Multiobjective Comparative Analysis Between an Organic Production System and a Conventional Production System

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ABSTRACT

Presently, world agricultural production finds itself in full development with the objective of supplying both human and animal food necessities. This way, technological advance in fertilizers and chemical fertilizers production is in full expansion and were identified, through studies about natural resources sustainability, problems for today's and future generations, caused by the contamination of food, water resources and soil. Nowadays, a change in humanity's food matrix is gradually occurring, which consists in the exchange of food proceeding from a conventional technologic model with the usage of agrochemicals (pesticides and chemical fertilizers) to a kind of agriculture based on organic management, in which stands out the usage of naturally originated fertilizers (manure, ashes, leaves, etc) and ecological management of plagues, diseases and others. The present work had the objective of making a multiobjective comparative analysis between a production system that utilizes conventional management (using agrochemicals) and a production system that utilizes organic management, based on the irrigated perimeter of Epitácio Pessoa Reservoir, that is geographically located between the coordinates 07°28'4" and 07°33'32" of south latitude, 36°08'23" and 36°16'51" of west longitude, on a 420m altitude, in the city of Boqueirão, State of Paraíba, Brazil. However, was utilized a multiobjective optimization model for optimal allocation of water for irrigated agriculture, developed by GOTA (Grupo de Otimização Total da Água – Water Total Optimization Group) from UFCG. Two scenarios were elaborated, one for conventional agriculture and other for organic agriculture, taking as objectives the net budget maximization, the labour usage maximization and the minimization of defensives and fertilizers, to a 10 climatic years series. According to the study, it can be noticed that occurred economical and social gains referring to the sustainable usage of organic food, principally in the rising of labour used in organic agriculture, as well as environmental gains.

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Keywords: optimization, organic agriculture, multiobjective analysis, linear programming, sustainability.

1. INTRODUCTION

Nowadays, a change in humanity's food matrix is gradually occurring and it consists of the natural substitution of food proceeding from a conventional technological model that utilizes agrochemicals (pesticides and chemical fertilizers) for a kind of agriculture based on organic management, in which can be highlighted the usage of naturally originated fertilizers (manure, ashes, leaves, rock powder, etc.) and ecological management of plagues diseases and others. According to Magdoff (2008), 75% of poor people in the world are rural and depend on agriculture for a living. Agriculture is today, more than ever, a fundamental instrument to combat hunger, malnutrition, to support sustainable development and poverty reduction.

On the other side, according to Trigueiro (2003), in the year of 2025, 83% of world's expected population, 8.5 billion inhabitants, will be living in countries in development. Nonetheless, the capacity of this available resources and technologies of satisfying the demand for food and other agricultural products of this growing population remains uncertain.

Nowadays, the agriculture finds itself before the necessity of attending the challenge of utilizing the must efficient technologies, in what refers to the rising of production on already explored lands, and tries to avoid the even bigger exhaustion of the lands that are only marginally proper for cultivation, also trying to improve the quality of the produced food. In order to assure the sustenance of a population in expansion is necessary to give priority to the maintenance and improvement of agricultural lands with greatest potential. However, the conservation and rehabilitation of natural resources of these lands with less potential must be intensified with the objective of maintaining a sustainable man/land relation. A greater diversification of incomes, a better land conservation and a better management of agricultural inputs are also necessary

Noticed this, the necessity of utilizing inputs, that is, natural resources – as water, soils, fertilizers, defensives (chemical and organic) and others – is fundamental, being necessary the utilization of techniques that better harmonize with the policies of environmental management, aiming the maximization of the social, economic and environmental benefits.

According to Primavesi (2001), sustainability ideals are each day more aimed in agriculture. The term 'Sustainable' means using the natural resources in the present without compromising the necessary supply of the future generations, that is, not destroying the soil, the water and the air and also to permit that our descendents be still able to produce their food in a clean way and without scarceness. That is becoming each day more difficult, since humanity doesn't duplicate in a 200 years period anymore, as in the XVII Century, but in a 12 years period.

Nowadays, the consumers are preferring food that wasn't produced with infantile labour exploitation, without environmental aggression and with production technologies of low cost. This way, without the usage of agrochemicals (organic products), the preservation of not renewable natural resources becomes more important (BURG and MAYER, 2006). The organic agriculture emerges as alternative for human alimentation, aiming to make the alimentation free of agrochemicals and searching sustainability (ORMIND, 2002; HANKALY, 2001).

The conventional agriculture uses chemical fertilization and agricultural defensives (the so called pesticides). According to Fernandes et al (2005), conventional agriculture emerged as a technological package called "green revolution", adopted since World War II, the agriculture modernization lead to the adoption of ordinary practices, such as: agricultural ecosystems simplification through the adoption of production systems based in monoculture; superposition of cultural cycles; intensive mechanization; heavy irrigations; fertilizations that are many times excessives, specially with the use of highly soluble fertilization and indiscriminate and massive usage of pesticides, with high intake of dependency of the external inputs of high cost (HORNE and MCDERMMOTT, 2001).

Such practices increased world's production of food to levels never reached. However, still in the 1960 decade, the negative effects of the adoption of these practices, such as erosion, contamination of soils and springs, loss of fauna and flora diversity, resurgence of plagues and their resistance to pesticides, began to be noticed. This production model has contributed to the growing and accelerated ecological imbalance of the agricultural ecosystems (PINHEIRO et al, 1985).

