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To cite this article: Francisco das Chagas Oliveira, Angel Calle Collado & Luiz Fernando Carvalho Leite (2012): Peasant Innovations and the Search for Sustainability: The Case of Carnaubais Territory in Piauí State, Brazil, Journal of Sustainable Agriculture, 36:5, 523-544

To link to this article: http://dx.doi.org/10.1080/10440046.2012.656342

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Peasant Innovations and the Search for Sustainability: The Case of Carnaubais Territory in Piauí State, Brazil

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This article pursues two aims. The first is to assess the degree of sustainability in peasant agroecosystems through the application of the systemic approach, allowing an integrated understanding of technical, environmental, economic, and social impacts to support the agroecological transition process; the second is to comprehend the basis farmers have and the strategies they use in locally favoring the emergence of the innovations that constitute the object of analysis. The conceptual framework used ia that of the MESMIS method, which is based on a set of system attributes for agroecosystem assessment. Results indicate that innovations made by family farmers favored improvements in essential elements of system sustainability, making possible sustainable land use, assuring an increase in income, and maintenance of family employment and farm structuring. These factors cast light on the relevance of local knowledge as a key factor in policies that promote the sustainability of family systems, and as a basis for an agroecological transition process.

KEYWORDS agroecological transition, endogenous technology, local knowledge, peasant agriculture, production of innovations, socio-environmental crisis

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1. INTRODUCTION

The transition process using agroecology is essential to allow the consolidation of a sustainable model in agricultural production, becoming one of the main demands of research in agroecology (Altieri 2002; Gliessman 2002; Canuto 2003; Vanloqueren and Baret 2009). The understanding of agronomic, biological, ecological, economic, and sociocultural processes involved when redesigning production systems is crucial for success when transitioning from conventional practices to agroecological practices (Flores and Sarandón 2004; Altieri and Nicholls 2007; Calle Collado and Gallar 2010; Gliessman and Rosemeyer 2010).

Productive diversification is one of the main tenants of technical management in family agriculture that favors sustainability. It satisfies different economic needs (self-sufficiency of the family among them), and favors the optimization of family labor usage, area, as well as valuable and available natural resources. Productive diversification also assures flexibility in system management, to be able to withstand adverse circumstances and boost favorable conditions (S. G. Almeida et al. 2001; Amekawa et al. 2010).

The agroecological approach is based on assessment of traditional logic related to intensive use of biodiversity in productive systems (Petersen 2003). From local knowledge of agroecosystems management, we can systematize important technical and methodological teachings when intensifying usage of the agricultural area on a more sustainable basis (Guzmán Casado and González de Molina 2009). Therefore, systematization and analysis of technologies and empirical processes developed by small farmers constitute an indispensable heritage for the construction of agroecosystem designs from an agroecological transition standpoint (Petersen and Silveira 2002; Gliessman 2003; Abbona et al. 2007; Fernandes and Woodhouse 2008; Pacífico and Dal Soglio 2010).

In the Carnaubais territory in the north of Piauí state, small farmers are carrying out development processes through an innovative system for watermelon production, based on the use of bagana (straw waste) from the Carnaubá palm tree (Copernicia cerifera Miller) to cover the soil (mulch system). These processes play a relevant role at a local level (Oliveira et al. 2008; Oliveira and Leite 2009, 2010; Leite et al. 2010). These endogenous factors are inserted in a context of uncertainty, at political and institutional levels. They are marked by privation and dependence, and at the same time they modify and restructure the potential to achieve the goals of local development.

This article is focused on demonstrating an interesting potential for research on agriculture through the experience of ecological management based on a low cost agricultural style (van der Ploeg 2000). It provides tools for reflecting on the construction of transitions from the leading
sociotechnical regime to the creation of new configurations (van der Ploeg 2008) headed toward sustainability achievement.

This article seeks to assess the degree of sustainability in family agroecosystems in the Carnaubais territory, mid-north Brazil. It applies the systemic approach, allowing an integrated understanding of technical, environmental, economic, and social impacts in order to support the agroecological transition process in the territory. At the same time, the research seeks to comprehend the fundamentals (purposes) and strategies locally developed by small farmers favoring the emergence of innovations that constitute the object of analysis.

2. MATERIAL AND METHODS

The study is on land use systems in Carnaubais territory, at Jatobá do Piauí (04° 46’ 6” S and 41° 49’ 04” W), Piauí state, northeastern Brazil. This choice was based on the fact that the region has a predominance of family agriculture, but is currently going through deep socioeconomic transformations.

