

## AN EVOLUTIVE STUDY ON ECONOMIC-FINANCIAL FEASIBILITY OF BRAZILIAN FAMILY FARMS BY USING MATHEMATICAL OPTIMIZATION MODEL

**Maria A. Biagio**

**Elisete N. Abe**

Departamento de Estatística  
Fundação Universidade de Brasília  
Brasília – DF - Brasil  
mamelia@unb.br  
[naomi@unb.br](mailto:naomi@unb.br)

### ABSTRACT

Based on agro-technical aspects for the Brazilian cerrado region, and considering financial conditions like monthly expenses and long-term investments, a mixed integer, and dynamic, linear model has been proposed for representing a agriculture system. This model states a monthly dynamic treatment for production and financial activities in a long-term planning horizon for a farm system based on crops production. In this work, by considering recent government financial policies for small and medium farmers, the mathematical model cited above was updated to distinct situations derived from the use of short and long-term loans for Brazilian agricultural sector. In this way, by considering credit lines for the years of 2002, 2006 and 2009, scored results were obtained for several scenarios and are presented. Also, an evolutive analysis on social-economic and financial feasibility of the agriculture farm system was drawn for this period.

**Key words :** agricultural production planning, farm systems, modelling

### RESUMO

Com base em aspectos agrotécnicos para a região do cerrado brasileiro, e considerando condições financeiras tais como despesas mensais e investimentos de longo prazo, um modelo matemático da programação linear inteira-mista, e dinâmica, foi proposto para representar sistemas de produção agrícola. Este modelo descreve atividades de produção e financeiras de fazendas através de equações dinâmicas, com períodos mensais, para horizonte de planejamento de longo prazo. Neste trabalho, o modelo acima citado foi adaptado para distintas situações derivadas da utilização de linhas de crédito de longo e curto prazos disponibilizadas para pequeno e médio produtores agrícolas. Desta maneira, considerando linhas de crédito dos anos 2002, 2006 e 2009, resultados foram obtidos para diferentes cenários e são apresentados juntamente com uma análise evolutiva sobre a viabilidade sócio-econômica e financeira destes sistemas neste período.

**Palavras-chave :** planejamento de produção agrícola, sistemas de fazenda, modelagem

## 1. Introduction

The economical and social importance of the Brazilian family farms has been underlined during the last decades. Particularly, in the last years the production participation of these small agriculture systems has improved when considering either gross production and exportation of the country ( [www2.brasil.gov.br/noticias/em\\_questao/](http://www2.brasil.gov.br/noticias/em_questao/)).

During the last decades some studies with financial emphasis have been proposed technical policies for a crops production farm system located in the *Cerrado*, Brazil. This important Brazilian region presents a very good climate for agriculture because there is no strong temperature changes neither rain storms, and infested plant problems are under control. In this region the agriculture year is divided into dry and rainy seasons. The former begins on May and finishes on October when temperatures drop between 12°C and 26°C, and the second one begins on November and finishes on April when temperatures remain between 18°C and 33°C.

Based on agro-technical aspects for the region (Veloso, 1990 and Veloso *et al*, 1994), and considering financial aspects like monthly expenses and long-term investments, a mixed integer linear mathematical model was presented by Biagio *et al* (2007) for representing a farm system with crops production. This model states a monthly dynamic treatment for production and financial activities in a horizon of long-term planning for a system based on crops production like soybean, wheat, corn and rice, which are produced in a particular rotation scheme: soybean may be produced following any of the other three crops.

In the present work, by considering recent government financial policies for small and medium farmers, the mathematical model cited above was updated to distinct situations derived from the use of short and long-term loans for Brazilian agricultural sector. In this way, this work presents new results related to the implementation of credit lines available in the year of 2007, and 2009 separately. Also, a comparative analysis on social-economic and financial feasibility of the agriculture farm system is drawn from the obtained results and some known results for credit lines available in the year of 2002 (Biagio *et al*, 2007).

For that, in the section 2 this article resumes the main mathematical model considerations, which are mathematically described in Biagio *et al* (2007), and the updated Brazilian credit lines for the years of 2007 and 2009; in the section 3 the paper presents and describes the obtained results, in the section 4 it presents a discussion on the results, and the conclusions are presented in the section 5.