On the other side, organic agriculture, according to Altieri (1989), is an agricultural system that maintains a production excluding synthetic fertilizers and pesticides. Therefore, the organic cultivation counts with the most extensive cultural rotations, as organic fertilization (to supply plants with nutrients), through crop residues, mechanical cultivation, biologic control (use of repellent plants, viruses, soap, etc.), mechanic control (collecting, weeding, etc.), plagues and diseases control (invasive plants, animals or insects). All of that is done in order to maintain productivity and soil cultivation and also to control insects, invaders and other plagues.

Organic agriculture, according to Santos and Santos (2008), take as objective improving the quality of products, preserving natural resources and not utilizing toxic residuals in food production. Because of this factor, there are restrictions on a higher price of products and to productivity reduction, which is, currently, about 30% smaller. Because of the fact that cultures productivities are still smaller when compared to the traditional cultivations, is natural that the production has the necessity of higher prices, however, the productivity difference tends to be reduced as times goes by, since the soil fertility rises gradually in consequence of the microorganisms activity in the decomposition of organic matter, occurring, from this moment on, the soil fertilization in a balanced and continuous form, reaching productivities very similar to the obtained in traditional agriculture.

Before the exposed, this research work had the objective of comparing agricultures that uses conventional management and agricultures that uses organic management, using the linear programming model, more precisely the multiobjective optimization model of water optimal allocation for irrigated agriculture, developed by GOTA (Grupo de Otimização Total de Água – Water Total Optimization Group) from Universidade Federal de Campina Grande, State of Paraíba, Brazil (Santos, 2007). The adapted model utilizes optimization processes to find optimal values through variables maximization that represent benefits and minimization of variables values that represent loss and costs.

2. MATERIAL AND METHODS

2.1. General Data from Boqueirão Reservoir.

The research here described was developed utilizing as base the irrigated perimeter of the public reservoir Epitácio Pessoa, known by the name of Boqueirão Reservoir, placed in the outside of Boqueirão city, in the state of Paraíba, where are registered 186 people with a required volume for irrigation of proximately 0.28 m³/s (AIAB, 2008; VIEIRA, 2008; DNOCS, 2008; EMATER, 2008). The area comprehends both right and left side of the reservoir (figure 1). The main cultures utilized were tomato, lettuce, pepper, bean, cabbage and onion (these in harvest and time between harvest), banana, guava, papaya and lemon.

The irrigated perimeter of Boqueirão is geographically located between the coordinates, 07°28'4" and 07°33'32" of south Latitude, 36°08'23" and 36°16'51" of west longitude, on a 420m altitude (DNOCS, 2007; DNOCS, 1963). According to AESA (2008), Boqueirão reservoir needs urban supply of 1m³/s, and also of a variable demand for irrigation.

Figure 1 – Irrigated perimeter, Culture: papaya. With Epitácio Pessoa Reservoir (Boqueirão) at back (may, 2008). Source: Research data.

The accumulation capacity of this reservoir has diminished, as time goes by, because of the siltation of its hydraulic basin, the watershed covers a 12,410 Km² area, and its accumulation capacity is, nowadays, of 411,686,287 m³ in 361 quota (SEMARH, 2004; DNOCS, 2008). Originally, the dam was planned for the following use: Paraíba River perenization, electricity generation, water supply, irrigation, psiculture and tourism. The projects of psiculture and tourism occurred in small scale and the water supply and the irrigation are the most important points, while the electricity generation was never implanted.

In what refers to the irrigation in the dam perimeter, it doesn't exist a well defined planning, however exists an approximate 1,020 Ha area of planted lands (EMATER, 2008). Presently, the main destination of its waters it's for human supply and it has the following canal systems: Campina Grande System, Cariri Canal System and Canudos System (currently deactivated). The general data of this reservoir can be better seen, as in Chart 1:

Chart 1 – General characteristics of Boqueirão Reservoir.

General characteristics of Boqueirão Reservoir	
Capacity	411,686,287 m³
Localization	Boqueirão - PB
System/Subsystem	Paraíba
Dammed river	Paraíba
Watershed area	12,410 Km²
Hydraulic basin area	2,680 Ha
Annual avarage precipitation	661 mm
Dead volume	35,000,000 m³
Maximum water level	381,36
Project	DNOCS
Construction	DNOCS

(Source: DNOCS, 2008)

The Campina Grande Canal System includes the following location (all in the state of Paraíba): Campina Grande, Barra de Santana, Queimadas, Caturité, Pocinhos, Galante and São José da Mata. The Canudos System is formed by: Riacho de Santo Antônio and Canudos. At last, Cariri Canal System includes the following municipalities: Boa Vista, Soledade, Juazeirinho, Seridó, São Vicente do Seridó, Pedra Lavrada, Cubatí, Boqueirão, Cabaceiras and Olivedos (ARAGÃO, 2008). The total benefited population is of approximately 506,534 inhabitants (SEMARH,2006).

2.2. The Model Utilized in the Research.

The model used in the research was based in Operational Research (OR) techniques and in Decision Support System (DSS). According to Barbosa (2002) and Puccin and Pizzolato(1989), the OR models are methodologies destined to solve optimization problems through objective function in the search for optimal values, that will be maximized or minimized, and of restrictions, that determine the limits and exceptions of physical and operational aspects of the system. In this context, Linear Programming (LP) is an important optimization tool in many practical problems in Operational Research that can be expressed as linear programming problems.

