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Development of an investment model for the smallholder cattle sector in the western Amazon. II. Baseline results

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Sumário

Development of an Investment Model for the Smallholder Cattle Sector in the Western Amazon II. Baseline Results

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Resumo

Foi desenvolvido um modelo para analisar a produção leiteira da pequena propriedade da Amazônia Ocidental, seus aspectos financeiros abordando a propriedade rural como um todo. A propriedade hipoteticamente estudada sumariza as condições da pecuária de leite em Ouro Preto do Oeste, Rondônia. Inicialmente acatou-se a suposição que as pastagens da propriedade eram inapropriadas e mal manejadas, sem o plantio de leguminosas e variedades recomendadas. Nestas propriedades os piquetes são muito grandes e o manejo fitossanitário inadequado. A melhoria de produção do rebanho foi baseada em investimento na melhoria de pastagens utilizando *Brachiaria brizanta.*e leguminosa, subdivisão de pastagens e suplementação mineral. A sanidade animal foi melhorada através de vacinação e controle de parasitas. O melhoramento do rebanho foi alcançado através de compra de touros melhorados e aumento do descarte. Finalmente, o desempenho reprodutivo foi melhorado através de um maior número de divisões de pastagens para permitir melhor separação do rebanho e uma menor relação vaca-touro.

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Os resultados mostram que a renda da propriedade foi influenciada pelo nível de investimento. Investimentos iniciais foram necessários para estabelecer a pastagem melhorada, construir cercas adicionais e outras benfeitorias adicionais como curral e açude. As despesas operacionais também aumentaram. Este aumento se deu de maneira mais acentuada nos primeiros anos, por causa de melhorias no manejo do rebanho e, a partir daí, de maneira mais lenta, de acordo com a evolução do rebanho. O sistema de manejo melhorado do rebanho causou expressivo aumento na renda da propriedade pelos seguintes motivos: 1) aumento da produção diária de leite por vaca; 2) aumento do período de lactação; 3) maior proporção de vacas em lactação no rebanho; 4) aumento do rebanho em decorrência do acréscimo da capacidade de suporte da pastagem.

As análises mostraram valor presente positivo do retorno aos investimentos, com taxa interna de retorno de 12,6%. Assim, como na maioria dos investimentos agrícolas, houve fluxos negativos nos 4 primeiros anos e fluxos positivos crescentes até o fim do projeto.

A análise financeira da propriedade envolveu um grande número de valores de parâmetros que podem afetar os resultados. Projeções otimistas ou pessimistas para preços e produtividades podem alterar a viabilidade do projeto. Em adição, a natureza essencialmente determística dos resultados do modelo não permite visualizar o efeito da incerteza. Deste modo, análise de sensibilidade foi feita para os parâmetros-chave: produção de leite diária por vaca, período de lactação, preço de venda de animais, taxa de crescimento do rebanho e rendimento de pastagens. Pelo fato de o plano de investimento ser centrado no melhoramento de pastagens a produtividade das mesmas é crucial para o resultado do modelo. Os resultados se mostraram, ainda, sensíveis à produtividade e o preço do leite. Mas foram pouco influenciados por variação do período de lactação e preços de animais.

O investimento em um sistema melhorado, centrado na implantação de pastagem melhorada associada com leguminosa pareceu ser um investimento adequado para pequenos produtores. Entretanto, o investimento criou um longo período inicial de fluxos negativos que têm que ser financiados de alguma maneira através de reservas existentes na própria unidade de produção ou por fontes externas. E esta é, provavelmente, a maior restrição à adoção da tecnologias propostas.

Abstract

A whole-farm model was developed for a typical mixed livestock production system, with technical coefficients and prices relevant for Ouro Preto do Oeste, Rondonia, in the western Brazilian Amazon. Using this model, two alternative scenarios are were run and their results in terms of financial performance compared. Scenario 1 simulated a low-input, low-productivity system in which both pastures and the herd were of poor quality and were poorly managed. Scenario 2 simulated the costs of and returns to a higher-productivity system requiring investments in pastures (moving from traditional pastures to Brachiaria brizanta with legumes) and the herd (improved genetic stock), and improvements in pasture and herd management.

Results suggest that, despite substantial cash outlays during the first few years to improve pastures and the herd, and higher operational costs thereafter, the higher-productivity system is more profitable than the low-productivity system. Indeed, the internal rate of return on these investments was 12.6%. Primary reasons for increased profitability were: a) increased milk production per lactating cow; b) longer lactation periods; c) a higher proportion of cows lactating at any given time; and d) larger herd size due to increased carrying capacity of pastures. Although profitable, this higher-productivity livestock production system may not be adoptable by all small-scale farmers. Large negative cash flow during the pasture establishment and herd improvement periods will have to be financed out of savings, other farm activities, or from external sources — some small-scale farmers might not have access to any of these sources of capital.

To test for consistency and to compensate for the absence of risk in the model, sensitivity analysis was performed separately on the following critical parameters — daily milk production per lactating cow, lactation period, cattle prices, herd growth rates, and pasture carrying capacity. Results of this analysis are reported in the appendix to this paper.

1. Introduction

This paper is the second in a two-part series of working papers describing the development of an investment model for the smallholder cattle sector in the Western Amazon. The first paper (Faminow et al.,

1997) describes the basic components of the investment model, the data gathering process, and the structure and use of the herd projection model that is incorporated into the investment model. This paper focuses on the actual components of the investment model, the specific approach utilized to develop the baseline case and the analysis of the output from the base model.

The data-gathering process described in Faminow et al. (1997) can be classified into the participatory processes described by Chambers (1994). Participatory research methods may not meet the narrow and rigid specifications of statistical sampling theory but, nonetheless, can often fairly and accurately reflect the underlying population. Where available, statistical sample data for the Western Amazon are utilized (Witcover and Vosti, 1996) but the model parameters also reflect data gleaned from available secondary information, on-farm interviews, discussions with a range of agricultural organizations, extension specialists and researchers, all developed over one and a half years of field research. Although no strong claims are made regarding statistical properties of many of the parameters utilized in the model, taken as a whole and combined with basic sensitivity analysis, we are confident that the results are broadly representative of smallholders in the study region.

The baseline model presented below is calibrated to reflect conditions in the region around Ouro Preto D'Oeste (hereafter simple Ouro Preto) in central Rondônia. This region was originally a planned settlement in the early 1970s, associated with the construction of the Federal Highway (BR-364) from Cuiabá, Mato Grosso, through Rondônia to Acre. Subsequent paving of the road to Porto Velho and expansion of the set of feeder roads and large-scale settlement in Rondônia occurred in the 1980s with the Northwest Regional Development Pole, commonly called POLONOROESTE (Fearnside, 1987). The region around Ouro Preto has developed into a major milk shed in Rondônia (Table 1). In 1994, the cattle herd was almost 180 thousand head, 5.2% of the Rondônia total. The amount of cows milked and milk production are both about 12% of the Rondônia total. Notice that milk productivity per cow in Ouro Preto (and Rondônia) is roughly 80% of the Brazil average, which itself is low by world standards. The recent establishment of a milk processing plant in Ouro Oreto by Parmalat, the huge Italian agribusiness company, probably signifies growing importance as a regional milk production center and will likely stimulate further increases.

In order to conduct the simulations, a pattern farm is established for a case typical of the Ouro Preto region, the small "emerging" cattle operation described in an earlier working paper (Faminow et al., 1997). The pattern farm described below is designed to illustrate the effects of an investment to improve the cattle management system for the farm, but focused around the establishment and proper management of "improved" pasture that utilizes a mix of *Brachiaria brizantha* and *Pueraria phaseoloides* (tropical kudzu), a legume. The term "improved pasture" in the context of the Brazilian Amazon can mean various things but normally refers to the combined use of pasture varieties that are well adapted to the acidic and infertile soils common to the region, along with the use of fertilizer (Sanchez, 1976). In most cases in the Amazon, nitrogen-fixing legumes, such as tropical kudzu, are used for fertilization in place of chemical fertilizers.

There are four technological entry points for improving herd indices: genetics, animal health, reproduction management and nutrition. Not all forms of technological improvement are appropriate for all farmers. In the Western Amazon many smallholders have *dual-purpose cattle herds*, primarily oriented to milk production but with the objective of producing male calves that will be well suited to beef production. These farm families will generate income from the sale of beef and milk, but may also consume a share of production on the farm or utilize oxen for draft purposes and integrate cattle into crop production by using manure to fertilize soil. Cattle will be the main "investment" for these families, both for asset value growth and also for financial liquidity. Narrow beef/milk production criteria will be less important for these families in the design of their cattle systems and the adoption of improved technology packages. Thus, specialized production systems that focus on providing high output, such as high rates of beef production, are inappropriate for these smallholders because they will need to forgo other desired characteristics (such as milk production) in order to get very high beef gains.

1.1. Overview of the Investment Model

The investment model is a set of 16 interlinked spreadsheets, plus the spreadsheet containing the cattle herd growth model, patterned after the model developed in Gittinger (1982). Financial values are in the Brazilian Real and denominated as \$ or \$ Reais in figures and tables. The model runs in Corel Quattro Pro 7. Quattro Pro uses the concept of "pages" and "notebooks" for files. Each file is a "notebook" which has many "pages", each of which can be separate spreadsheet. Each spreadsheet in the model is located on a subsequent page (e.g., Spreadsheet "C" is on page "C"). Calculations occur within individual spreadsheets on specific pages and also between spreadsheets on different pages in the notebook. Calculations are interlinked in order that changes made in one place be reflected in all other places where that number is utilized. Most changes are automatic but, because the model is not fully automatic, care must be taken in some cases to ensure consistency. In order to protect the integrity of these calculations, cells with formulas are protected by the "write-protect" property available in Quattro Pro. Table 2 describes each page of the entire spreadsheet, where it is found in the notebook containing the model and what it contains. For convenience, each table is referenced to the table in Gittinger (1982) from where the model is derived.

