements in herd health, fertility, etc., do not occur instantaneously but are introduced and adopted over time. Second, the benefits of improving technical coefficients are at first small but they accumulate over time as herd growth occurs. As will be shown below, seemingly modest improvements to technical coefficients can lead to radically different herd trajectories when projected over a 20-year time horizon due to the accumulation effect. The fastest way to increase herd size is to purchase pregnant steers and heifers.

The primary use of the herd growth projections is to trace through the effects of changes to total carrying capacity and strategies to increase herd size to utilize this enhanced capacity. These projections are linked to the financial calculations by prices. Increased sales of beef and milk generate revenue. Of course, there will usually be investment and operating costs associated with the increased production so it is necessary to evaluate the net benefits to the farm from increasing cattle output. But as will be shown below, the herd projections themselves can illustrate important clues to understanding the decisions of cattle producers in the Amazon.

4.2. Measuring benefits from cattle

Beef cattle herd productivity is comprised of two components, the off-take rate and herd growth rate. The off-take rate is calculated by dividing net sales by the herd's opening stock for the year. The herd growth rate measures the percent change in opening stock. Thus, when an increase in total carrying capacity encourages the retention of heifers for herd growth or the adoption of a new production system (e.g., steer fattening) are there will be a temporary decline in off-take rates because sales are diminished. But this will be reflected in the herd growth rate which measures the effect of increases in the herd inventory from internal growth and also outside purchases.

Herd productivity for beef production is the sum of the two components. In periods of rapid herd growth the off-take rate will understate the productivity of a beef herd because some of it is reflected in herd growth. Similarly, the herd growth rate can overstate the natural productivity of a herd if it includes purchased additions to the inventory. Note that a failure to make these distinctions and the reliance on off-take rates as the measure of herd productivity during a period of very rapid herd buildup has resulted in the Amazon cattle sector being branded in the literature as having one of the lowest beef production rates in the world (Hecht, 1993; Browder, 1988) and being minuscule (Fearnside, 1983, 1989). However, as will be demonstrated below, the off-take rate can be a very misleading measure of herd productivity when rapid herd growth is occurring, as in the Amazon during the 1970s and 1980s.

Cattle off-take from many small farms in the Amazon can be a minor component of their output. Small farms with cattle tend to focus on milk production because the payoff from the investment in cattle occurs much sooner, is more steady and the returns can be higher. However, most of these small farms are not specialized dairy operations but what can be called dual-purpose systems, where the primary orientation is milk production but where cattle sales are a significant component of total farm revenues. Dual system milk production is important throughout much of Latin America (Simpson & Conrad, 1993; Kaimowitz, 1995; Nicholson et al., 1994, 1995). In the Ouro Preto region of Central Rondônia almost all small farms with cattle are of this type. The distinction between specialized systems (beef and dairy) and dual-purpose ones is partly a matter of degree, with increased specialization in output and intensive use of resources signifying the focus on one component or the other (beef or dairy). Breed selection, particularly the relative weights of Zebu versus European shares in cross-breeding, is an important factor. The Zebu share in cattle owned by smallholders in Central Rondônia can be as high as 75 percent, which limits the milk-producing potential of the cattle (EMBRATER, 1987). Some farmers reported during interviews that it was necessary to maintain identifiable beef cattle characteristics in the male calves in order to receive compensatory prices. It is important to keep in mind that there is a "continuum of intensification alternatives" between the extreme endpoints represented by specialized, intensive beef and dairy systems in temperate-zone countries and the low-input/output

Similarly, the focus on low milk productivity from dairy production in the Amazon (Mendonça & Magalhães, 1990) and elsewhere in Latin America (Simpson & Conrad, 1993) relative to more intensive production technologies must be interpreted carefully because of the dual milk and beef components of many smallholder production systems. There are tradeoffs between beef and dairy production that must be balanced by producers in view of their objectives and financial constraints. For example, for farmers located near a main road and close to an urban point (and with access to marketing services) increased specialization and sale of milk might be justified. However, a farmer located in a remote region might choose to delay weaning calves from lactating cows with the objective of marketing some of the surplus milk production in excess of home consumption needs through enhanced weight of calves.