Certain linear programming special cases, as network flow problems and multicommodity flow problems, are considered important enough for having generated a lot of research in specialized algorithms for its solutions. Many algorithms for other kinds of optimization problems work solving LP problems as sub-problems. Historically, ideas of linear programming inspired many central concepts of the optimization theory, as duality, decomposition and the importance of convexity and its generalities.

The application of the LP in studies of water resources, agricultural resources and natural resources vary from relatively simple problems of direct allocation of resources to complex situations of management and reservoirs operation. Under certain hypotheses, non-linear problems can be linearized and solved by iteration or approximation procedures (BARBOSA, 2002; CURI and CURI, 2001A;CURI and CURI, 2001B; SANTOS, 2007).

Allied to the LP models, governmental agencies utilize computational tools to support a decision taking that, typically, have: a) A great volume of information about management of water

utilization, obtained from historical registers and real time monitoring, all of that stored in database; b) Numerical models that simulate the behavior of usage; c) Mathematic models of decision taking (optimization, simulation, scenario generation, etc.) (SHIM et al, 2002; RAFAEL, NETO, 2000).
For this research were elaborated two scenarios, one for conventional agriculture and other for organic agriculture, having the following objectives considered: Maximization of net budget and labour and minimization of the use of fertilization and of chemical defensives, in a 10 climatic years series.
In conventional agriculture scenario (S1) were attributed equal priorities to the net budget maximization, to the labour maximization and to the minimization of fertilizers and chemical defensives usage, while in organic agriculture scenario (S2), were considered the net budget maximization and labour maximization. The productivity of organic agriculture is 30% smaller in relation to conventional agriculture, but the selling prices are a lot higher (around 25% for fruits and 50% for other products).
For the multiobjective analysis, it was precisely utilized (and functionalities added) a model of multiobjective optimization of optimal water allocation for irrigated agriculture, developed by developed by GOTA (Grupo de Otimização Total de Água – Water Total Optimization Group) from Universidade Federal de Campina Grande, State of Paraíba, Brazil (Santos, 2007), that is based in linear programming, utilizing the toolbox optimization of MATLAB 6.5 software with the Inner Points Method for searching an optimical solution. So, linearizations that comes from intrinsic non-linearity to the procedures of each of its components had to be searched and implemented through the combined usage of Linearization Artifact through Segments and of Sequential Linear Programming.
The model is designed to optimize the multiple usage of a system of reservoirs, with the implementation or improving of an operation of one or more irrigated perimeters. It also works with variables related to natural elements, such as: hydroclimatics and hydroagricultural, as also other variables (water demands, physical characteristics of components, etc.) identified in the water system study. The information necessary to the model for the data entrance is defined for these elements and it involves: reservoirs, demands, river rails and irrigated perimeters.
The operation of reservoir and of the knots is based in the water balance equation of these, even when it makes use of fixed and variable demands. The water demand of an irrigated perimeter is determined based on the additional net irrigation need, established through water balance in the soil for selected cultures, when the area to be planted is limited by other reservoir usages. The model also takes into account the different types of irrigation systems and their necessities of manometric height, the areas to be irrigated for each kind of culture, the water and production costs, the economic aspects and the combination or variation in pumping sources and the water abstracted amount.

3. RESULTS AND DISCUSSION

3.1. Conventional Management

The results of the research realized in the irrigated perimeter of Epitácio Pessoa Reservoir (Boqueirão), through multiobjective optimization process of the model of Water Total Optimization Group – GOTA (SANTOS, 2007), were according to the following description: the Table 1 presents the culture data of scenario S1 (conventional management, in which both net budget and labour were maximized and the minimization of fertilizers and chemical defensives usage). The total planted area was of 875 Ha, in which can be highlighted the banana cultivation with a 352.5 Ha planted area, indicating that this culture must be stimulated because of the net budget that was of about 5 million Reais per year (Figure 2). Through the seasonality of lemon culture, the net budget was about 4,356,000 Reais per year. The banana, lemon and pepper (harvest and period between harvest) cultures were the most profitable ones in the optimization process (Figure 3).

Table 1 – Scenario Results - S1 – Conventional Managements (input/year).

Cultures	***Planted Area (ha)***	***Net Budget (R$)***	***Labour (M/D)***	***Defensives (kg)***	***Fertilization (T)***
Onion	9.00	13,868	1,899	108.00	6.30
Onion seas.	9.00	27,050	1,900	108.06	6.30
Guava	15.00	61,356	1,650	201.30	14.01
Papaya	15.00	101,267	2,880	255.00	14.01
Bean seas.	40.76	85,535	3,098	203.81	19.00
Bean	40.76	55,381	3,098	203.81	19.00
Lettuce	32.70	316,145	5,101	228.90	30.54
Lettuce seas.	32.70	415,076	5,101	228.90	30.54
Lemon	50.00	4.355,986	5,650	408.50	46.70
Tomato	41.69	136,913	15,298	1,125.50	58.36
Tomato seas.	41.69	256,985	15,298	1,125.50	58.36
Cabbage	52.50	655,712	7,455	210.00	61.27
Cabbage seas.	52.50	837,053	7,455	210.00	61.27
Pepper	44.70	857,898	8,582	1,564.50	62.58
Pepper seas.	44.70	1,086,421	8,582	1,564.50	62.58
Banana	352.50	4,996,361	75,082	2,467.50	246.75
TOTAL	875.20	14,259,007	168,131.43	10,213.78	797.56