The investment model is designed to calculate the financial effects of an investment (called a project) on a *pattern farm*, a stylized farm operation designed to represent typical farm operations in an area. The budgeting process is called "whole farm analysis" because the effects of a change in any one activity are analyzed in the context of the entire farm enterprise. The pattern farm will not necessarily reflect the characteristics of each specific farm in the region, but will broadly reflect one of more classes of farm operations. In this case, the model is designed to be reflective of smallholder cattle producers who have a small herd, but the intention of expanding over the subsequent time period. More will be said about this below as the model is explained, in detail, on a table by table basis.

A brief overview of how the spreadsheets are linked together will assist in understanding the interlinked structure of the calculations. Ultimately, most data entered as input or calculated in specific spreadsheets affect the farm budgets, without the project (Spreadsheet P) or with the project (Spreadsheet Q). For example, land use for the pattern farm (Spreadsheet C) is interacted with yield and carrying capacity (Spreadsheet G) in order to calculate crop and pasture production (Spreadsheet H). The crop production data in Spreadsheet H are then multiplied by farm-gate prices (Spreadsheet J) in order to calculate the value of production for each crop (Spreadsheet K). These production values are then entered (by interlinked cell addresses) in the appropriate cells in the two farm budgets (Spreadsheets P and Q). Thus, for example, a change in land allocated to one in Spreadsheet C would ultimately change the financial outcomes for the pattern farm shown in the final farm budget (Spreadsheet Q) via the set of interlinked calculations described above.

Roughly the same process occurs for cattle activities but the process is a little more complicated. Pasture production is summarized in Spreadsheet H in terms of pasture carrying capacity, which then is transferred to the herd simulation model (Spreadsheet T), where it plays a fundamental role in defining the limits to herd growth and, hence, decisions involving herd management. Linked cell addresses are then used to write key parameters from the herd simulation model into Spreadsheet I of the investment model. Animal sales shown in Spreadsheet I and milk sales (calculated in Spreadsheet I) are then linked through farm-gate prices (Spreadsheet J) to value of production (Spreadsheet K) and, ultimately, the farm budgets (Spreadsheets P and Q).

The other principal spreadsheets affecting the final budgets are the ones for investment expenses (Spreadsheet M) and operating expenditures (Spreadsheet N). Some of these expenses are directly tied to other spreadsheets in the model. For example, the magnitude of some operating expenditures (such as vaccines or minerals) is affected by the size and composition of the cattle herd, both of which change over time. Where necessary, these expenses are linked to herd size from Spreadsheet I and change automatically with changes in herd size. Investment and operating expenditures are linked, in turn, directly to the farm budgets.

The remaining spreadsheets have specific purposes. The set of labor budgets (Spreadsheets D, E and F) allow analysts to assess labor use for farm activities and determine if labor needs are within the labor available to the farm family. In keeping with the opportunity-cost method for valuing on-farm labor used by Gittinger (1982, pp. 138-139) family labor is valued at the best alternative use, which is taken to be the returns to the pattern farm without the investment. Thus, labor is not entered as a separate cost entry, but is considered to be one of the residual claimants to the returns to the pattern farm enterprise. A major problem can arise when labor needs for farm activities exceed available on-farm labor resources. Thus, monthly labor requirements in Spreadsheet E interact with land use (Spreadsheet C) and herd size (Spreadsheet I) to calculate family and hired labor needs by month and year (Spreadsheet F).

1.2. Specific Differences Relative to Gittinger Model

Several unconventional features in model design were necessary in order to reflect important characteristics of smallholder livestock production in the Western Amazon. The most critical is the issue of pasture production dynamics. It has been widely reported that pastures in the Amazon are often not sustainable, due to physical and managerial characteristics (Serrão and Toledo, 1990). Thus, it was necessary to devise a method for allowing pasture productivity to degrade over time in order to simulate this process. This was accomplished by establishing a type of pasture "vintage" to track the life of a pasture. If pasture productivity is dynamic then keeping track of the age of a specific pasture would allow the pasture area to be multiplied by the (reduced) carrying capacity for (older) pasture. This then means that an initial (and broadly representative) profile of pastures is necessary in order to track these dynamics over time. The specific format of the pasture components for land use (Spreadsheet C) and carrying capacity (Spreadsheet G) reflect the need to be able to simulate pasture degradation processes.

A second difference shows up in the herd simulation model (Spreadsheet T). Although discussed in another working paper (Faminow et al., 1997) it is worth repeating here. Gittinger (1982, pp. 174-175) recommends a short-cut method of approximating animal units (AU), where all adult animals in the herd (adults less calves) are counted as each contributing 1 AU. Computationally, it is much more straight forward to keep track of the herd inventory in the herd simulation model using this short-cut, so Gittinger's suggested convention is followed. In additional, many smallholders may not be comfortable with the concept of animal units and likely do not use it when making managerial decisions, so there is a good practical reason for following the convention. However, livestock specialists sometimes prefer to use animal units, so the herd projection model also calculates over- and under-stocking in this manner.

2. Detailed Description of Investment Model

This section of the working paper presents a detailed description of the investment model on a spreadsheet by spreadsheet basis. Due to the complexity of many of the spreadsheets and the large number of interlinked calculations, a description of each entry is not possible. The intent is to provide sufficient information so that readers can track specific calculations. Copies of each spreadsheet, along with cell addresses, are contained in the appendix to this paper.

2.1. Land Use

Land use for the pattern farm is separated into two main components, land use with and without the project. Farm size is 100 hectares, typical for farms in the Ouro Preto region. Seventy-five hectares are in pasture, 18 hectares covered with secondary forest growth and 6 hectares in primary forest. Technically, Brazilian law required that a maximum of 50% of land holdings could be deforested, with the remainder reserved as forest, but fieldwork in the Ouro Preto region suggests that most smallholders have already exceeded the allowable limit. The house plot covers 1 hectare. The 75 hectares of pasture contains 4 vintages — there are 30 hectares of new pasture (in the first year of grazing use) planted to an "improved" type of pasture grass, *Brachiaria brizantha* and the remaining pasture is all older *Brachiaria decumbens,* in three 15 ha paddocks of different vintages (3, 5 and 7 years old). This pattern reflects the staggered process in which pasture is generally formed, due to labor and financial constraints, in order to provide forage to a steadily growing herd.

Land could also be allocated to other uses such as annual and perennial crops. The model has been set up for easy introduction of annual crops (e.g., maize, rice, beans and mandioc) and perennial crops (e.g., coffee, agro-forestry systems) into the pattern farm, if desired. These activities are all set at zero in the base model because of the predominance of specialized smallholder cattle farms in the Ouro Preto region.

The farm investment revolves around the introduction of improved pasture. In the first year, the manager needs to make a pasture reformulation decision. Alternatives are possible, but EMBRAPA pasture and livestock specialists recommend the introduction of a grass-legume composite (*B. brizantha* and tropical kudzu). The reformulation should be spread over several years, in order to provide grazing land for existing cattle and also to avoid excessive cash needs in any one year. Thus, the following pasture reformulation plan is followed.

Year 1 - Burn 30 ha of old pasture and re-seed to the grass-legume mix in late September. This will be ready for grazing the following year. Separate the existing 30 ha of *B. Brizantha* into two paddocks.

Year 2 - Separate the 30 ha of newly-formed pasture that were seeded in year 1 into three 10 ha paddocks, which can be grazed once the rainy season starts in September. Seed kudzu in the 30 ha of *B. brizantha* that existed before the investment and re-seed the last remaining 15 ha of pasture to the grass-legume composite.

Year 3 - Separate the 30 ha of legume-seeded *B. brizantha* into two 15 ha paddocks.

Beginning in year three, the pattern farm will have 75 ha of newly seeded improved grass-legume pasture, separated into three 15 ha and three 10 ha paddocks, capable of supporting 1.5 AU per hectare (Spreadsheet C).

2.2. Labor Use

Labor availability is an important determinant of farm success in Ouro Preto (Léna, 1991). Witcover and Vosti (1996) report average household size of 5.38 (s.d. = 2.36) and the average adult equivalent of 4.22 (s.d. = 1.80) for Theobroma, a community near Ouro Preto. Pedlowski and Dale (1992) gave family composition data for Ouro Preto as follows: household size = 5.70; adult equivalent = 4.85. Family labor can, and often does, work on all days of the week, at least during peak times. In most cases, smallholders are more likely to require extra work from family members during peak times, rather than contact supplemental labor, unless the peak labor needs greatly surpass the capacity of the family household. Accordingly, it is assumed that family labor can contribute 120 person-days (4 × 30) each month. Given the household data reported above, this seems to be a conservative estimate of adult-equivalent household labor availability.