## 2. Mathematical Model Considerations

The updated mathematical model describes monthly the production problem through a linear integer problem that presents constraints on land, machineries, man labor and financial allowance. These constraints are related with the total income, general expenses, credits and debts that have to be monthly and/or annually realized.

As it is explained in section 2.1, during an agriculture year the work activities at the farm are monthly determined by the type of its production. Consequently, once the crops production is considered as a business, the farmer may monthly control the cash of the farm along the planning horizon. In this way, he may monthly provide an amount of money to be spent with his family provisions, and also he may transfer the monthly cash surplus to the next monthly cash by considering an interest rate of 1%. This last condition defines a monthly dynamic structure for the mathematical model of the farm production planning.

Integer variables, as the number of employed workers necessary for operating owned machineries (as tractor and/or harvester), define a combinatorial structure to the problem. The objective of the farmer is to maximize the cash surplus and to minimize the use of his credit card in every month of the whole planning horizon.

## 2.1 System Production Conditions

The Brazilian *Cerrado* region presents a climate that is characterized by both dry season and rainy season. Dry season occurs in the period from May to September, and rainy season happens from October to April. The soil in this region is classified into three main types: the LVA, the LV and the LHI soil that represent 20%, 60% and 20% of the *Cerrado* area, respectively. Soils of the type LV are richer in vegetation than the two other types.

The crop yields depends on both the season and the type of soil; i.e., rice, corn and soybean crops are produced on LVA and LV soils in the rainy seasons, and wheat and soybean crops are produced on irrigated LV and LHI soils in the dry and rainy seasons, respectively. In this way, the three first crops mentioned above have to be planted in the months of October and November, and harvesting may be made in the months of January, March and April. Wheat crop must be planted in May and its harvests may be made in September by considering its rotation system with soybean crop.

The rotation system constraints are: soybean crop is produced by following any of the three cereal grains, and the land area used for planting has to remain at least with the same size in the next agriculture year. Soil preparations for planting must be made between seasons, when the farmer may to rent machineries like tractor and/or harvester. The agricultural year corresponds to the period beginning on 1<sup>st</sup> of May and finishing on 30 of the next April.

Just one family member manages and operates the farm in a full-time; i.e., he may dedicate 200 hours a month for managing and operating production activities, including sows and harvests. An additional of 200 hours of seasonal farm family labor is previewed in the months of intensive of both sowing and harvesting activities in the rainy season, as well as the necessity of hiring seasonal work labor.

## 2.2 Financial Conditions

In the mathematical model, it is supposed the total crops production is sold to a Co-operative Group, and a tax of 2,5% is retained by a government rural fund, namely *FUNRURAL*. It is considered the possibility to the farmer to use an own financial resource and/or his credit card for balancing monthly the cash of the farm. Furthermore, it is supposed the farmer monthly set an amount of money to be spent with family provisions.

For having access to a credit line, the farmer must have no debts and may prove that the production farm system has a minimum annual average of gross income. Recently, for the banks, small and medium farmers have to present an annual average of the gross farm income ranging from 1,153.84 u.m. to 7,051.28 and from 7,051.28 u.m. to 32,051.28 u.m., respectively.

For obtaining upgrade systems, they are considered financial packages including the credit lines *Pronaf* (National Program for Family Farm) for farmer having available an up to 60 ha of land, and financial packages including the credit lines *Proger* (Program for Rural Employment and Revenues Generation) for farmers owning a land area with size ranging between 60 ha and 100 ha.

A short-term credit line is considered into every financial package. This type of credit line may finance costs with inputs and/or investments for soil preparation, and credit amounts can be taken from the bank in the months of May, July, September, October, November, and/or February depending on both the type of crops to be produced and the size of land area used for that. This type of credit line may also finance maintenance costs of machineries and its debts may be integrally paid in July of the next year.

### 2.2.1 Financial Packages *Pronaf*

The financial package *Pronaf* was proposed to help farmers that own an up to 60 ha of land and it offered several credit lines. Here, the monetary unity, u.m., is equivalent to R\$ 15.6.