(ha – hectare; M/D – man/day; kg – kilogram; T – ton)

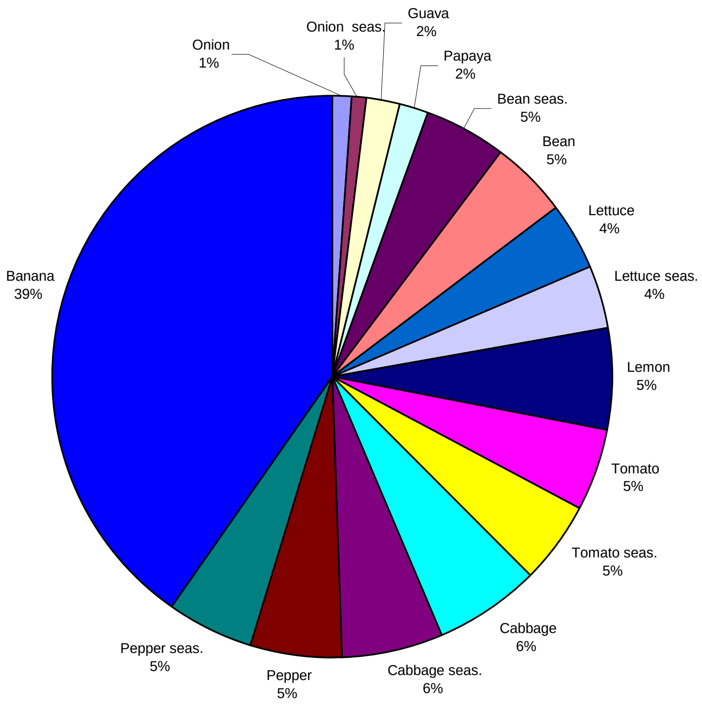

Figure 2 – Percentage of planted area of conventional management cultures.

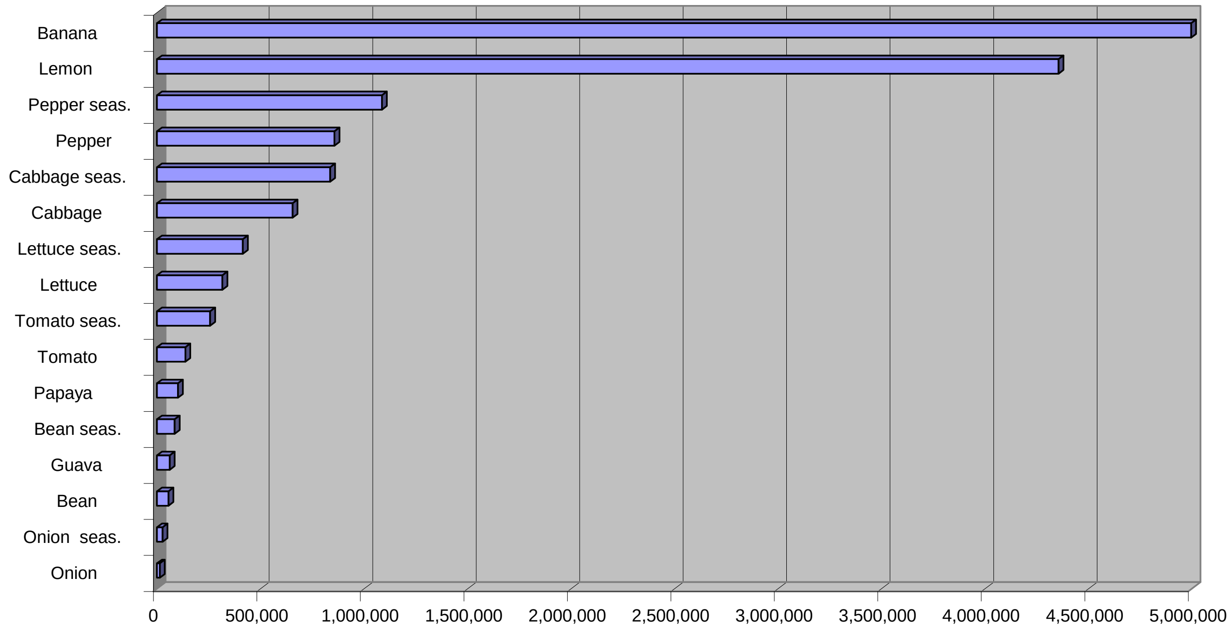

Figure 3 – Net budget of each culture in conventional managements (Reais/Year).

In what refers to labour, that was the social aspect investigated, the cultures of banana (with 75,082 men/day), tomato (with 15,298 men/day) and tomato's season (with 15,298 men/day) can be highlighted, as shown in Figure 4. Since the chemical defensives usage in banana, pepper (harvest and period between harvest) and tomato (harvest and period between harvest) cultures was higher, they, consequently, presented a higher cost and more environmental damages (Figure 5). In chemical fertilization, the banana, pepper (harvest and period between harvest), cabbage (harvest and period between harvest) and tomato (harvest and period between harvest) presented a higher consume an, thus, cost and environmental damage (Figure 6).