Labor requirements for specific tasks were not easily determined. Partly, this may be due to the lack of good systematic data that allow differentiation between technologies, skill levels, on-site conditions, etc. The labor requirements per hectare, by operation, used in Spreadsheet D are summarized in Table 3 below, along with the months in which these activities occur (from Spreadsheet E). Labor activities were allocated to months when they typically occurred. Spreadsheet D also includes additional labor requirements for several other crops (maize, rice, beans, and coffee) but these are not discussed in this report because land area for these crops in the pattern farm was set to zero. Labor time for handling cattle is somewhat subjective. Animal care was calculated assuming an average of 3 minutes of time per head per day. Three minutes per day over the entire year would be 1,080 minutes (or 18 hours), which equals 2.25 person days. Milking requirements assumed 9 minutes per cow, which gives 3240 hours annually (54 hours) or 6.75 person days.

2.3. Yield and Carrying Capacity

It is difficult to accurately portray yields and carrying capacity with one set of parameters because production will vary according to variables such as soil fertility, plant variety, and management. For example, Serrão and Toledo (1990) have described a process where pastures can degrade to a point of abandonment after just 7 years of grazing, but point out that pastures can last up to 15 years and more in the region around Paragominas, Pará, where they collected their data. What factors might cause pasture productivity to fall to very low levels within 7 years? Probably the most important factor is pasture variety. Unless a grass variety such as *B. brizantha*, which is well adapted to acid infertile soils and resistant to the grass spittlebug, is used there is a high probability that insect attacks will cause weed encroachment in pastures. However, factors such as level of soil fertility, how well the pasture is initially established, number of pasture divisions and day-to-day management (e.g., frequency of burning, adequacy of rotation and intensity of grazing) interact to cause degradation as well. Serrão and Toledo (1990) primarily analyzed pastures grown on Oxisols, which are lower fertility than many of the soils in the western Amazon.

Pasture yields used in the model reflect the pasture grasses and management systems that are assumed to be used on the pattern farm. In the "without investment" case, the pattern farm is assumed to have several vintages of *B. decumbens* and a new vintage of *B. brizantha*. *B. decumbens* will generally have lower productivity rates than *B. brizantha* because *it* is generally less productive and also highly susceptible to insect attack if over-grazed, especially in the dry season. Starting at a lower initial carrying capacity (1 AU/ha), it will also generally display a greater tendency to degrade over time, so carrying capacities decline. InSpreadsheet G, the without investment case assumes that carrying capacity falls to very low levels in the 8th year. This pattern reflects weed encroachment in pasture at about the following rates: 3 years - 10 to 15% weeds; 5 years - 40 to 45% weeds; and 7 years - 80% weeds. Accordingly, it is assumed that the pasture management scheme is to allow weed cover and grass to grow in the 9th year to accumulate nutrients (short fallow). After the grass seeds fall and the seeds allowed to germinate, the weeds are burned to make the nutrients available and promote pasture re-establishment. The pasture is thus reformed, but with slightly lower carrying capacity (0.8 AU/ha). This process can be repeated once more in the 20-year period. Note that this pattern or pasture productivity attempts to model production under the somewhat artificial question of what would be if improved varieties were not adopted.

What is an improved pasture in the Western Amazon and what are the consequences for pasture productivity? In general, EMBRAPA pasture specialists are defining improved pastures as pastures containing one or more of selected grasses (*B. brizantha*, *B. humidcola*), preferably planted with a legume (e.g., tropical kudzu). This is largely consistent with Sanchez's (1976) definition, described earlier. Integration of tropical legumes with pasture grasses is a main ingredient in livestock system planning in Brazil and elsewhere in the Amazon region. This is a form of technology transfer intended to replicate the high-production systems of temperate legumes in countries such as New Zealand and also the successes in developing tropical legume-pasture grass mixtures in Australia (Preston and Leng, 1987). Benefits from incorporating legumes into grass pastures include: (1) increases in crude protein content and minerals; (2) extending grazing into dry season because legumes such as tropical kudzu remain green; (3) providing nitrogen to companion grasses; (4) increasing voluntary intake; and (5) providing stability to pasture system through different reactions to pests and other environmental stresses (Crowder, 1985).

Under appropriate fertilization and grazing management, a range of empirical studies suggests that annual production ranging between 250 - 650 kg/ha. can be achieved under test station conditions (Teitzel and Wilson, 1991; Teitzel et al., 1991; Crowder, 1985; EMBRAPA, 1995) In Australia, pasture-legume mix development began in the 1940s and generated initial success in the fertile rainforest land classes, but over time pasture vigour tended to decline which eventually led to weed infestations (Teitzel et al., 1991). Productivity and stability of grass-legume mixes in Australia has been shown to be a function of management (particularly stocking rates) and appropriate fertilizer application, irrespective of initial soil fertility, which provides some optimism for the possibility of attaining productive and stable systems in the Amazon (Teitzel and Wilson, 1991). Management is particularly important.

Discussions with an EMBRAPA pasture specialist in Acre and test station data from Pará (Valentim, various; EMBRAPA, 1995) indicate that improved pasture can display high and extended levels of productivity, when properly established and managed in the western Amazon. It is difficult to project ahead for 20 years, given that data from field trials and on-site evaluations are not available for this length of time. Accordingly, pasture productivity levels must be regarded as speculative. Valentim (various) reports observing grass-legume pastures that have been highly productive for 13-14 years and are still not showing signs of degradation, although he believes the pastures will eventually begin to degrade unless fertilizer is applied. He estimates that the improved pasture technology modeled in the pattern farm (with all relevant costs included) would be capable of supporting average annual stocking rates of 1.5 AU/ha. over a 20-year time period. In order to assess the payoff from investing in new pasture technology the potential productivity of that technology must be accurately reflected, so that the net benefit calculation can properly reflect the financial returns. This type of calculation will necessarily be speculative and assess possible returns for agricultural technologies that are not widely adopted or used.

A potential problem of this approach is that overly-optimistic pasture yields can result from agricultural research systems that do not properly consider the financial conditions faced by smalholders and the possibility that they will properly utilize the technology. As a result, test station production often exceeds actual realized field results. Accordingly, sensitivity analysis will be utilized to estimate the returns under different levels of pasture productivity.

Crop production is calculated in the model by simply multiplying land area allocated to specific crops and pasture by yield. In the base example, production of annual and perennial crops is zero because no acreage is allocated to these crops.

2.4. Cattle Herd and Production

Another working paper described the structure and calculation conventions for the herd growth model (Faminow et al., 1997), which is used to calculate herd productivity for beef and milk. Sales of cattle come about from culling decisions and from sale of surplus animals. Cows and bulls are culled according to set percentages. Herd improvement usually requires an increase in culling percentages, with less productive animals removed from the herd in order to improve aggregate herd productivity. Once the maximum carrying capacity of the pasture is reached, some heifers that reach breeding age will be integrated into the herd as replacements for cows that are culled and surplus heifers will be sold.

Male calves will normally be treated in a different fashion. It is assumed that the pattern farm sells all male calves before they are 1 year old. Alternative management strategies could be followed. First, the pattern farm could fatten male calves for beef production. Although some smallholders fatten beef, most do not. Second, male calves could be traded for female calves. In locations where there are many "emerging" smallholder cattle production systems this is fairly common, as a way to better utilize rapidly increased pasture capacity resulting from expansion of area in pasture and/or investment in improved pasture that permit higher stocking rates. The financial returns to rapid herd buildup by trading male for female calves is considered in a later section.

Milk production is calculated by multiplying the number of lactating cows by daily milk yield per cow and days of lactation. Revenue from milk is adjusted, however, by the proportion of milk sold.

2.5. Investment expenditures

Investment expenditures (Spreadsheet M) are defined by the technology utilized. In the land use plan for the pattern farm no new pasture is formed from forest cover. However, pasture recovery occurs on the various vintages of *B. decumbens* in years 1 and 2 of the investment at a rate of $113 per hectare. Most of this cost is labor (8 days/ha clearing and burning, 3 days/ha planting). Given the substantial amount of pasture recovered in the first two years of the project and the labor needs for doing so, it is assumed that this is a contracted job. Similarly, it is assumed that legume planted in the *B. brizantha* in year 2 is done on a contract basis (3 days/ha) at $36 per hectare.

Corral expenditures are not trivial. Although many smallholders do not have a corral, they are commonly seen in the Ouro Preto region. Investment in a covered milking corral usually occurs when smallholders expand and improve their production systems in order to sell fresh milk to commercial dairies. Corrals are generally constructed by contractors, but with the farm owner providing some assistance. Prices vary, depending upon size, roof or no roof, and whether wood is available on farm by cutting down trees. Discussions with contractors in the Ouro Preto region indicated that construction of an 18m × 18m corral with no roof would cost $1,524 if wood were available and $600 more without on-farm wood availability. Corral construction costs of $2,124 are budgeted in year 1 and the life is 20 years. EMATER budgets for the Pedro Peixoto area in Acre were similar: $1,288 for a 12m × 12m corral with no roof and $1,875 for a 20m × 20m corral with a 8m × 10m roof, both assuming that wood is available on-farm, which is generally the case in Pedro Peixoto.