For the year of 2002, the considered financial package, namely *Pronaf\_02*, was composed by the credit lines *Pronaf\_D*, *Pronaf Agregar* and *Proger Rural Tradicional* (as described in Biagio *et al*, 2007). The *Pronaf\_D* and *Pronaf\_Agregar* were proposed to help infrastructure improvements for family farm with agricultural production, including irrigation system and machineries acquiring. Each of the credit lines had an interest rate of 4 % a year and the total credit amount was considered about 1,105.77 u.m. - 15% larger than the real credit amount allowed in 2002. Exceptionally, *Pronaf\_02* did not offer a short-term credit line.

Differently to the year of 2002, the financial package *Pronaf\_06* offered a long-term credit amount of up to 2,307.7 u.m. with interest rate of 7.25% a year for investment purposes, and a short-term credit line, namely *Pronaf Custeio*, allowing an up to 1,794.87 u.m. every two years, with interest rate of 7.25% a year. This last line was available for soil inputs purposes. For obtaining credit from *Pronaf\_06* the user may prove that his farm had an annual average of the gross income ranging from 2,564.1 u.m. to 3,846.15 u.m..

The more recent financial package *Pronaf\_09* was composed by a long-term credit line that allowed an amount of up to 2,307.7 u.m. for investment purposes and the short-term credit line *Pronaf Custeio* that allowed an amount of up to 2,564.10 u.m. every two years. For the first and second credit lines, the annual interest rate varied from 1,0% to 5,0% and from 1,5% to 5,5% a year, respectively, accordingly to the amount of money taken from them.

### 2.2.2 Financial Packages *Proger*

The financial package *Proger* was proposed to help medium farmers. In this work, it was supposed that medium farmers own a land area with size ranging from 60 ha to 100 ha.

The financial package considered for the year of 2002, namely *Proger\_02*, was composed by the credit lines *Modfrota*, *Prosolo* and *Proger Rural* (Biagio *et al*, 2007). The former offered credit with no bound for machineries acquiring as tractor and harvester, and a credit amount of up to 5,128.2 u.m. and up to 1,923.07 u.m. was possible to take from the second and third credit lines for soil input expenses and irrigation systems investments, respectively. An interest rate of 8.5% a year was pre-determined to each of these credit lines.

The short-term credit line *FCO* (Brazilian Constitutional Funds for the Middle-West Region), that was considered into the 2002 package, offered a credit amount of up to 3,205.13 u.m. over a period of two years with an interest rate of 8.5% a year. The *FCO* credit line also offered a discount of 15% on the interest rate for that farmer with no late debt payments.

The financial package *Proger* considered for the year of 2006, namely *Proger\_06*, was composed by the credit lines *Moderfrota*, *Moderagro* and a new version of *Proger Rural*. The

credit amount allowed by the former did not have an upper bound, it had an interest rate of 9.75% a year and it was defined to assist the farmer that present a gross income with annual average up to 9,615.38 u.m.. The second and third credit lines allowed amounts of up to 12,820.5 u.m. and 3,076.92 u.m. with an interest rate of 8.75% and 8.% a year, respectively. The short-term credit line *Proger Custeio* was defined to assist the farmer that had an annual average of the gross income up to 5,128.20 u.m.. For each period of two years, the allowance that could be took from both together *Proger Rural* and *Proger Custeio* was up to 3,846.15 u.m..

For the year of 2009, the financial package *Proger* was also composed by the credit lines *Moderfrota*, *Moderagro* and *Proger Rural*. When comparing them to those of the year of 2006, they presented the following changes: to the former, the interest rate was 7,5% a year; the second and third credit lines had an interest rate of 6,75% and 6,25% a year and they allowed amounts of up 16,025.64 u.m. and 12,820.51 u.m., respectively. The short-term credit line *Proger Custeio* allowed an amount of up to 16,025.64 u.m.. For each period of two years, the maximum allowance to be took from both together *Proger Rural* and *Proger Custeio* credit lines was up to 12,820 u.m..

### 3. Results

With the aim of obtaining system feasibility, the original model (2007) supposed that the credit amount took from either the packages *Pronaf\_02* or *Proger\_02* could be paid along an extended horizon of ten years and five months.

Differently to the original one, the new versions of the model supposed that the credit took from *Pronaf\_06* and *Pronaf\_09* may be paid along the planning horizon of eight years and five months. Consequently, as it happens in dynamic programming, the number of variables and constraints of the updated model were reduced if comparing to the original one. On the other hand, new constraints related to bounds on short and long-term Brazilian loans were added to the mathematical system.