One of the principal characteristics of this type of agriculture is multi-functionality (van der Ploeg 2008), along with most labor provided by the family (or other members of the rural community through reciprocal work relationships), as well as the land belonging to the family, as do all other means of production. The production is aimed at the market, but also at sustaining the agricultural unit and the family.

The climate of the area is predominantly semi-arid and hot, with an eight-month dry period and four-month rainy period. The average annual precipitation falls between 800 and 1,000 mm, with highest concentration between the months of January and March. The average annual evaporation changes from 1.425 mm to 1.710 mm, increasing from September to November. The region receives an average of 3,000 hours per year of sunlight, the period of the most sunlight being July through October. The soil is a Typic Hapludults (Argissolo Vermelho-Amarelo, Brazilian Soil Classification). The vegetation is savanna and caatinga.

The surface area of Carnaubais is approximately 19,653.77 km², which represents 7.81% of the state. It has a population of 168,232 residents, of which about 52% live in rural zones, and live from family agriculture—the principal economic activity. This consists of the crops of the dry period (corn, beans, yuca, etc.); raising small animals like goats, sheep, pigs, and chickens; and vegetation extraction, especially of carnaúba wax. Agricultural production in the area suffers losses annually due to the “green drought” (periods of extensive drought directly following the planting of crops). This creates a serious economic obstacle for family farms.
In the beginning of the 1990s, an attempt to find alternatives to the socioeconomic and environmental crisis in which they found themselves, farmers began to grow watermelon as a new product for the market, basing the production on agroecological principles using a mulch system that employs bagana of carnaúba. When analyzing the degree of sustainability of the different systems of management, the results will be shown in simultaneous comparison, with a system of reference (transversal analysis).

For this analysis, the following systems were used: a) innovative system with an ecological base, using bagana (chopped straw) of carnaúba and organic fertilizer (goat manure, 40 m$^3$ ha$^{-1}$) cultivated over 15 years, and b) as a reference system, shifting cultivation with slash and burn practices, with 4 years under secondary vegetation, that was traditionally practiced by the farmers. These systems will be better characterized further on, in section 3.

To assess progress in the degree of sustainability of the systems, we adopted the conceptual framework used by the Framework for Assessing the Sustainability of Natural Resource Management Systems (MESMIS, from its acronym in Spanish; López-Ridaura et al. 2002), based on a set of system attributes for agroecosystem assessment. This article is comprised of a combination of instruments based on these references and diagnostic tools grounded in a participatory model, presenting the results, as we will see further on, in a section specifically analyzing the sustainability in the management of this agricultural subsystem.

The attributes$^2$ of sustainability selected were productivity, stability, resilience and reliability, adaptability, equity and autonomy. From there, a list of indicators was created and, finally, the indicators most closely related to the detected problems of the Carnaubais territory were those ultimately selected. From this procedure a list of 27 strategic indicators emerged, presented in Table 1.

The most appropriate measurement mechanism was determined for each selected indicator, including semistructured interviews, in-field observation, documentation reviews, and field measurements and lab analysis, which are presented in greater detail below.

2.1. Semi-Structured Interviews

Interviews were carried out according to a prewritten script in an attempt to gather information responding to the study objectives. The data concerning the cultivated plots were gathered alongside the farmers of the communities of Montanha and Tamarindo; in the municipality of Jatobá do Piauí.

We also obtained socioeconomic data from each farmer, including an overview about the number of family members, level of education, participation in family agricultural activity, living conditions, land tenure situation, total area of land and of cultivated area, land use and agricultural
TABLE 1 Sustainability indicators for assessment of different crop systems management in *Carnaúbas* region—Piauí, northeast of Brazil