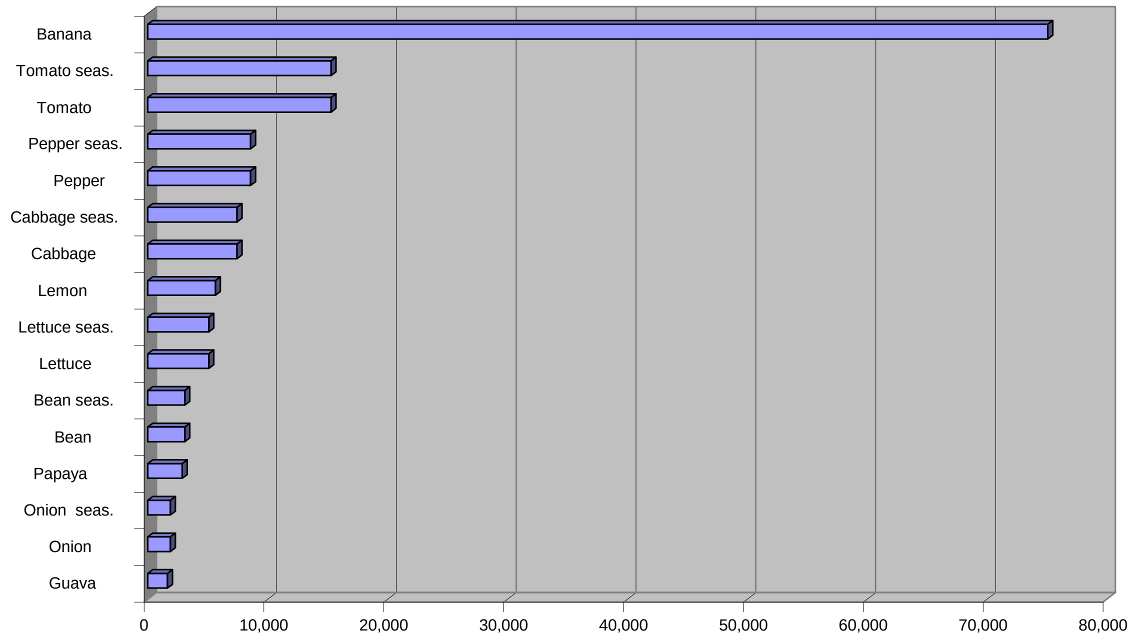

Figure 1 – Labour per culture in conventional management (men/day).

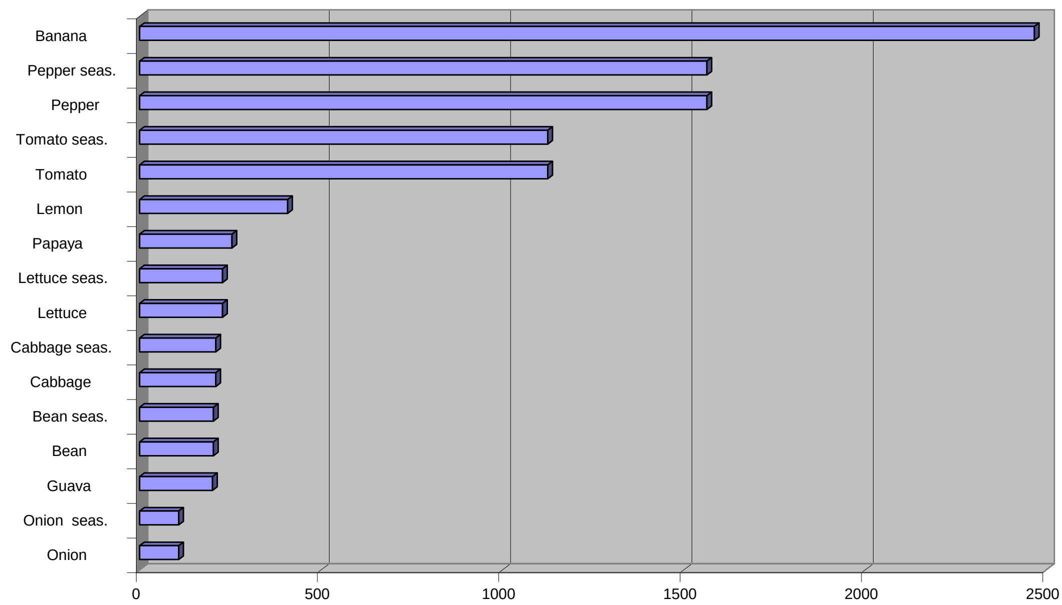

Figure 2 – Chemical defensive use per culture (Kg/year) in conventional management