The computational tests were run in a *PC Pentium® 4*, 1,80 GHz, by using the software CPLEX 9.0. The original version of the mathematical model presented the following matrix dimensions: 1758 constraints and 2722 variables for *Pronaf\_02*, 1677 constraints and 2508 variables for *Proger\_02*. The new versions of the mathematical model, which were obtained by upgrading the financial packages of the year of 2006, and 2009 separately, presented the following matrix dimensions: about 1424 constraints and 2190 variables for the packages *Pronaf*, and about 1356 constraints and 2019 variables for the packages *Proger*.

Other important updates were realized into the mathematical model. In order to get feasibility, the original model supposed the farmer monthly set a minima amount of 57.69 u.m. to be spent with family provisions. Differently, the new versions supposed that increase amounts of 67.3 u.m. and 89.42 u.m. were monthly held for family consumptions in the years of 2006 and 2009, respectively.

In all computational tests presented below, the long-term credit lines allowed to their users to pay small percentages of the debts along the four first years from the draft date. The credit card interest rate was 8,3% monthly in the year of 2002, and 7,9% monthly in the years of both 2006 and 2009. The cost of hiring seasonal work was 0.12 u.m. and 0.17 u.m. a hour in the years of 2006 and of 2009, respectively.

For the simulation tests, two distinct situations were considered: in the former, the farmer had available only 200 monthly hours of farm family labor, and in the second one he had an additional of 200 hours of seasonal farm family labor.

The tables below show the obtained results by using the following notation: IC - is the minimum initial capital resource that the farmer may own for obtaining the indicated solution; TF - is the total credit amount took from the financial package; CC - is the monthly average of the amount he may take from his credit card; TL - is the total area of land annually used for planting; LI - is the total land area annually irrigated; GI - is the annual average of the gross farm income; and CS - is the cash surplus of the farm at the end of the planning horizon.

### 3.1 Financial Packages *Pronaf*

In the tables 1 and 2, below, the financial packages considered for the years of 2002, 2006 and 2009 are namely *Pronaf\_02*, *Pronaf\_06* and *Pronaf\_09*, respectively. Both the Table 1 and Table 2 show the obtained results from running the new versions of the model applied to *Pronaf\_06* and *Pronaf\_09*, separately.

The results displayed for the financial package *Pronaf\_02* are as mentioned in Biagio *et al* (2007). For updating reasons, a hypothetical short-term credit line was embedded to the financial package *Pronaf\_02* and there was no upper bound on its credit amount. Additionally, it was supposed for this credit line a high rate of interest of 15,25% a year as a penalty factor.

#### 3.1.1 With no Surplus Family Labor

As it is depicted on table 1, in the year of 2002 it was necessary for the *Pronaf* user to own a minimum initial capital of 7,500. u.m. for obtaining production system feasibility. Furthermore, in the first year, the farmer may finance the total amount of 2,211.54 u.m. from the financial package *Pronaf\_02*. This amount is 15% larger than the real amount allowed by the long-term credit line *Pronaf* in that year. With these initial conditions, he could plant wheat in rotation with soybeans and corn in rotation with soybean crops by using a land area of 45.60 ha. The gross farm income presented an annual average of 2,402.38 u.m.. He need to take 408.23 u.m. from the hypothetic short-term credit line, in the 10th year, and he closed the cash of the farm with 252.08 u.m. at the end of the planning horizon of ten years and five months.

Table1: Financial and production results for the farmer using the financial packages *Pronaf*

Package	IC	TF	CC	TL	LI	GI	CS
<i>Pronaf_02</i>	7,500.	2,211.54	0.0	45.60	0.60	2,402.38	252.08
<i>Pronaf_06</i>	968.	all	0.0	49.82	10.82	3,953.92	5,035.41
<i>Pronaf_06</i>	100.	all	87.47	49.82	10.82	3,368.82	1,126.76
<i>Pronaf_09</i>	100.	all	21.13	50.03	11.03	3,670.52	977.37

In the year of 2006, the user of credit from the *Pronaf\_06* could pay his debts along the real planning horizon of eight years and five months without taking money from his credit card if owning an initial amount of 968. u.m. for investments. For that, he may take all allowance from the long-term credit line *Pronaf\_E* and also an annual average of 897.43 u.m. from the short-



term credit line in the eight first years. In this way, by using a total area of 49.82 ha for planting corn, soybeans and wheat in the rotation system, the gross farm income presented an annual average of 3,953.92 u.m. and the cash of the farm was closed with an amount of 5,035.41 u.m. at the end of the planning horizon.