Fencing generally is done on a contract basis. In the Ouro Preto area contractors quoted a cost of $1,347 per km, while prices were reported to be somewhat higher in Pedro Peixoto ($1,730). Construction costs for shared fences between neighbors are generally split, so the perimeter fence costs of the pattern farm are allocated at 50% the costs. Fence construction is spaced out over the first 3 years in order to: (1) match the process of improved pasture establishment and (2) avoid lumping investment costs in any single year. Fence expenditures are necessary in order to separate improved pasture into paddocks for cattle rotation. Insufficient rotation is common because fencing costs are high and the interior fences necessary to separate pastures into small paddocks can not be shared. However, it is hard to ensure optimal harvest of available pasture capacity from large paddocks and large paddock size can result in overgrazing, tramping and compaction in specific areas, like watering holes, where animals congregate. The pasture improvement plan developed in an earlier section requires the construction of interior fences as follows: year 1, 0.5 km; year 2, 2 km; and year 3, 2 km. Fences typically have a life of 10 years. The perimeter fence is assumed to be 4 years old at the time of the investment, so it must be replaced in year 6.

Water availability is important, especially during the 4 month dry season. The separation of pasture into smaller paddocks requires the investment in an additional dam for water storage. This costs $716 according to EMATER budgets made available to the research team. Costs are comprised of: (1) 10 hours use of a D6 Caterpillar tractor at $70/hr and (2) 2 days of labor (at $8/day) to clean and plant grass on the dam.

Additional investment costs are incurred for milking equipment as the herd size grows. Most of these expenses enter intermittently, depending upon equipment life. In addition, livestock purchases can be considered as an investment or an operating expense. Purchase of animals for herd expansion is considered here to be an investment, while herd replacements enter as operating expenses (see next section).

2.6. Operating expenditures

Operating expenses (Spreadsheet N) are linked to herd inventory and management system changes that occur as a result of the project investment. Most expenditures are linked to other spreadsheets because they are affected by activity levels.

Initially, in the without-investment case it is assumed that the pattern farm does not vaccinate cattle or treat them for pests. However, the improved cattle management system that is adopted with the project requires expenditures. Vaccination expenditures are: hoof and mouth disease, all cattle every 6 months at $0.50 per dose; brucellosis, once only for all female calves at $0.35 per dose; carbúncolo, all calves and heifers once annually at $0.17 per dose. Annual parasite and pest management is budgeted at $2.05 per animal. Medicines are included in contingencies at 3% of livestock operating costs.

Mineral supplementation is necessary in order to counteract the effects of mineral deficiency from tropical pastures and to improve milk production rates. Dosages are EMATER recommendations: 50-70 gram per day of salt-mineral mixture, depending upon size. For example, 60 grams for 365 days requires 21.9 kg and a 30 kg bag of salt-mineral mixture costs $15, a median annual dosage cost of $10.95 per head. EMATER budgets for the region utilize $11.55 as the annual cost per animal, so this figure is used.

Pasture maintenance is minimal in most poorly managed smallholder systems. The without investment case assumes that no outside labor is used for pasture maintenance so there is no operating expense for pasture maintenance (returns to household labor are included in the net benefits). Manual weeding of pastures normally utilizes 3 person-days per hectare but many smallholders do it incompletely, intermittently or not at all. As a result, pastures tend to degrade. In the with investment case, however, pasture maintenance is necessary in order to maintain pasture vigor and productivity. In the

Ouro Preto region it is common to contract laborers to manually clean pastures. Thus, the with investment case assumes that contract labor is utilized to manually weed pastures at a rate of $8 per day.

Each year the farm operator must clear along fences to prevent them from being destroyed by the use of pasture burning as a managerial tool (roço). Even though the farm manager does not burn pastures, it is necessary to protect perimeter fences against fires cause by neighbors burning their pasture so this cost is included in the with and without investment cases. Normally done on a contract basis the annual cost is $80 per km for the 4.5 km of perimeter fences that are shared with neighboring farms (the front fence is normally separated by a road from neighbors).

Fence maintenance is calculated using 5% of the initial fence construction costs as the annual maintenance cost. In the without investment case, the pattern farm has 5 km of perimeter fence which is shared, plus 2 km of internal fence. Interior fencing grows to roughly 6 km by the 3rd year of the with investment case.

Other operating expenditures for livestock include corral maintenance (at 5% of construction costs) and animal replacement costs. Equipment maintenance is assumed to be 10% of the cost of equipment investments in the same year (because the without investment case has no capital investment, equipment maintenance is assumed to be $18 annually).

2.7. Farm budgets

The without-project farm budget (Spreadsheet P) calculates the returns to the pattern farm over 20 years, assuming that the initial production system remains in place without modification or change. The primary objective is to provide a reference point by which improved systems can be compared. Given the accounting procedures in the model, the return to the without-project case is treated as the opportunity cost to use of farm resources (land, labor and capital) for an improved production system. Evaluated in this static sense over a 20 year period, this reference case is somewhat artificial. It was argued earlier that pasture productivity would fall substantially over time, without investment in the improved grass-legume pasture system recommended by EMBRAPA, and this fall in pasture productivity would also cause a downward spiral in net farm returns. The without-project farm budget (Spreadsheet P) shows a constant net benefit, because the inflow (gross production value) and outflow (operating expenditures and taxes) are unchanged. However, this is not a serious defect for three reasons: (1) the overall objective of the budgeting process is to measure the returns to the *incremental* investment, relative to a base case; (2) the without-project budget probably overstates the returns by ignoring declining pasture productivity, which will help guard against an overly-optimistic assessment of the incremental benefits to the new technology and (3) the overstatement of the without-project returns will tend to increase over the time span of the analysis, but this will tend to be canceled by the effects of the time discounting procedure in calculating net present worth of the investment.

The with-project farm budget (Spreadsheet Q) calculates the total inflow as the sum of gross value of production from agriculture, off-farm income (if any) and incremental residual value. Incremental residual value come about from the changes in farm assets that result from the investment (asset quantity and quality values) and is assigned in the last year of the investment time period. Total outflow is the sum of investment expenditures, operating expenditures, taxes and incremental working capital. Incremental working capital is minor adjustment made to ensure that the pattern farm holds back sufficient revenue to cover an changed working capital needs that result from the investment.

Net benefit before financing is shown as the total amount and the increment, relative to the without-investment case. Normally, a major investment, such as analyzed here, would require farm financing of some sort. In many cases for which this methodology was designed, agricultural projects included a significant public agricultural development finance component which was directly included in order to show financing needs. In the case of improved pasture, the lack of financing might be a major constraint to adoption of the technology package by smallholders. The recommendations analyzed here require quite profound and sudden changes in the production system, that must be made in the initial years in order to generate improved returns. The slow progress in livestock system productivity improvement and general failure of most smallholders to adopt these recommendations might reflect capital investment constraints. Thus, this analysis helps identify these financing requirements.

3. Base simulation

This section highlights the results from the base simulation, using the data for the Ouro Preto region of Rondônia. Although a wide amount of detailed information is available in the spreadsheet tables for the simulation provided in the appendix, this section will highlight the main points.

3.1. Labor use

Labor availability can be an important constraint. Recall that farm families in the region normally have the equivalent of roughly 120 person-days of farm family labor available each month. This is an extreme upper limit because it allows no time for rest and time of work. Farm family members might contribute their time in this fashion for short periods of intensive need (e.g., at harvest time) but would be unable to maintain this work load over extended periods of time. Thus, when labor needs exceed availability the options faced by the household are: (1) contract off-farm temporary laborers; (2) utilize labor-saving equipment, either by purchasing or contracting the work; (3) pool and/or trade labor with neighbors and (4) eliminate some labor-using activities. All four alternatives are commonly utilized, although cash flow constraints tend to limit the use of the first two alternatives for many smallholders in the Western Amazon.

Figure 1 shows the labor use in the pattern farm without the investment, while Figures 3 and 4 highlight the labor requirements over the first 2 years of the investment in herd improvement when much of the pasture improvement takes place. Without the investment, labor needs are well within the family labor constraint. Pasture maintenance (3 person-days per hectare to weed pastures) requires 75 person-days per month for the May-July period. Total labor requirements are just over 96 person-days, which would allow all family members one day of rest each week. For the remainder of the year, labor needs are greatly reduced and limited to livestock maintenance (handling, health management, herding, etc.) and daily milking. Undoubtedly, some minor farm labor needs are overlooked so the profile of monthly labor needs would normally be less even than shown in Figure 1.

Labor needs caused by pasture reformulation in years 1 and 2 of the investment project greatly exceed labor availability (Figures 3 and 4). May and June are the two months that needs exceed availability by a large amount. In year 1, labor needs in June alone are more than 300 person-days, while the June needs remain high at 200 person-days in the second year. Labor use is also quite high in the July-October period. Possibly some of the work load could be re-allocated to August, when labor use is budgeted at 52 and 36 person-days in year 1 and 2, respectively. The two principal labor uses are reforming pasture and clearing secondary growth from week-infested pasture. It should be emphasized that this labor budget might underestimate the labor needs because some investments, such as building fences and a corral, are assumed to be contracted to off-farm labor but some farm household management and/or participation might be required.

The average farm family labor availability is exceeded in the initial years of the investment project. After the initial two years of the investment in herd improvement, labor use returns to similar levels as existed in the "without investment" case, but then trends slowly upward as herd size and the number of cows milked grows over time (Spreadsheet C in the appendix). In all likelihood there will be some changes in farm family composition and labor availability as adults leave the household through death and marriage. Thus, labor availability may become a problem again. It should also be pointed out that shortages of temporary labor are increasingly problematic, particularly during the dry season (May - August) when labor needs for cattle and crops tend to be high. Regional labor availability is likely to be a problem if subsidy programs for pasture/production system improvement are implemented, extension programs to improve pasture are highly effective or economic conditions provide incentives for smallholders to re-form pasture.