Cattle can also help farmers achieve other objectives. This has been noted for the Amazon (Hecht, 1993) and is also a feature of smallholder production in Africa (Samberg, 1992). For example, Arima & Uhl (199-) describe the use of cattle to fertilize fields in the Amazon state of Pará. Prior to the planting period, cattle are moved from pastures onto fields (to be later planted to crops) each evening for a period up to several months to deposit manure and enrich the soil. This type of system uses cattle to transfer nutrients from pasture in other fields and the crop yield increases that result could be considered a benefit from raising cattle. Financial services are another important benefit to small farmers; cattle provide a way for farmers without banking services to store wealth and often present one of the few investment opportunities on the frontier. Based upon time-staged surveys in 1980 and 1987 of the same farms, Léna (1991) has observed that the number of cattle on farms in Central Rondônia serves as a proxy for farm "success". In addition to their capacity to produce revenue through the sale of milk and animals, cattle are used as a wealth reserve to pay for unexpected expenses such as medical care, as a method to reward departing family members for their contributions to farm activities, to make other capital investments, etc. (Léna, 1991).

With these qualifications in mind, Table 7 presents off-take rates and herd productivity for the beef production component of a smallholder dairy herd. This example is for a different herd than described above and demonstrates the way in which the herd growth sub-model can be used independently to gain insights about the dynamics of cattle herds in the Western Amazon.

The stable herd without development has opening and closing stocks of 388 animals. Beef off-take from the herd is 71 head (18%), calculated as sales (92 head) less purchases (21 head). Since there is no herd growth the off-take rate and the herd productivity rate are the same. Table 6 traces these calculations over the development period. Off-take and herd productivity rates do not change dramatically because technical coefficients and the production system for the herd are assumed to be constant. Off-take first falls to 16% and then rises to 19%. The reason for this change is the constant level of herd purchases (limited to bulls) and the gradual growth in the herd sales, due to the number of culled cows and male calves increasing as herd size grows. However, off-take disguises total herd productivity because heifers are being retained to build up the herd. In this example, herd growth adds 2-3% to herd productivity.

TABLE 7 - Off-take rates and herd productivity for base example

	herd size	off-take sales		herd growth	
	(number)	number	rate (%)	number	rate (%)
Stable	388	71	18	0	18
Year 1	388	62	16	9	18
Year 2	396	65	16	9	19
Year 3	406	67	17	10	19
Year 4	415	69	17	10	19
Year 5	425	72	17	10	19
Year 6	435	74	17	10	19
Year 7	445	77	17	11	20
Year 8	456	79	17	11	20
Year 9	467	82	17	11	20
Year 10	478	84	18	12	20
Year 11	490	87	18	12	20
Year 12	502	90	18	12	20
Year 13	515	93	18	13	21
Year 14	528	96	18	13	21
Year 15	541	99	18	14	21
Year 16	555	102	18	14	21
Year 17	569	106	19	15	21
Year 18	583	109	19	15	21
Year 19	598	113	19	16	21

Off-take and herd productivity measured in terms of the percent of total herd inventory provides a crude measuring stick for the productive level. In order to develop a complete picture of beef productivity other indicators such daily rate of gain and weight gain per hectare per year could also be utilized. Because a dual system also produces milk, however, it would be advantageous to have similar measure of the productivity of the dairy component in terms of the size of the herd. Standard measures of dairy productivity include the calving rate, average daily milk yield per lactating cow and length of the average lactation period. When combined, daily milk yield and length of lactation period give total milk production per lactating cow, a commonly-used overall indicator of system productivity.

Thus far, much of the discussion of herd dynamics focused upon tracing the effects of herd growth, which is a purely physical factor. How the cattle herd affects a farm is best expressed in terms of financial performance, where all activities are expressed in financial values. The two basic outputs from a cattle herd, beef and milk, are measurable and can be valued using normal monetary measures. But care must be taken because home consumption, particularly in the case of milk, can be an important component of herd production for very small producers. When home consumption is large, off-take calculations should be adjusted to show this benefit. A subsequent working paper will develop the financial contributions of the dairy and beef components of smallholder cattle production.