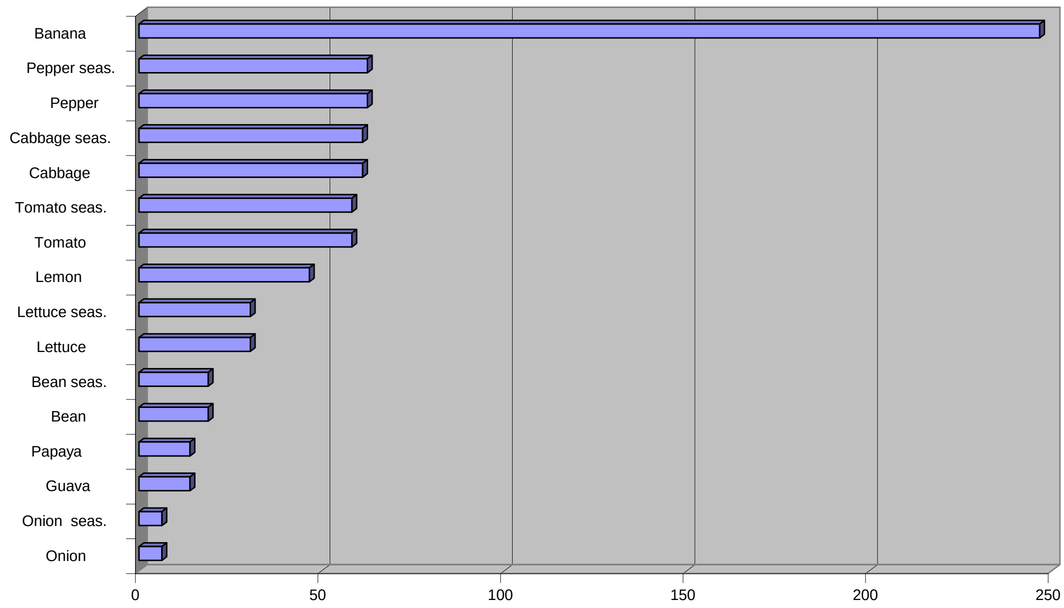

Figure 3 – Chemical fertilization usage per culture (Ton/Year) in conventional management

3.2. Organic Management

The table 2 presents the cultural data of scenario S2 (organic management, in which both net budget and labour were maximized), for organic management. The total planted area was of 1,537 Ha, in which can be highlighted banana cultures with a 352.5 Ha, indicating that this culture must be stimulated because of the net budget, that was of almost 6 million Reais per year (Figure 7). Through the seasonality of lemon culture, the net budget was proximately 4,686,000 Reais per year. The cultures of banana, lemon and pepper (harvest and period between harvest) were the most profitable ones in the multiobjective optimization process (Figure 8).

Table 2 – Scenario Results S2 – Organic Management (input/year).

Cultures	***Planted Area(ha)***	***Net Budget (R$)***	***Labour(M/D)***
Lettuce seas.	32.70	402,482	5,101
Lettuce	32.70	314,367	5,101
Guava	50.00	342,010	5,500
Lemon	50.00	4,685,274	5,650
Onion	29.99	73,416	6,328
Onion seas.	30.00	113,278	6,330
Cabbage seas.	52.50	807,668	7,455
Cabbage	52.50	653,895	7,455
Bean seas.	114.35	221,216	8,691
Bean	114.35	148,151	8,691
Papaya	50.00	486,947	9,600
Pepper	149.00	2,866,736	28,608
Pepper seas.	149.00	3,521,203	28,608
Tomato	138.95	682,387	50,995
Tomato seas.	138.95	1,006,203	50,995
Banana	352.50	5,824,728	75,082
TOTAL	1,537.00	22,149,961	310,189

(ha – hectare; M/D – man/day; kg – kilogram; T – ton)

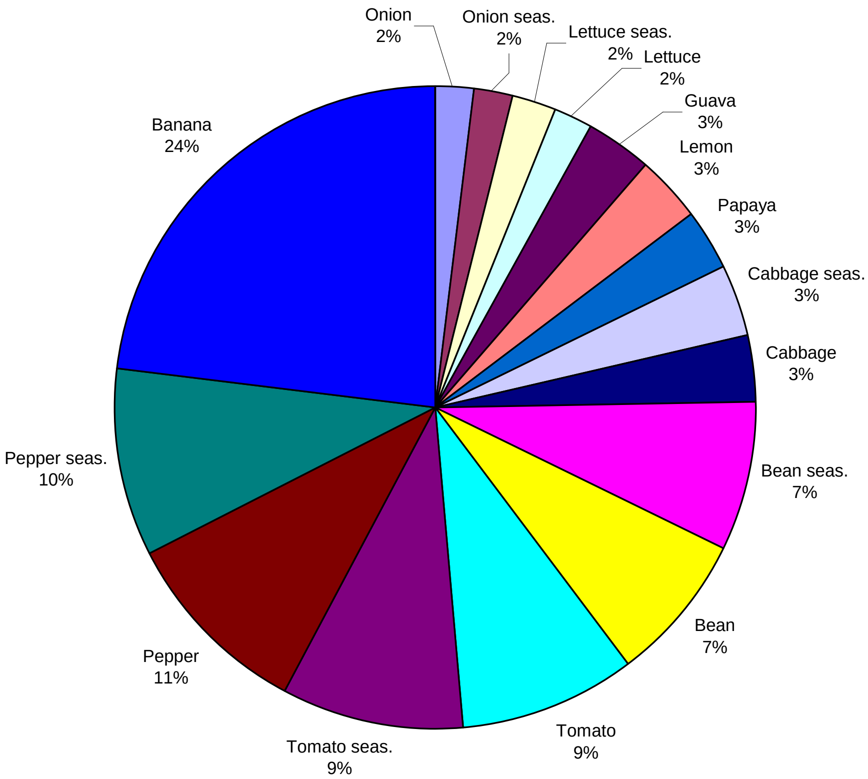

Figure 4 – Percentage of planted area of organic management cultures.