3.2. Herd Growth and Productivity

Carrying capacity of the available pasture decreases from 57 AU/head in the "without investment": case to the 42 AU/head level in the first year of the investment project (Figure 5). Some overgrazing of remaining *B. decumbens* pasture would likely occur, but this is permissible because the pasture will be re-formed to a *B. brizantha* and kudzu mix the following year. By year 3, however, the carrying capacity of the 75 ha of reformed *B. brizantha* and legume pasture has increased to 112.5 AU/ha, a level which is maintained over the remaining life of the investment (the heavily bolded line in Figure 5). The cattle herd size, given by the fine line in Figure 5, decreases slightly to account for extra-high culling in year 1 and then grows steadily until year 10, when the carrying capacity limit is approached and the stable equilibrium herd size can be maintained at 112.5 AU (recall that these are approximate AU, as explained by Faminow et al., 1997).

The gap between herd size and carrying capacity is substantial between years 2 and 10, as indicated by the area between the heavy and fine lines in Figure 5. This occurs because the pasture reformation strategy focuses on improving all the available pasture in the first several years, while herd growth is restricted to the level that can be generated from internal herd growth. Recall that the herd growth model is based upon the decision rule that all female calves are retained, all male calves sold and the farm operator does not purchase heifers for herd growth. With increases in reproduction and survival indices, herd growth also increases, but this is a lagged response because of the time that it takes for heifers to finally enter the breeding cow herd (after 3 years).

Farm managers do have the option to follow other decision rules. For example, the pasture reformation process could be staged to more closely match herd growth potential. This is risky, however, because: (1) insect attacks and pasture degradation could put pressure on the remaining pasture and (2) money might not be available at a later date to fund the pasture reformation process. A second option available to farm managers would be to trade male calves for female calves, thus permitting faster overall herd growth to the allowable carrying capacity. The net effect of this decision rule is unclear, without more detailed analysis, because cash earnings from male calf sales in the initial years would be lost in favor of future earnings from accelerated herd growth. However, because this is commonly utilized by smallholders for rapid buildup in their herds, the subsequent section on sensitivity analysis will provide an example under rapid herd growth. Finally, farmers could rent out the excess pasture capacity to other farmers, a common practice identified in Witcover and Vosti (1996).

Past experience has shown that many smallholders tend to experience downward pasture production spirals like the dashed unimproved pasture line unless steps are taken to recover and then properly manage degraded pastures. Without pasture improvement, traditional management and/or poorly suited pasture grasses would eventually lead to degraded pastures over the 20-year planning horizon so that carrying capacity of the original 75 hectares of pasture could be as low as 12 AU in year 20. Put another way, with pasture improvement the pattern farm is capable of supporting a herd with

112.5 AU. The pattern farm would have 3 bulls, 70 breeding cows, 44 calves, and 43 heifers. Assuming the downward spiral in carrying capacity, land would need to be abandoned and additional primary forest cleared to provide new pasture, so that over 500 hectares of cleared land would eventually be necessary in order to support a herd of this size over 20 years.

The pattern farm herd not only grows but composition changes also (Figure 6). After the initial drop in herd size in year 2, the number of young heifers (1-2 years), old heifers (2-3 years) and breeding cows in the herd grows steadily. However, when the stable herd is reached and maintained after year 10, the proportion of breeding cows in the herd is considerably smaller, relative to heifers. This is a direct result of the improved calving and survival rates that result from the investment in the improved pasture and herd management system. One outcome is that the farm manager will have a better selection of mature heifers to choose from when making decisions about which to use as heifer replacements for culled cows.

Graphs illustrating the improvement in herd indices are shown in Figures 7 and 8, which show the selected indices for the "without" and "with" investment stable herds. The number of lactating cows in the herd increases from 19 to 46. Net cattle sales increase from 15 head annually to 43 head. Milk production per cow increases from 540 to 1200 liters. This increase comes from two components: (1) the increase in daily yield from 3 to 5 liters/day and (2) the lengthening of the lactation period from 180 to 240 days. This post-investment milk yield is very high, relative to yields prior to the investment and also relative to average milk productivity in other regions of Brazil, so sensitivity analysis on daily milk productivity and lactation period will be performed in a subsequent section.

3.3. Revenues, expenses and net returns

The investment in the improved pasture and cattle management system substantially affects revenues, expenses and net returns. The composition and size of revenues adjusts. For the "without investment" stable herd case, revenues from livestock sales ($2,019) actually exceed revenues from dairy ($1,589), with most of the livestock revenues coming from sales of male calves and culled cows (Spreadsheet K in Appendix). In the initial years of the investment (Figure 9), revenue from livestock sales continues to comprise a large share of gross revenues, but these revenues grow slowly due to the retention of all heifers for herd growth. A sharp rise in revenues from livestock occurs in year 10 because of the substantial sales of surplus heifers that are necessary to maintain a stable herd size. In year 1, livestock contributes over $3,000 because of the high cull rate necessary to remove undesirable bulls and cows from the herd. The sharp rise in gross production value between years 2 and 5 is due primarily to the increase in milk production per lactating cow, itself due to improvements in daily yield and lactation period length. Subsequent increases in dairy product yields are due to the rapid growth in the number of producing cows in the herd. The stable revenue level achieved after year 10 is comprised of over $8,900 of dairy production revenue (59%) and over $6,200 of livestock sales revenue (41%).

Expenditures associated with investment in the improved pasture and management system are irregular (Figure 10). In the initial years of the investment, large investment expenses push expenditures to very high levels. In year 4, investment expenditures have dropped off but subsequent large spikes occur in years 6, 13, and 16 as a result of the need to rebuild fences, purchase horses, and purchase farm equipment, all which have a useful life between 2 and 10 years. The spikes occur because some of the investments are lumpy and must be replaced fairly often. Incremental working capital and other expenses are fairly minor.

A detailed picture of investment expenses is shown in Figure 11. Substantial expenses in the first two years are for land improvement, which is primarily pasture recovery and planting legumes, and construction (fencing, corral and dam). The critical role played by fencing expenditures in the later years in the investment is clearly highlighted in years 6, 12, 13 and 16. A key problem with the use of smaller paddocks for more intensive grazing management is that it involves substantial initial cash outlays that must be repeated within 10 years. The financial investment requirements could be exacerbated in these years if the assumed pattern of stable pasture productivity is too optimistic. If pastures begin to degrade 10-15 years after establishment then the farm operator would be faced with a pattern of investment expenditures between years 12-16 at levels similar to those in years 1 and 2. Another exacerbating factor could be expected price fluctuation, especially if low prices were expected when there would be a need to replace degraded investments like fences.

Notice also that operating expenditures are a large component and that they increase over time. This can be seen clearly in Figure 12, which shows a line graph of operating expenditures. A large one-time rise occurs in year 1 of the investment project with adoption of the improved (and more costly) management system. Operating expenditures then rise steadily and remain roughly constant beginning in year 12. The substantial operating expense difference between the "without" and "with" project cases is especially crucial when it is recalled that gross production value for the pattern farm actually fell in years 1 and 2 of the investment.

Figure 13 provides a graphical view of net financial benefits from investment in the improved herd performance system. Recall that these are incremental benefits, relative to the returns under the "without investment" scenario. Land, labor and capital resources used in farm production are valued at opportunity costs, using the "without investment" case as the forgone opportunity. The pattern of financial benefits shown in Figure 13 is typical for agricultural projects, where large initial expenditures are required and response lags delay the financial returns to the improved productivity, so financial benefits are negative in the initial years. However, over the remaining period, returns are positive, but somewhat irregular. The large increase in year 20 is caused by the underlying assumption that the farm operation valued (as if it were liquidated) in that year. This permits the benefits from the increase in farm asset size and quality to be accounted for in the analysis. In this case, the residual value uses the same prices as in the initial period, even though herd quality has been dramatically improved. Thus, the incremental value in year 20 likely is a conservative estimate of the actual value.

The financial net present worth (NPW) of the investment is shown in Figure 14 for five different real discount rates: 3, 6, 9, 12 and 15 percent. NPW is positive for all discount rates, except 15%. For smallholders with the low discount rate of 3% the NPW is positive and large in value, almost $40,000. At a 12% discount rate, NPW is positive but near zero. The internal rate of return (IRR) for the investment is 12.6%.

4. Sensitivity analysis

Sensitivity analysis is useful for assessing the impact that variation in key paramaters can have on the results. This is a particularly important tool for farm financial analysis, such as used in this paper, because the parameters and model design are determined, in part, by expert assessment. Sensitivity analysis is normally conducted by systematically varying one (or more) parameters and assessing the effect that this has on the model results. For example, parameters such as milk productivity and price play a key role in the model described above because well over half of the farm revenues comes from the sale of milk. The parameters utilized in the analysis are reflective of past levels over the past several years in the Ouro Preto region and expectations regarding the response to technology, but do not necessarily accurately indicate all conditions faced by farmers. Thus, in order to properly assess the financial potential of the investment in new technology it is helpful to determine how sensitive are the base results to variations in key parameters. Although not an explicit test of uncertainty, sensitivity analysis can identify parameters which have a strong effect on the results.