In the case the farmer owned just 100. u.m. of initial capital, he may take the total credit allowed by the financial package *Pronaf\_06*. And, equally the earlier case, for a total area of 49.82 ha of land used for planting mainly corn, soybean and wheat crops, the obtained annual average of the gross farm income was 3,368.82 u.m., and the cash of the farm could be closed with an amount of 1,126.76 u.m. at the end of the planning horizon. But, in order to obtain these results, he must use a monthly average amount of 87.47 u.m. from his credit card over the five first years for balancing the monthly cash of the farm.

In order to obtain system feasibility, in the year of 2009 it was necessary to set a monthly amount of 79.42 u.m. for family consumptions. In this way, the user of *Pronaf\_09* could take the total amount from the long-term credit line *Pronaf* and an annual average of 1,282.04 u.m. from the short-term *Pronaf Custeio*. By using a land area of 50.03 ha the farmer could plant wheat, rice, corn and soybeans in the rotation system for obtaining an annual average of the gross farm income of 3,670.52 u.m., and he could close the cash of the farm with the amount of 977.37 u.m. at the end of the planning horizon. But, for that, he had to take a monthly average of 21.13 u.m. from his credit card during the five first years.

### 3.1.2 With Surplus Family Labor

For that farmer having available a monthly additional 200 hours of seasonal family labor, a minimum of owning initial capital of 1,500. u.m. was required, in the year of 2002, in order to provide feasibility to the production system. With these initial conditions satisfied, the farmer need to take the total amount of money allowed by the credit line *Pronaf* and part of that allowed by the credit line *Proger* with *TJLP* (Long-Term Credit Rate), in the first year. With the financed amount of 2,760.09 u.m., it was possible for him to plant corn, soybean and wheat by using the rotation system in a land area of 47.76 ha. In addition to the initial credit amount, the farmer may take money from the hypothetical short-term credit line in the seven first years with an annual average of 247,52 u.m., by paying interest rate of 15,25% a year. The annual average of the gross farm income was 2,715.75 u.m., and he got to close the cash of the farm with just 147.58 u.m. at the end of the planning horizon.

Table2: Production and financial results for the farmer using both the financial packages *Pronaf* and the surplus family labor

Package	IC	TF	CC	TL	LI	GI	CS
<i>Pronaf_02</i>	1,500.	2,760.09	0.0	47.76	2.76	2,715.75	147.58
<i>Pronaf_06</i>	968.	all	0.0	49.82	10.82	3,955.06	5,234.84
<i>Pronaf_06</i>	100.	all	68.55	49.82	10.82	3,383.50	1,362.27
<i>Pronaf_09</i>	100.	all	38.50	50.03	11.03	3,729.60	1,263.10

In the year of 2006, if owning an initial amount of 968. u.m. for investments, the farmer may take both all allowance from the credit line *Pronaf\_E* and an annual average of 897.43 u.m.

from the short-term credit line in the eight first years. In this way, he could pay his debts along the real planning horizon of eight years and five months without taking money from his credit card. In this case, by using a total area of 49.82 ha for planting corn, soybeans and wheat in the rotation system, the gross farm income presented an annual average of 3,955.06 u.m. and the cash of the farm was closed with an amount of 5,234.84 u.m. at the end of the planning horizon.

If owning an initial capital of just 100. u.m., the farmer may take the same amount of credit from the financial package *Pronaf\_06* than the earlier case. The results on the table show that with the land area of 49.82 ha for planting mainly corn, soybean and wheat crops, the farmer could get a gross farm income with average of 3,383.5 u.m. a year, and the cash of the farm could be closed with 1,362.27 u.m. at the end of the planning horizon. But, he may take a monthly average of 68.55 u.m. from his credit card over the six first years for balancing the monthly cash of the farm.

In the year of 2009, by setting the monthly amount of 79.42 u.m. for family consumptions, the user of *Pronaf\_09* could take the total amount from the long-term credit line *Pronaf*, and an annual average of 1,206.63 u.m. from the short-term *Pronaf Custeio* in order to use a land area of 50.03 ha for planting wheat, rice, corn and soybeans crops. In this way, the obtained annual average of the gross farm income was 3,729.60 u.m. and the cash of the farm could be closed with 1,263.10 u.m. at the end of planning horizon. But, to get balanced the monthly cash, the farmer had to take a monthly average of 38.50 u.m. from his credit card during the three first years.