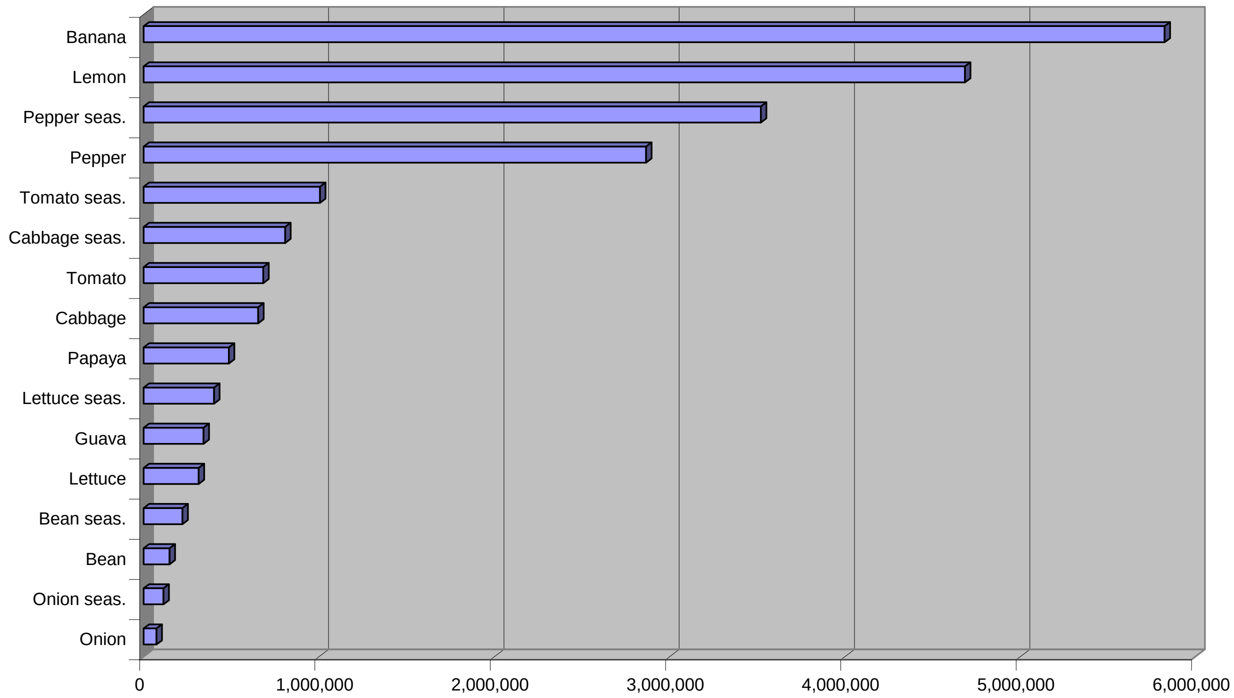

Figure 5 – Net budget per culture (Reais/Year) in organic management.

In what refers to labour, that was the social aspect investigated, can be highlighted cultures of banana (with 75,083 men/day), tomato (with 50,995 men/day) and tomato season (with 50,995 men/day), as exposed in Figure 9. The usage of defensives and chemical fertilization doesn't exist in organic management agriculture.

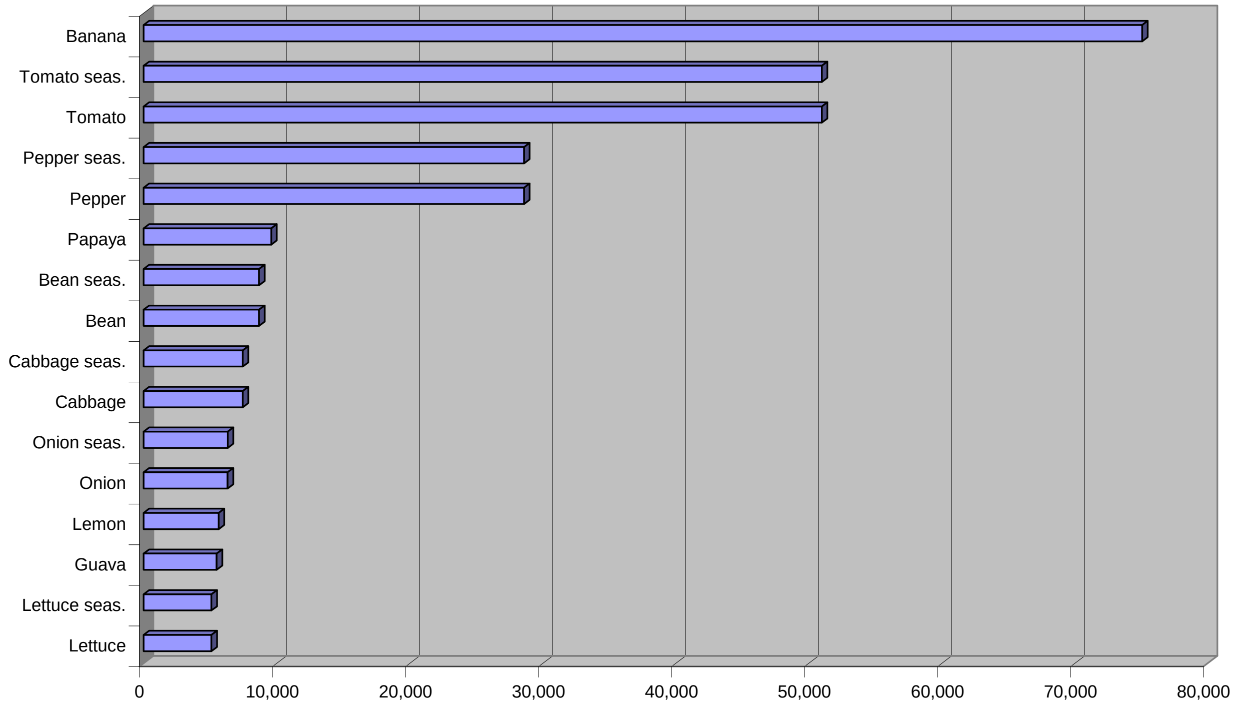

Figure 6 – Labour per culture (men/day) in organic management.