4.1. Milk Productivity

As indicated earlier, the increases in milk productivity that were utilized in the simulation were based upon expert assessment by EMBRAPA specialists. In the case of agricultural development of the Amazon, some critics have argued that EMBRAPA has been overly-optimistic in yield projections. Actual realized yields may be lower, due to a number of reasons. For example, when agricultural technology is tested in experiment stations, the main research objective is usually to maximize yield, not profit, so minimal attention is paid to the question of whether the maximum productivity is actually profitable. In contrast, profitability is crucial to the technology adoption decisions of farmers. Second, farmers may be unable to adopt the entire technology package, because of capital constraints, or they may lack sufficient human capital to apply the technology properly. As a result, expected yield increases might overstate actual responses when technology is applied in the field by smallholders. Evidence suggests that lower on-farm productivity, relative to experiment station results, is generally realized in the case of improved pasture technology in the Amazon, the core of the improved management system assessed above in section 3 (Reátegui et al., 1995).

A main benefit of the improved management system is expected to be milk production, because of a higher average daily yield (rising from 3 to 5 liters/day) and an extended lactation period (increasing from 180 to 240 days). If milk production per cow does not rise in this fashion then the payoff from adoption of the technology would seem to be in doubt.

Figures 15-17 provide an assessment of the sensitivity of the NPW of the investment to realized milk production levels that are lower than the projected levels. The first figure evaluates sensitivity to daily milk yield, the second to length of lactation period and the last to combinations of daily milk yield and lactation period. Because the common concern is that expected production is biased upward, no evaluation is conducted on higher than projected levels. In all three figures, the base case shown earlier is presented in order to provide a common yardstick with which to judge the relative sensitivity. Note also that the vertical scale on the three figures is the same. Two alternative cases are compared to the base (Table 4). *Low* measures the NPW across all discount rates for a production increase that is low, relative to the base simulation. For milk yield, the low case allows milk to increase to 3.8 liters/day by the 4th year (from 3.0 liters/day). The low case for lactation period allows an increase from 180 to 210 days by the 5th year. *Medium* measures the effect on NPW of a medium-level increase in milk yield (from 3.0 to 4.4 liters/day) and lactation period (from 180 to 225 days). Figure 17 combines these: low (medium) milk yield and low (medium) lactation period for a low (medium) combined.

Initially, sensitivity was assessed by varying first milk yield and then lactation period, both relative to the base simulation levels for each. Lower realized milk yield reduces NPW (Figure 15) and the sensitivity is more pronounced than is the case for lactation period (Figure 16). This is an expected result because the percentage change is greater for milk yield than lactation period. However, if the base assessment of the production increase from the technology is overly optimistic, it would likely involve high projections of milk yield *and* lactation period, so Figure 17 provides an assessment of the two interacted effects. The low production case (interaction of low milk yield and low lactation period) results in negative NPW for four of the discount rates (except the 3% rate). The medium production case is mixed, with the IRR falling just below 9%. Taken together, this analysis suggests the following.

For low increases in production the investment does not appear feasible using usual discount rates.

Medium increases in production appear to offer better, but modest, prospects for investment feasibility.

NPW is more sensitive to the changes in level of milk yield than lactation period.

Accurate estimates of actual production increases that smallholders are likely to experience on farms is crucial to overall feasibility for investment in improved smallholder dairy management systems based upon improved pasture systems.

4.2. Milk and Cattle Prices

Milk and cattle prices utilized in the base model were roughly representative of price levels over the 1994 - 1996 period. However, over this period price levels were quite volatile with price swings ± 20% of mean levels (Faminow et al., 1997). For example, raw milk prices ranged in this period between $0.14 and $0.20 per liter, averaging $0.16. Similarly, the price of male calves ranged between $75 and $130 per animal, with a mean of $100.95. Figures 18-20 systematically evaluate sensitivity of net present worth to variations in milk and cattle prices. A similar strategy to production is followed. NPW is calculated for five different price levels: (1) the base case; (2) prices 20% below base case; (3) prices 10% below base case; (4) prices 10% above base case and (5) prices 20% above base case. Sensitivity is evaluated first for variations in milk price, next for variations in cattle prices and finally for variations in both milk and cattle prices. All three graphs are drawn to the same scale to permit comparison.

NPW is not highly responsive to milk price (Figure 18). A milk price 20% below the base case ($0.13 per liter) is below recent experience in the region. Even at this very low price the investment is viable at 9% and lower discount rates. A milk price that is 20% above the base ($0.20 per liter) is within recent price experience in the region and results in a positive NPW, even at the 15% discount rate.

NPW is even less responsive to variation in cattle prices (Figure 19). Price variation does not appear to substantively affect the feasibility of the investment in the improved system. However, cattle price variability is likely correlated with milk price variability, so it is necessary to evaluate the sensitivity to milk price interacted with cattle price (Figure 10). Here the sensitivity appears more pronounced. A 20% reduction in milk price combined with a 20% reduction in cattle prices allows the investment to be financial viable only at quite low discount rates. However, a 20% increase in both (which is within recent experience) makes all NPW's positive, even at high discount rates. In summary, these results suggest the following.

Sensitivity to fluctuations in milk and cattle prices, when considered individually, is very low.

With higher prices, within the range of recent experience, NPW is positive, even for high discount rates.

Only very combined low milk and cattle prices cause the investment to show poor financial prospects.

4.3. Rapid herd growth

One method that smallholders utilize for rapid herd growth is to trade male for female calves. Beef cattle producers normally prefer to feed male animals because of their greater growth potential. Smallholders interviewed in the Ouro Preto region reported that, when they bred cows for dairy production, they deliberately tried to select for beef cattle appearance in male calves as a way to enhance desirability of the calves for beef production. Rapid herd growth would provide one means to eliminate some of the excess pasture capacity that was highlighted in Figure 5. A simulation was carried out under the assumption that all male calves were traded for female calves in order to maximize herd growth until the carrying capacity of 112 AU was reached. As can be seen in Figure 11, rapid herd growth under this decision rule (fine line) eliminates much of the excess capacity that comes about from herd growth in the base case (dashed line).

Considerable changes in revenue and cost flows occur as a result of rapid herd growth. Revenues from the sale of male calves in the early years of the investment are forgone, while rapid herd increases cause operating costs to rise much more rapidly than in the base case. In comparison, rapid herd growth allows the smallholder to take advantage of the increase in milk production much sooner in the investment period. Figure 12 compares NPW at all five discount rates for the two herd projections. Notice that rapid herd growth dominates the base case for all discount rates. For a 15% discount rate, rapid herd growth results in a positive return. These results indicate the following main points.

The practice of trading male calves for female calves provides a method for smallholders to rapidly expand herd size to take advantage of increased pasture capacity and milk productivity.

This decision rule results in higher NPW at all five discount rates, relative to the base case. Care should be exercised in use of these results because it was assumed (implicitly) in the simulation that incoming female calves would reflect the same improved milk production capacity as the improved herd in the base case.

4.4. Pasture yield

It is possible (perhaps probable) that actual realized pasture productivity by smallholders will be lower than yields realized in test stations or on large-scale ranches. The 1.5 AU stocking rate was selected by EMBRAPA specialists as a reasonable and attainable level of pasture productivity for smallholders. Actual pasture yields on test stations have been reported at much higher levels, ranging between 2 and 3 AU/ha (EMBRAPA, 1995). However, it is critical that sensitivity to this pasture productivity be assessed.

Figure 13 presents NPW at the five discount rates across different levels of sustainable pasture productivity. The 5 scenarios range from the base case: 1.5 $\pm$ 0.5 AU. If a very low stocking rate of only 1 AU/ha is achieved then the investment is only feasible at the low discount rate of 3%. marginally higher productivity (1.25 AU/ha) causes the investment to be feasible for higher discount rates. Notice that investment infeasibility at a 15% discount rate appears to be quite certain, even with very optimistic expectations about the stocking rate that will be achieved on the improved pasture. These data suggest the following points.

Sensitivity to stocking rates is an important concern, because improper use of the pasture technology that lowers pasture productivity renders the investment infeasible.

High discount rates erect a barrier to investment feasibility because of the time path for revenues and expenditures.

5. Conclusions

This paper provides a description of the farm investment model developed to analyze smallholder dairy production in the Western Amazon. The base case is developed for a pattern farm that summarizes conditions for a small emerging dairy producer the Ouro Preto region of central Rondônia. Initially, it is assumed that most of the pasture in the pattern farm is an inappropriate variety and none is planted with the recommended improved grass-legume mix. Pasture paddocks are too large and animal health and breeding management poor. Herd production improvement is centered upon an investment in improved pasture utilizing a *Brachiaria brizantha* - legume mix, along with pasture subdivision and proper mineral supplementation. However, improvements along the other entry points for herd improvement also occur. Animal health is improved by a regular vaccination program and utilization of conntrol measures for parasites. Herd genetics are improved through the purchase of improved bulls and higher culling rates. Finally, reproductive performance is improved by utilizing the more numerous pasture divisions for herd separation and a lower cow to bull ratio in the herd.

Assessment of the base case shows that pattern farm revenues and expenditures are dramatically affected by the investment. Large initial expenditures are needed to establish the improved pasture, build additional fences and construct additional facilities (a milking corral and dam). Operating expenditures also rise, a sharp initial increase needed for the improved herd management system and then slower growth over time as herd size increases. Revenue increases take time because of the biological responses that constrain natural herd growth. The improved management system ultimately causes dramatic increases in herd production from four sources: (1) increased daily milk production per cow; (2) extended lactation periods; (3) a higher proportion of producing cows in the herd and (4) overall herd growth to utilize increased pasture carrying capacity.

Analysis shows generally positive net present worth for the investment, with an internal rate of return of 12.6%. The pattern of net financial benefits is typical for many agricultural investments, with negative flows over the first 4 years and then generally positive and increasing returns over the remainder of the investment time period.