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Diagnosis criterion</th>
<th>Sustainability indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>Yield and quality</td>
<td>1. Yield</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Quality of product</td>
</tr>
<tr>
<td>Economic profitability</td>
<td></td>
<td>3. Net income</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Profit/cost ratio</td>
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<tr>
<td></td>
<td></td>
<td>5. Return to labor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. Number of weedings</td>
</tr>
<tr>
<td>Stability, resilience</td>
<td>Biological vulnerability</td>
<td>7. Pest effects and diseases</td>
</tr>
<tr>
<td>and reliability</td>
<td>Economical vulnerability</td>
<td>8. Stability on prices of watermelon</td>
</tr>
<tr>
<td></td>
<td>Soil usage</td>
<td>9. Market diversity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10. Time of sowing</td>
</tr>
<tr>
<td></td>
<td>Agricultural settlement</td>
<td>11. Coverage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12. Physical structure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13. Conditions of soil fertility</td>
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<tr>
<td></td>
<td></td>
<td>14. Organic matter content</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15. Soil microbial biomass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16. Soil microbial activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17. Carbon balance</td>
</tr>
<tr>
<td>Adaptability</td>
<td>Change ability and innovation</td>
<td>18. Number of years of continuous cultivation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19. Evolution of number of producers by system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20. Surface given over to innovations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21. Degree of innovation of farmers</td>
</tr>
<tr>
<td>Equity</td>
<td>Costs and environmental</td>
<td>22. Biodiversity maintenance</td>
</tr>
<tr>
<td></td>
<td>benefits</td>
<td>23. Soil protection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24. Decrease of forest fire risk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25. Absorption of atmospheric carbon</td>
</tr>
<tr>
<td>Autonomy</td>
<td>Self-sufficiency</td>
<td>26. Degree of dependence on critical external input</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>27. Usage of local knowledge and abilities</td>
</tr>
</tbody>
</table>

operations during each season, as well as livestock breeding, income, costs, and resource use.

As far as information related to land use, crop systems and resources is concerned, the research tried to assess aspects related to the application of *bagana of carnaúba* by farmers and how that knowledge has been transmitted over the years. These family operations were observed and monitored with the intention of determining the benefits of using the mulching method of *bagana of carnaúba* in agricultural systems.

2.2. In-Field Observation

We performed the research in the region from February 2007 through August of 2010, developing a participatory research project while creating
alternatives in the management of agroecosystems to support and strengthen family-based agriculture. By observing and participating in daily activities of farmers, we could access information that provided innovative ideas and offered different ways of assigning and confirming information coming from other sources (García Fernando and Sanmartín 1986).

2.3. Documentary Reviews

Reviews consisted of economic statistics, population numbers, as well as cartographic and sociohistorical material about the region. Bibliographical review was carried out by consulting data about the topic of research in books, theses, scientific journals, and electronic information from the Internet.

2.4. Field Measurements and Lab Analysis

Before watermelon harvest, soil samples were collected from an area of approximately 1 ha in every system of land use, after prior subdivision into four plots. In each plot, eight samples were collected at 0–10 and 10–20 cm depths, in order to form a composite sample. In order to carry out the analysis, samples were crushed, air-dried and sieved through 2 mm mesh sieves.

To determine the levels of total organic carbon, the soil samples were crushed in a mortar and passed through a mesh of .21 mm, and were then quantified by oxidation of organic material via moisture with a dichromate solution of potassium in an acid medium with an external source of heat. The total nitrogen of the soil was determined through sulfuric digestion and quantified by Kjedhal distillation. The microbial biomass (Cmic) was determined through the method of irradiation-extraction, using a microwave oven (at a frequency of 2450 MHz, with energy at 900 W for 180 seconds). The K2SO4 .5 mol L-1 extractor and the carbon content in the extracts were quantified through the process of moisture oxidation; the conversion factor (KC) was .33 using the flow of C to C of the microbial biomass (Cmic). The stocks of total carbon were used to calculate the contribution of the management systems in the emission to sequestration of C- CO2 by the soil, converting the stock of C into CO2 (conversion factor: 3.67—molar mass of CO2 /molar mass of C) and subtracting the value of CO2 from the management system for the native vegetation. The conversion factor of C to CO2 was considered 3.67.

To evaluate the production yields of the different systems two indicators were used: number and weight of fruit that each plant produces. To do this, a sample was taken in four plots of 18m² per system, counting the total number of fruits from six plants from the central area of the plot. Only the fruit that was free from mechanical damage, marks, and deformations
was counted, and with a weight greater than 6 kg. In the analysis of the characteristics related to the quality of the fruit, two fruits were selected to represent each plot.

The system’s effect on the quantitative variables under study was subjected to an analysis of variance for each depth of the layers of soil in the different management systems for chemical and biological indicators jointly.

3. RESULTS

Family production systems in Carnaubais territory are based on polycropping (food, commercial, and forage crops) and livestock breeding. Currently there are up to six subsystems found in the productive family units: annual, agricultural crops (slash and burn), perennial crops (fruit trees), animal breeding (cattle, sheep, goats, pigs, and chickens), vegetable gardens, small irrigation systems (rare), extractive (highly relevant), and forests (Figure 1).