4.3. An illustrative case of the land-use trajectory: crops to cattle

This illustrative case is developed to demonstrate the use of the herd growth sub-model by simulating the buildup of a herd from an initial level that is very low to the herd size that would permit commercial milk sales. Full development conditions of this simulation roughly conform to the average conditions for Pedro Peixoto (PP) as reported by Witcover et. al. (1996). Farmers in PP have on average: 18.24 ha. of pasture and 22.06 head, being mainly adult cattle (64% or 14.12 head). Therefore the average stocking rate is about 0.75 animal units (AU) per hectare. Interviews with specialists at Embrapa Rondônia and EMATER-RO, and augmented by field data, revealed that one typical crop sequence is a one-year rotation of maize, rice, and beans (sometimes partly planted to mandioc) wich is then seed into pasture for the following year. The basic pattern of this rotation scheme is:

<u>Year 1:</u>	
May - August	slash and burn,
September - February	plant rice and maize in an intercrop,
March - April	plant beans on part of area,
March - August	prepare remainder of area for pasture;
<u>Year 2:</u>	
May - August	slash and burn new area,
September – October	plant pasture/mandioc on last year's crop area,
September - October	begin same crop sequence on newly cleared area.

The herd development trajectories developed below use two alternative assumptions about the land clearing process. One is a rapid pasture buildup which assumes that 4 hectares are cleared each year for crops and eventually converted into pasture. This fast buildup probably exceeds the labor resources of many small farmers so the slow buildup case presumes only 2 hectares are cleared each year. Miranda et al. (1995) report an average rate of pasture creation in Machadinha d'Oeste (located in eastern Rondônia) of 1.65 hectares per year in the 1986-1993 period, but with rates somewhat higher (2.44 ha./yr.) between 1989-1993. Data reported by Léna (1991) suggest that in Ouro Preto (Rondônia) an average of 2.5 hectares of pasture were planted per year (per farm) between 1980 and 1987. But, because the distribution of growth in pasture area and herd size between colonialists displayed considerable inequality, some farms likely achieved the rapid rate of annual pasture preparation. Initial pasture/herd conditions are 5 hectares of pasture and 4 AU as follows: 1 bull, 1 replacement heifer, 1 cow with calf, and 1 dry cow.

Animal units for the different classes of cattle are given below in Table 8. Some studies use a short-cut by counting all animals one year and older as 1 AU and ignoring calves (Gittinger, 1982). This convention was adopted above as a simplifying device to illustrate the effects of herd parameters on herd growth and simulations will utilize this convention. Line 143 of the herd growth sub-model calculates over (under) stocking utilizing these animal unit weights, so that the approximate AU calculation (line 97) can be compared to actual AU (line 143).

TABLE 8 - Animal units for different classes of cattle in Amazon

Animal class	A.U.
Bulls for reproduction	1.5
Lactating cows	1.0
Dry cows	1.0
calves	0.25
Yearlings	0.5
heifers	0.75

Source: Embrapa Rondônia, EMBRATER.

Small herds might not all have a bull, relying instead on borrowing one from a neighbor or cooperative ownership arrangements. However, for simplicity it is assumed that all farms have one bull for reproduction. The model farm is assumed to decide at the start of year 1 to expand pasture to accommodate a growing herd. But because the land is first planted to crops (for farm consumption and cash generation to finance pasture planting - seed, fence, etc.) and the pasture must be allowed to mature before being grazed any herd growth over the first 2 ½ years will not have any additional pasture available. This herd overstocking occurs until year three when the new pasture planted in year 2 is ready for grazing. Thus, farmers will either need to rent pasture or over-graze existing pasture which will ultimately lead to the pasture being degraded as weed invasion occurs. The calculations below assume that the farmer opts to over-graze the original 5 hectares of pasture, which leads to weed invasion and declining carrying capacity until the pasture is abandoned to capoeira in year 8. This is the process described by Serrão & Toledo (1990) and reflects a fairly pessimistic outlook for pasture; producers could avoid the degradation with proper management practices but experience suggests that first-generation pastures tend degrade to capoeira. New pasture brought into production is grazed at a rate of 0.8 AU/ha., which is assumed to be sustainable. This might not be representative of producers (a not insignificant proportion) who do not follow management strategies for sustained pastures. Some farmers appear to allow pastures to slowly degrade into capoeira and the recover the pastures. Average carriyng capacity for the model farm is the average of the carrying capacity for the original and new pasture (Tables 9 and 10).