Farm financial analysis involves a wide number of parameter values, the choice of which can seriously affect results. Overly optimistic (or pessimistic) projections of prices, productivity and other parameters can bias project feasibility upward (downward). In addition the essentially deterministic nature of the base model results does not provide insight into uncertainty. Thus, sensitivity analysis was carried out for key parameters: daily milk yield, lactation period, milk price, cattle prices, herd growth rate and pasture yield. Because the investment plan centered on development of improved pasture on the pattern farm, it is not surprising that actual pasture productivity (in terms of stocking rates that can be sustained) is crucial. Not much is actually known about the capacity of smallholders to achieve high rates of production from improved pastures, so this is clearly a concern. In general, the base results appear to be particularly sensitive to daily milk yield and milk price, and less sensitive to the length of lactation period and cattle prices. However, in the likely case that low milk yield would occur simultaneously with shorter lactation periods, or low milk and cattle prices would occur simultaneously, considerable variability from the base results occurs. Producers can increase returns to the investment by altering herd decision rules and adopting a rapid herd growth plan.

In conclusion, investment in an improved system, centered on improved grass-legume pasture, appears to be a feasible investment for smallholders at usual discount rates. However, the investment creates a lengthy period of initial negative cash flow that must be financed in some manner, either from cash reserves on the farm, liquid assets or farm financing. This likely is a major constraint to adoption. A second cause for concern is variation in results as revealed by sensitivity analysis. Negative returns typified many of the pessimistic scenarios utilized in the sensitivity analysis. Because good and representative data on farm system actual parameters realized by smallholders is not available, one cannot say with certainty that positive investment returns would actually be forthcoming.

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ANEXOS

TABLE 1: Summary Statistics for Milk Production in 1994

	Amount	Share of Rondônia (%)	Share of Brazil (%)
	Ouro Preto		
Cattle herd	179,922	5.2	0.1
Cows milked	31,291	11.9	0.2
Milk produced	19,713	11.7	0.1
Yield	630	97.8	80.1
	Rondônia		
Cattle herd	3,469,519	--	2.2
Cows milked	262,330	--	1.3
Milk produced	169,031	--	1.1
Yield	644	--	81.9
	Brazil		
Cattle herd	158,243,229	--	--
Cows milked	20,068,266	--	--
Milk produced	15,783,557	--	--
Yield	786	--	--

Note: Units as follows: cattle herd and cows milked, number of head; milk produced, thousand liters; yield, number of liters per cow milked.
Source: Fundação I.B.G.E. data on the World Wide Web (http://www.sidra.gov.br/)

TABLE 2: Tables in the Investment Model

Spread-sheet No.	Brief Description	Page in Notebook	Gittinger Table No.
--	description of model simulation	A	--
B	working capital percentages	B	4-3
C	land use for farm	C	4-4
D	annual labor needs	D	4-5
E	labor distribution	E	4-6
F	monthly labor needs	F	4-7
G	yield and carrying capacity	G	4-9
H	crop and pasture production	H	4-10
I	herd statistics	I	4-11
J	farm-gate prices	J	4-12
K	value of production	K	4-13
L	incremental residual value	L	4-14
M	investment expenses	M	4-15
N	operating expenses	N	4-16
O	incremental working capital	O	4-17
P	farm budget, without project	P	4-18
Q	farm budget, with project	Q	4-19
T	herd growth model	T	4-27

TABLE 3: Labor Requirements per Activity

Activity	Labor Needs (person-days)	Activity Months
	Pasture	
seeding	1	Oct.
weeding	3	May-Jul.
reformation	11	May- Sept.
	Cattle	
animal care	2.25	Jan.-Dec.
milking	6.75	Jan.-Dec.

TABLE 4: Milk Production Increases for the Sensitivity Analysis

		Year of Investment						
Milk Yield (l/day)		1	2	3	4	5	6-19	20
	Base	3.3	3.6	3.6	5	5	5	5
	Low	3.2	3.3	3.5	3.8	3.8	3.8	3.8
	Medium	3.2	3.5	3.8	4.4	4.4	4.4	4.4
Lactation Period (days)								
	Base	180	190	200	220	240	240	240
	Low	180	180	190	200	210	210	210
	Medium	180	190	200	210	225	225	225