The Table 3 shows the total agricultural inputs used per year in each kind of management. Can be observed a 57% cultivated area raise, a 64% net budget raise and a 54% labour raise with the organic management when compared to the conventional agriculture. That fact occurred because of the multiobjective character of scenario 1 (S1), which besides maximizing the net budget and the labour, must also minimize the use of agricultural defensives and chemical fertilizers. In what refers to to conventional agriculture, the amount of chemical fertilizers and agricultural defensives was of about 798 tons/year. The increase in planted area, when compared to the maximal area, occurs in consequence of seasonal cultures (in which are cases of planting a culture only two times in a year). A proportions comparative is shown in Figure 10.

Table 2 – Total Summary of Conventional and Organic Managements (INPUTS/YEAR).

Cultures	**Planted Area (ha)**	**Net Budget (R$)**	**Labour (M/D)**	**Defensives (kg)**	**Fertilziation (T)**
TOTAL S1 (conventional)	875.20	14,259,007.40	168,131	10,213.78	797.56
TOTAL S2 (organic)	1,537.49	22,149,960.95	310,189	0	0

(ha – hectare; M/D – homem/dia; kg – kilogram; T – ton)

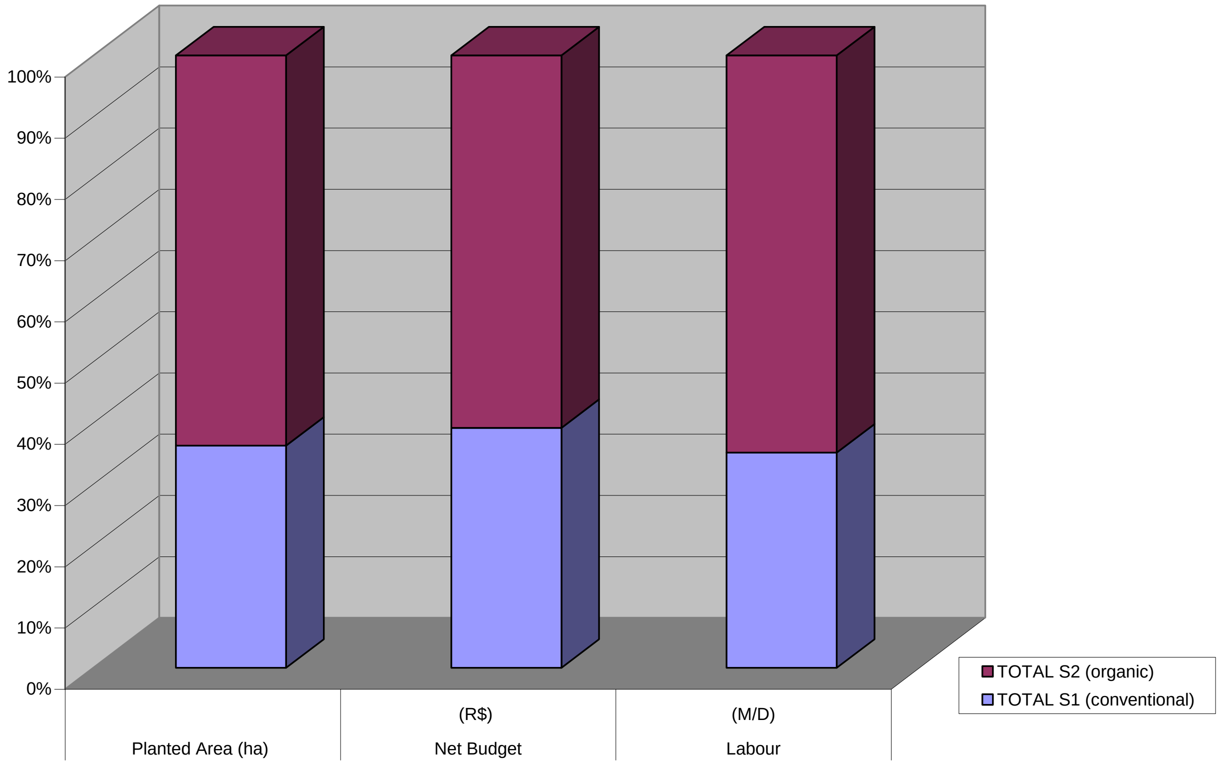

Figure 7 – Proportions between the conventional management and the organic management

4. CONCLUSIONS

According to the research, utilizing the adapted multiobjective model of Santos (2007), can be observed that organic agriculture offers a better cost/benefit relation when compared to conventional agriculture, since it reaches 57% more planted area, 64% more net budget, a better employability (54% more) and a greater environmental preservation, because of the fact of using natural fertilizer and defensives instead of agrochemicals. Before the exposed, the organic management has a better cost/benefit relation when compared to conventional management.

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