## 3.2 Financial Packages *Proger*

In the tables 3 and 4, below, the financial packages considered for the years of 2002, 2006 and 2009 are namely *Proger\_02*, *Proger\_06* and *Proger\_09*, respectively. Both the Table 1 and 2 show the obtained results from running the new versions of the model applied to *Proger\_06* and *Proger\_09*, separately. The results displayed for the financial package *Proger\_02* are as mentioned in Biagio *et al* (2007).

### 3.2.1 With no Surplus Family Labor

As it is depicted in table 3, for the user of financial package *Proger\_02*, it was necessary to own a minimum initial capital of 5,000. u.m. for obtaining production system feasibility. In the first year, the farmer may finance the total amount of 5,431.44 u.m. from both credit lines *Proger* and *Prosolo*. In this way, he could plant wheat, corn and soybean crops in the rotation system. The annual average of the gross farm income was 4,679.29 u.m. and he closed the cash of the farm with just 513.49 u.m. at the end of planning horizon. For that, he did need also to take money from the short-term credit line FCO in every year with an annual average of 1,602.56 u.m..

In the year of 2006, with the initial capital of 5,000. u.m., the user of credits from the financial package *Proger* could take the amount of 6,845.84 u.m. from the both credit lines PROGER Rural and MODERAGRO. Furthermore, an annual average of 384.61 u.m. was necessary to be took from the short-term credit line *Proger Custeio* in the entire planning horizon. In this way, he could use a total area of 79.33 ha of land for planting corn, soybean and wheat in the rotation system, also he could get an annual average of the gross farm income of 6,018.31 u.m., and could close the cash of the farm with 19,902.74 u.m. at the end of the planning horizon of eight years and five months.



Table 3: Production and financial results for the farmer using the financial packages *Proger*

Package	IC	TF	CC	TL	LI	GI	CS
<i>Proger_02</i>	5,000.	5,431.44	0.0	73.90	8.90	4,679.29	513.49
<i>Proger_06</i>	5,000.	6,845.84	0.0	79.33	14.33	6,018.31	19,902.74
<i>Proger_06</i>	600.	4,764.72	184.89	55.02	10.02	3,708.80	2,952.46
<i>Proger_09</i>	600.	12,085.60	196.12	100.00	35.00	9,153.62	14,128.48

If owning an initial capital of 600. u.m., the user of the package *Proger\_06* could take the amount of credits of 4,764.72 from both the credit lines *Proger Rural* and *MODERAGRO* in order to use a land area of 55.02 ha for planting mainly corn, soybean and wheat in the rotation system, to have got an annual average of the gross farm income of 3,708.80 u.m. and to close the cash with 2,952.46 u.m. at the end of the planning horizon. For obtaining these results, he had to take money from the short-term credit line *Proger Custeio* with an annual average of 797.78 u.m. during the entire planning horizon, and he must use a monthly average amount of 184.89 u.m. from his credit card over the five first years.

In the year of 2009, if owning 600. u.m. of initial capital, the user of *Proger\_09* could take the amount of 12,085.60 u.m. from the credit lines *Moderagro* and *Proger Rural*. He used 100 ha of land to plant mainly corn, soybean and wheat in the rotation system. The annual average of the gross farm income was 9,153.62 u.m. and the cash of the farm was closed with the amount of 14,128.48 u.m.. For obtaining these results, the farmer had to take an annual average of 2,655.53 u.m. from the credit line *Proger Custeio* and a monthly average of 196.12 u.m. from his credit card in the first year.

### 3.2.2 With Surplus Family Labor

For the farmer having available 200 monthly hours of surplus seasonal family labor, a minimum initial capital of 100 u.m. was required in order to provide feasibility for the production system, in the year of 2002. With these initial conditions, the farmer may take the total allowance from both the credit lines *Proger* and *Prosolo*, in the first year. In this way, with an amount of 4,483.34 u.m., it was possible for him to plant wheat, soybean and corn crops by using the rotation system in a land area of 65.26 ha. The annual average of the gross farm income was 3,958.14 u.m., and he got to close the cash of the farm with an amount of 1,773.67 u.m. at the end of the planning horizon. For obtaining these results, the farmer may take capital from the short-term credit line *FCO* in every year with an annual average amount of 1,602.57 u.m., and also he did need to use his credit card over the six first years with a monthly average of 78.46 u.m..