TABLE 9 - Carrying capacity under rapid pasture development (4 ha/ year)

Year	Original (ha)	carrying capacity	new (ha)	Carrying capacity	combined (ha)	average carrying capacity
1	5	0.8	0	0.8	5	0.8
2	5	0.8	0	0.8	5	0.8
3	5	0.7	4	0.8	9	0.74
4	5	0.6	8	0.8	13	0.72
5	5	0.5	12	0.8	17	0.71
6	5	0.4	17	0.8	22	0.71
7	5	0.3	18	0.8	23	0.69
8	0	-	19	0.8	19	0.8
9	0	-	19	0.8	19	0.8

Sources: Embrapa Rondônia, EMATER-RO, fieldwork.

TABLE 10 - Carrying capacity under slower pasture development (2 ha/ year)

Year	original (ha)	carrying capacity	new (ha)	Carrying capacity	combined (ha)	average carrying capacity
1	5	0.8	0	0.8	5	0.8
2	5	0.8	0	0.8	5	0.8
3	5	0.7	2	0.8	7	0.73
4	5	0.6	4	0.8	9	0.69
5	5	0.5	6	0.8	11	0.66
6	5	0.4	8	0.8	13	0.65
7	3	0.3	10	0.8	13	0.68
8	1	0.3	12	0.8	13	0.76
9	0	-	14	0.8	14	0.8
10	0	-	16	0.8	16	0.8
11	0	-	18	0.8	18	0.8
12	0	-	19	0.8	19	0.8

Source: Embrapa-Rondônia, EMATER-RO, fieldwork.

4.4. Simulating herd trajectories

In order to demonstrate the linkage between pasture development, total carrying capacity and herd size three different herd trajectories are tracked. *Scenario 1* assumes that rapid pasture development occurs (Table 9) while *Scenario 2* assumes the low rate of pasture development (Table 10). The low growth case presumes that labor and capital constraints limit the capacity of farms to clear and plant new land. In both cases model farms are not allowed to purchase heifers or cows from off-farm sources (liquidity constraints) so all herd growth is from natural reproduction. In *scenario 3* this restriction is relaxed and the model farms are allowed a rapid buildup by purchasing heifers from off the farm. In order to focus on small farms, which are primarily dairy operations it is assumed that all male calves are sold at the end of each year. The convention followed is that carrying capacity is a loose constraint on the herd that can be stocked, within limits plus/minus 10 percent.

Simulations were carried out under a variety of levels for herd performance. The base levels are the same as used above in the example of the herd model and assume very low herd productivity rates, with productivity progressively increasing through the four alternatives (Table 11). These levels of herd performance were selected to broadly represent the ranges among small dairy farms in the Eastern Amazon and demonstrate the effects that herd productivity changes can make on the natural growth of a herd. In the simulations below the cumulative effects can be seen. Typically, herd growth is slow at first but accumulates and after several years begins to grow quite rapidly. Herd growth is graphed in Figures 1 and 2.

TABLE 11 - Herd performance statistics

	calving rate(%)	calf mortality(%)	adult mortality(%)
Base	50	10	5
Improved #1	55	8	4
Improved #2	60	6	3
Improved #3	65	4	2
Improved #4	70	2	1

[Figures 1 and 2 about here]

Scenario 1. In the rapid pasture buildup case, total carrying capacity for the 100-farm herd begins fully utilized at 400 and remains stable until the third year when newly formed pasture is available for stocking (Figure 1). Total carrying capacity then increases rapidly and reaches the stable full development level of 1520 head in year 8. For the first two years herd size under all levels of herd performance roughly equal total carrying capacity, but overstocking does occur. Then as newly formed pasture becomes available considerable excess capacity develops that cannot be utilized under the most optimistic natural herd growth (Improved #4). This over-capacity is shown by the large gap between total carrying capacity and the different herd projections between years 3 and 11, when a herd with high performance levels (high calving rate and low mortality rates) would reach the carrying capacity. Normally, when making realistic herd projections it would be assumed that farms would either begin selling off excess stock to maintain a stable herd when the capacity limit is reached or they would find a means to increase carrying capacity again. However, for demonstrative purposes these projections allow the herd buildup to pass the capacity limit. Notice that two cases (Base, Improved #1) never reach the limit and one case (Improved #2) only does in the 19th year.