Figure 1: Labour Use Before Investment

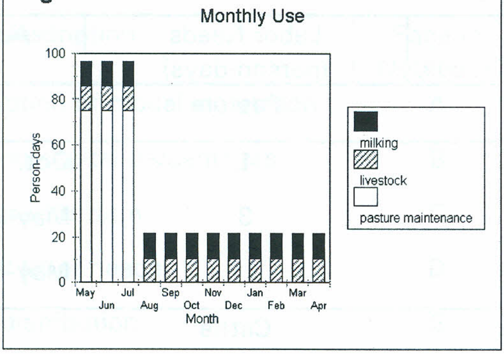


Figure 2: Labor Use, Year 1

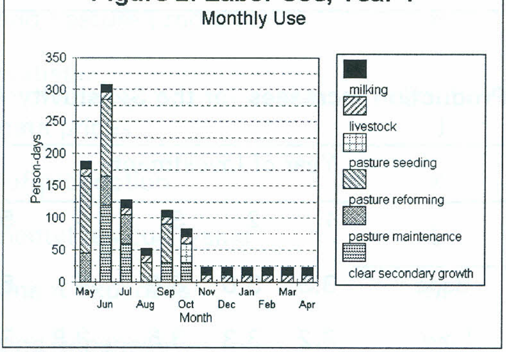


Figure 3: Labor Use, Year 2

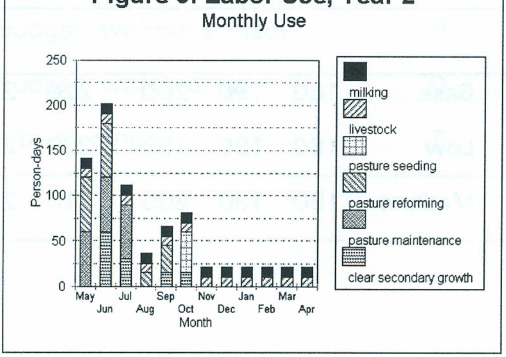


Figure 4: Herd Grows to New Capacity
From Pasture Improvement

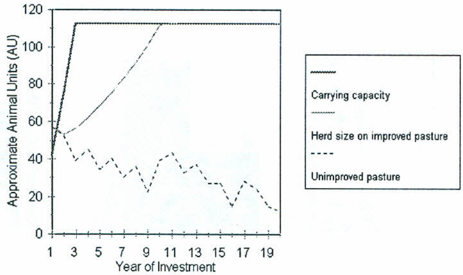


Figure 5: Herd Composition Changes
Investment in Improved System

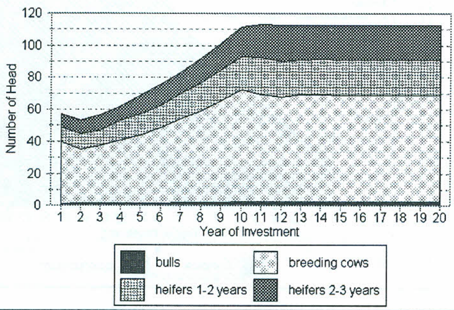


Figure 6: Herd Indices Improve
Result of Improved Technology

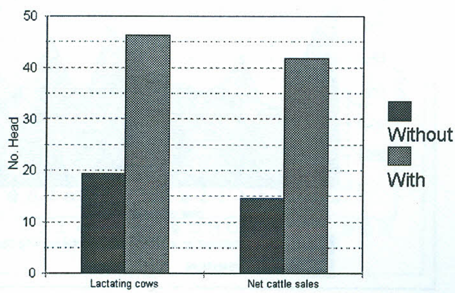


Figure 7: Milk Output Per Cow
From Improved Technology

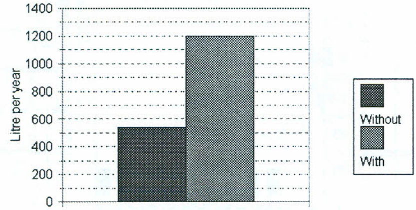


Figure 8: Gross Production Value
Investment in Improved System

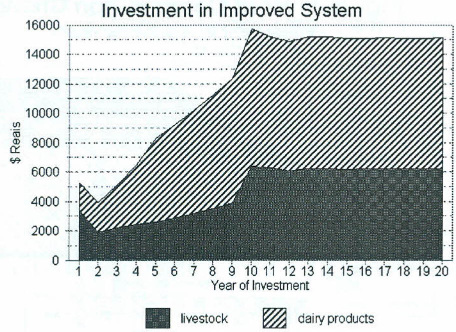


Figure 9: Expenditures
Investment in Improved System

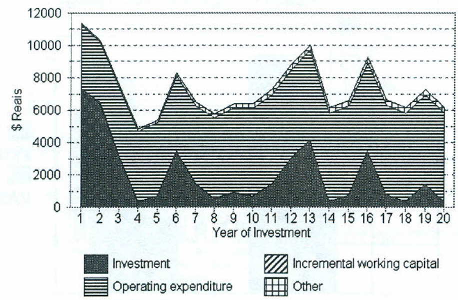


Figure 10: Investment Expenses

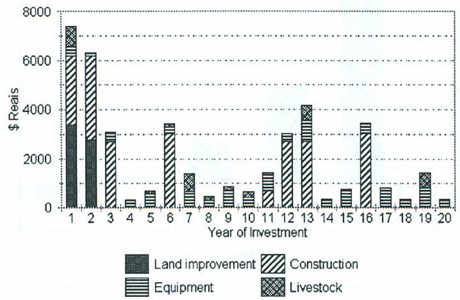


Figure 11: Operating Expenditures

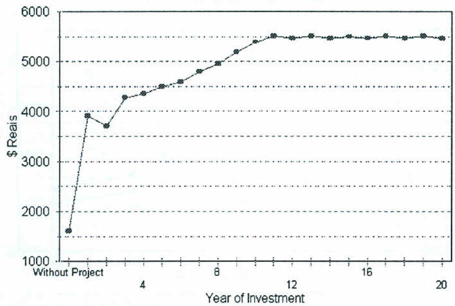


Figure 12: Net Financial Benefits
From Improved Herd Performance

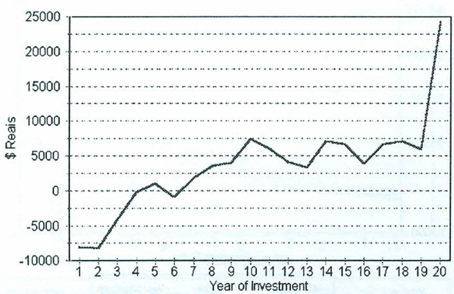


Figure 13: Net Present Worth
Alternative Discount Rates

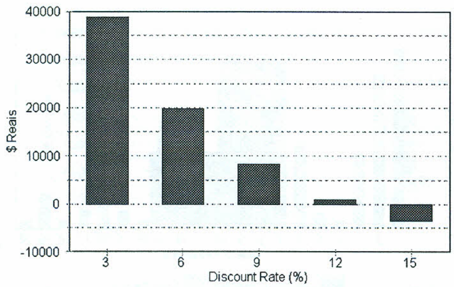


Figure 14: Sensitivity to Milk Yield
Base, Low and Medium

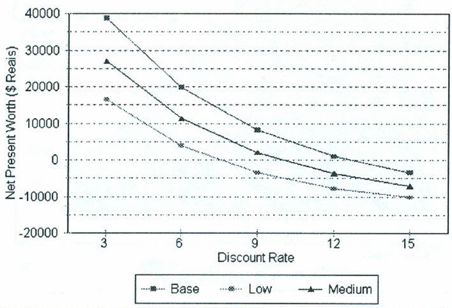
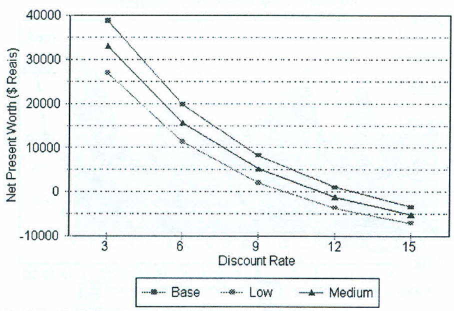


Figure15: Lactation Period Sensitivity
Base, Low and Medium



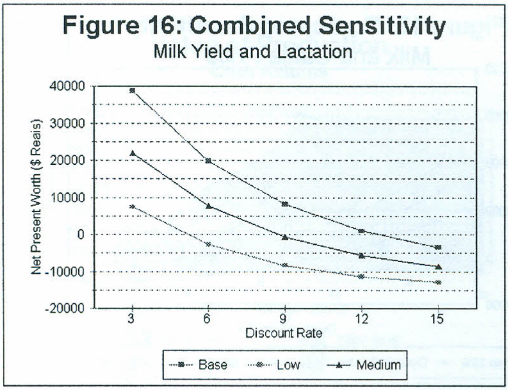


Figure 16: Combined Sensitivity
Milk Yield and Lactation
Net Present Worth ($ Reais)
40000
30000
20000
10000
0
-10000
-20000
3
6
9
12
15
Discount Rate
Base
Low
Medium

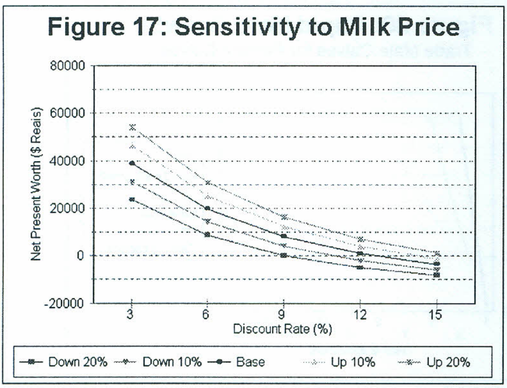


Figure 17: Sensitivity to Milk Price
Net Present Worth ($ Reais)
80000
60000
40000
20000
0
-20000
3
6
9
12
15
Discount Rate (%)
Down 20%
Down 10%
Base
Up 10%
Up 20%

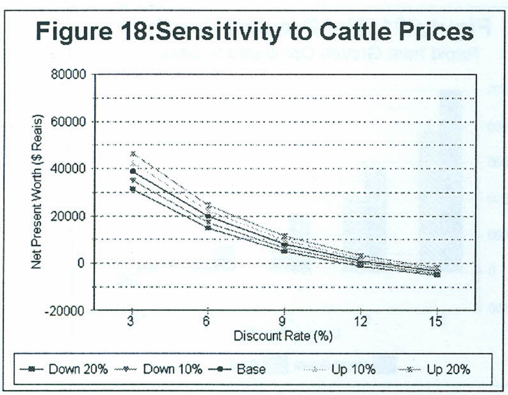


Figure 18:Sensitivity to Cattle Prices
Net Present Worth ($ Reais)
80000
60000
40000
20000
0
-20000
3
6
9
12
15
Discount Rate (%)
Down 20%
Down 10%
Base
Up 10%
Up 20%

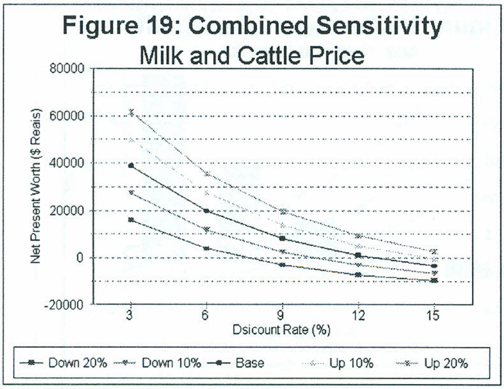


Figure 19: Combined Sensitivity
Milk and Cattle Price
80000
60000
40000
20000
0
-20000
Net Present Worth ($ Reais)
3
6
9
12
15
Dsicount Rate (%)
Down 20%
Down 10%
Base
Up 10%
Up 20%

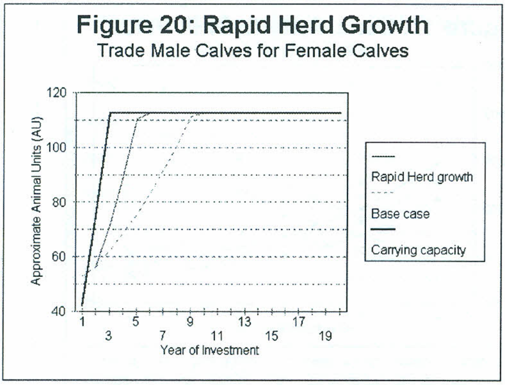


Figure 20: Rapid Herd Growth
Trade Male Calves for Female Calves
120
100
80
60
40
Approximate Animal Units (AU)
1
3
5
7
9
11
13
15
17
19
Year of Investment
Rapid Herd growth
Base case
Carrying capacity

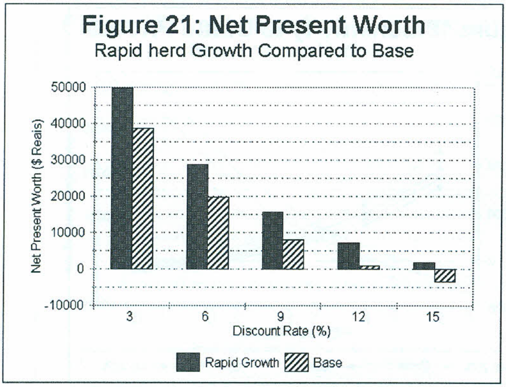
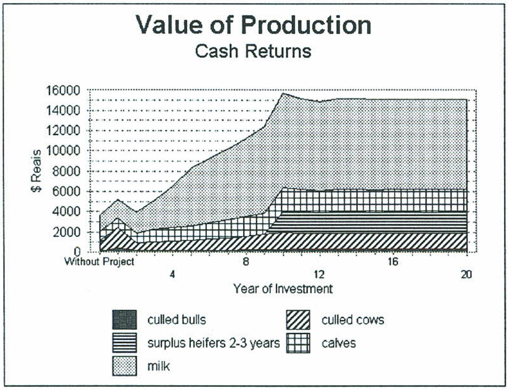


Figure 21: Net Present Worth
Rapid herd Growth Compared to Base
50000
40000
30000
20000
10000
0
-10000
Net Present Worth ($ Reais)
3
6
9
12
15
Discount Rate (%)
Rapid Growth
Base



Value of Production
Cash Returns
16000
14000
12000
10000
8000
6000
4000
2000
0
$ Reais
Without Project
4
8
12
16
20
Year of Investment
culled bulls
culled cows
surplus heifers 2-3 years
calves
milk

Embrapa

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