In the year of 2006, with the initial capital of 5,000 u.m., the user of credits from the financial package *Proger* could take an amount of 6,841.49 u.m. from the both credit lines *PROGER Rural* and *MODERAGRO*. Furthermore, an annual average of 404.61 u.m. was necessary to be took from the short-term credit line *Proger Custeio* in the entire planning horizon. In this way, he could use a land area of 79.25 ha for planting corn, soybean and wheat in rotation system, and also he could get an annual average of the gross farm income of 5,569.40 u.m., and could

close the cash of the farm with 20,847.65 u.m. at the end of the planning horizon of eight years and five months.

Table 4: Production and Financial results for farmer using both financial packages *Proger* and the surplus seasonal family labor

Package	IC	TF	CC	TL	LI	GI	CS
<i>Proger_02</i>	100.	4,483.34	78.46	65.26	8.9	3,958.14	1,773.67
<i>Proger_06</i>	5,000.	6,841.49	0.0	79.25	14.25	5,569.40	20,847.65
<i>Proger_06</i>	600.	4,751.96	147.92	54.92	9.92	3,696.80	3,374.37
<i>Proger_09</i>	600.	12,085.6	196.12	100.00	35.0	9,153.62	14,503.72

It is also possible to observe from Table 4 that, if owning an initial amount of 600. u.m., the user of *Proger\_06* could take a credit amount of 4,751.96 u.m. allowed by this financial package and he could also take money from the short-term credit line *Proger Custeio* with an annual average of 810.07 u.m.. In this way, by using a total area of 54.92 ha of land for planting mainly corn, soybean and wheat in the rotation system, the farmer could get an annual average of the gross farm income of 3,696.80 u.m. and to finish the planning horizon with 3,374.37 u.m. in the cash of the farm. For that, he had to take money from his credit card along the six first years with a monthly average of 147.92 u.m.

In the year of 2009, if owning the initial amount of 600. u.m., the user of *Proger\_09* could obtain results that only differ to those displayed on table 3 in the value of the final cash surplus, which was 14,503.72 u.m. at the end of the planning horizon.

## 4. Discussion

First of all, it is important to underline some differences existing among the initial conditions of the financial packages *Pronaf* and *Proger* considered for the years of 2002, 2006 and 2009. Mainly, in 2002, the long-term credit lines had the period for debt payments extended to ten years and five months. Furthermore, as mentioned in the section 3, the amount of money monthly set for the consumption of the farmer family and the costs with seasonal labor were updated.

From the results showed on both table 1 and 2, it was possible to observe that, for the farmer owning an up to 60 ha of land (or the user of packages *Pronaf*):

- (i) the use of the additional 200 hours of seasonal family labor improved the production and financial aspects of the farm system in the year of 2002;
- (ii) by using or not the additional hours of family labor, the user of *Pronaf\_06* did need to invest a smaller initial amount of owning capital than that one necessary in the year of 2002;
- (iii) differently to the situation in the year of 2002, the farmer who took money from the financial packages *Pronaf*, in the years of 2006 and 2009, could pay his debts along the real planning horizon of eight years and five months; but,
- (iv) if he had just an amount of 100 u.m. of initial capital, he may use his credit card in order to balance the monthly cash of the farm;

- (v) all cases related to *Pronaf\_06* presented a satisfactory solution for the production system, given that the annual averages of the gross farm income were viable and the cash balance of the farm reached good surplus at the end of the planning horizon;
- (vi) the user of *Pronaf\_09* got smaller amounts in the cash of the farm than the earlier case, at the end of horizon, but the production and the financial results of the system were better than those obtained from *Pronaf\_06* over the entire period of eight years.