Scenario 2. In this case the total carrying capacity has the same beginning and end points (400 and 1520 head) but the full development level is not reached until year 12 (Figure 2). But because the pasture buildup is much slower, all five herd performance levels result in herd growth that roughly tracks the total carrying capacity through the first 4 years. High herd growth (Improved #3 and #4) generally causes herd size to track total carrying capacity until year 12. In this scenario there really is not big gap between carrying capacity and herd size, except for the case of fairly low herd performance.

Scenario 3. A version of the model was fitted to the same herd parameters and allowing for the purchase of heifers to bring the herd up to the allowed carrying capacity. This might reflect the case of an urban businessman without experience in cattle investing in a small farm as a way to invest surplus earnings.

Although this investor might not have sufficient experience with dairy production to achieve high rates of output, liquidity would not be a problem and funds would be available to purchase heifers and ensure that available pasture capacity was utilized. This practice is common in other parts of the Amazon (e.g., Mattos and Uhl, 1994) and in field work it was apparent that urban businessmen are diversifying into dairy production in Ouro Preto as well. The simulation uses the very low rates of herd productivity in the base case (calving rate - 50%; calf mortality - 10%; adult mortality - 5%) and assumes rapid pasture development. Thus, there is a sharp rise in carrying capacity that is matched by the same increase in herd size (Figure 3). This is caused by a decision rule in the simulation to purchase heifers up to the level of under-stocking on the pasture that would occur from natural herd growth. Once the stable full development level is reached then the decision rule is to discard excess heifers. But, if additional pasture were developed and the rapid increases shown between years 2 and 8 were continued for a more extensive period of time, then this scenario would produce the type of explosive cattle herd growth exhibited in the Amazon region.

In general, neither the first or second scenario show the type of explosive cattle herd growth exhibited in the Amazon during the 1970s and 1980s. This is produced by a simulation where farms can purchase cattle. However, it is an open question whether farmers in the region use purchases to increase herd size to a new stable full development equilibrium and then cull excess stock to avoid exceeding limits imposed by total carrying capacity. It could be that other household objectives cause farmers to allow natural herd growth to continue and after a rapid buildup in herd size, such as in years 2 - 8 of scenario 3 they allow herd growth to continue along the natural herd development curves such as shown in Figures 1 and 2.

Scenarios 1 and 2 also demonstrate vividly how even small changes in herd performance statistics can lead to substantial differences in herd growth in later years after the initial investment in cattle. However, these effects are lagged and only start to accumulate in a significant manner after 5-10 years have passed. But, the actual realization of different levels of herd performance can lead to substantial differences in herd size at a point in time, as indicated by the vertical difference between the different herd growth curves in Figures 1 and 2.

5. Conclusions

This working paper is the first in a series of two working papers discussing the development of an investment model for the smallholder cattle sector in Acre and Rondônia. This sector is characterized by a large number of small producers, generally with fairly low productivity rates. However, because their production systems might be classified as dual-purpose, care must be taken in describing the rate of production in an isolated manner.

There are two components of the model under development. This working paper describes in detail the development of the herd projection component of the model and also presents examples of how the model can be adapted to study cattle herd development. A natural extension of the base case presented here would be the analysis of interventions to improve the technical coefficients of the herd through investments in genetics, nutrition, animal health and management.

Ideally, the impacts of interventions should be studied in terms of the financial benefits they producer for smallholders. Thus, the herd projections will feed into a general farm investment model developed along the lines described by Gittinger (1982). The ultimate impact that improvements to herd technological coefficients will be reflected in the revenues received. But, this is only one side of the picture. Improved production requires investments. Farm managers will only take steps to improve herd productivity if the necessary investments are cost effective and earn a return above the opportunity cost of the funds used. Thus, the returns and costs of the investment requirements must be evaluated relative to the status quo, maintenance of the production system currently in use, and relative to the payoffs from other investments such as agro-forestry production. These issues will be described in detail in the subsequent working paper.

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