For the farmer owning more than 60 ha and up to 100 ha of land (or the user of packages *Proger*), it was possible to see from tables 3 and 4 that:

- (i) in addition to an owning initial capital, the user of the package *Proger\_02* had to use the surplus seasonal family labor and his credit card in order to get financial feasibility for the production system;
- (ii) differently, the user of the package *Proger\_06* could get good results if investing a large amount of owning initial capital independent on the additional 200 hours of seasonal family labor;
- (iii) the use of the additional 200 hours of seasonal family labor could bring some improvements for the farm system accounts, in the year of 2006, given that it was possible to observe feasible financial results for a small initial capital of 600 u.m.;
- (iv) but, in the last case, the annual average of the gross farm income did not satisfied the lower bound established by the banks, and it was necessary the use of credit card over the six first years for balancing the monthly cash of the farm;
- (v) the financial package *Proger\_09* presented significant improvements, given the good results showed in both of the tables 3 and 4, and also the annual average of the gross farm income was in accordance to the recent bank criteria;
- (vi) In the last case, the use of the surplus family labor did not make significant financial importance to the final results.

The results displayed on tables 1 and 2 showed that, in the year of 2002, the presence of the seasonal family labor in the production and financial feasibility of the system was more important than in the years of 2006 and 2009. For this, it was possible to observe, for *Pronaf\_02*, a decrease necessity of owning an initial capital together with an increase annual average of the gross farm income when using the surplus seasonal family labor. In the year of 2006, with a larger amount of credit than the earlier case, the farmer who took money from the package *Pronaf\_06* could obtain a little larger cash surplus than that one obtained with no surplus seasonal family labor at the end of the planning horizon. In the year of 2009, it was possible to observe some financial system improvements in the presence of the surplus family labor, given that the annual average of the gross income and the final cash surplus presented a little increase.

Similarly to the *Pronaf* case, the results presented to the user of package *Proger\_02* underlined the importance of the use of additional family labor during the period of intensive agricultural activities. In the years of either 2006 or 2009, with a larger amount of credit than the earlier case, and some amount of owning initial capital, the user of the packages either *Proger\_06* or *Proger\_09* could obtain little financial improvements by using the surplus family labor.

## 5. Conclusions

By considering the discussion presented in the earlier section, the new versions of the mathematical model permitted to point out that:

- Differently to the financial packages used for the year of 2002, both the packages *Pronaf* and *Proger* allowed credit amounts, in the years of 2006 and 2009, that improved the initial financial conditions for obtaining system feasibility;

- However, these increase amounts of credit were not enough to bring significant improvements to small production systems, given that, in the recent years, the small farmer still need to own an amount of money for initial investments and also need to use his credit card to have balanced the monthly cash of the farm, independent on the use of the surplus family labor;
- The increase amount of credits available for medium farmers, in the year of 2009, could provide for agriculture systems better and more realistic solutions than those ones obtained for the years of 2002 and 2006. For that, the operators had to own some amount of initial capital for investments and also had to use his credit card to balance the monthly cash of the farm.
- The surplus seasonal family labor considered in the mathematical model did not show to have great financial importance for getting system feasibility in the years of 2006 and 2009, as it was in the year of 2002.

## References

- Biagio, M.A., Abe, E.N., O. Turnes,** (2007) Modelo para planejamento gerencial de produção em fazenda familiar no cerrado brasileiro. *Pesquisa Operacional*, **27**, n.3, p.377-405.
- Dalton, G.E.,** Managing agricultural systems. London: *Applied Science Publishers*, 1982.
- Dent, J.B., Anderson, J.R.,** Systems analysis in agricultural management. Sidney: *John Wiley & Sons*, 1971.
- Dent, J.B.,** Optimising the mixture of enterprises in a farming system. **In.:** *Systems Theory Applied to Agriculture and the Food Chain* [edited by J. G. W. Jones, P. R. Street], London, Elsevier Applied Science, p. 113-130, 1990.
- Guanziroli, C.E.,** (2007) PRONAF dez anos depois: resultados e perspectivas para o desenvolvimento rural, *Rev. Econ. Sociol. Rural*, **27**, p.301-328.
- Veloso, R.F.,** Crop farm development in the Brazilian Cerrado region: an ex-ante evaluation. PhD. Thesis, *University of Edinburgh*, 1990.
- Veloso, R.F., MacGregor, M.J., Dent, J.B., Thornton, P.K.,** (1994) Técnicas de modelagem de sistemas aplicadas em planejamento agrícola dos Cerrados. *Pesquisa Agropecuária Brasileira*, **29**, no. 12, p. 1877-1887.