The landscape is dominated by the slash and burn of the planting of annual crops, fundamentally food crops in character (agricultural subsystem), pastures (many of which are “capoeiras”—secondary vegetation), and the fruit trees. In all of the productive family units there

![Diagram](https://via.placeholder.com/150)

**FIGURE 1** Typical peasant production system in Carnaubais region, Piauí, northeast of Brazil.
is animal breeding. The domestic vegetable gardens function as ecological niches in which there is a wide range of food species, condiments, medicinal plants and ornamentals. The gardens are maintained permanently, often accompanied by the presence of small groups of birds.

As can be observed in Figure 1, the species (including native species) are combined in time and space using management practices that are deliberately oriented to optimize the productive efficiency of the system as a whole. Through the occupation of distinct ecological niches, these species provide different functions to the agroecosystem (functional diversity), ecologically creating a more stable and productive system. Notice as well that the biomass produced in the different subsystems is managed to favor the interaction between subsystems, for which they assume a significant degree of complementarity and synergy. This type of technical focus makes it so that the intensive use of the resources of biodiversity plays a fundamental role in the traditional techniques. The optimal conservation and management of the resources of biodiversity show the conditions necessary to reproduce this type of technical strategy and reach satisfactory level of productivity and stability in agroecosystems (Petersen et al. 2002).

Combined, these traditional practices configure a strategy of multiple uses of local resources addressing the generation of products and services necessary to satisfy the needs of farmer families. This approach, according to van der Ploeg (2008), consists of the same coming together of resources to generate a broad range of products and services, which reduces the cost of production of every individual product (Saccomandi 1998; van der Ploeg 2008) and increasing, at the same time, the added value in each agricultural unit.

Of the assortment of innovative practices in the region of Carnaubais, it is valuable to highlight the agricultural system cultivated with mulch technology (Figure 2), a strategy that was developed by farmers when searching for alternative solutions to the sustainability crisis of traditional fallow lands. This crisis is attributed to the new agrarian dynamics of land occupation that reduces the fallow period and, therefore, provokes the reduction of the natural fertility of the soil and the impoverishment of the farmers.

Figure 2: Technical itinerary of innovative crop system in family production units. Carnaubais region, Piauí, Brazil (color figure available online).
Agricultural plots cultivated with this innovation consist of the application of *bagana* from the *Carnaúba* palm tree over the soil, forming a layer of dead covering (mulch) on the surface during the fallow field period (dry season). The leaf coating typical of the production process of *Carnaúba* wax is extracted and the leaf waste is generated. This action is useful to reduce the loss of nutrients during the succession of production cycles, as well as providing a cooling of the soil.

As a reference, for the transversal comparison of sustainability, the natural fallow system is presented. The diagram describing the different phases of agricultural production of the familial unit is represented in Figure 3.

As can be seen, the typical production cycle of the natural fallow lands system has a duration of four years, composed of an initial, planting phase of annual crops (yuca, corn, and caupi beans), that culminates with the harvest of yuca, lasting a year and a half. The fallow lands phase starts with the spontaneous formation of vegetation, a process lasting three years. The phase of traditional fallow lands is interrupted by the slash and burn of said vegetation that grew spontaneously in order to initiate a new phase of planting.

It is appropriate to highlight that it is an oversimplification to characterize the agricultural farmer for his or her dependence on the productive processes concentrated on the natural fallow lands systems, where the management of natural soil fertility requires the low use of external inputs. This research conception homogenizes a reality that is profoundly heterogeneous. Consequentially, the production cycle does not even always last the same length of time (four years) in all plots of the productive unit. For example, a farming family can manage the plots intensively by planting vegetables, and making it so perennial crops permanently follow after annual crops. The choice to opt for one trajectory or another depends on the type or degree of integration that the farming unit has established with the market (Freitas 2005).

The research conception is that the productivity of the traditional system of fallow lands depends in large part on the duration of the fallow period and

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**FIGURE 3** Technical itinerary of slash and burn system with traditional fallow field of 4 years in rotary systems with annual cultivations (common case). *Carnaúba* region, Piauí, Brazil (color figure available online).
the vitality of the secondary vegetation. The principal function of the fallow vegetation is the accumulation of biomass and nutrients, as well as the suppression of weeds that invade the farms during the crop period. The growth of demographic pressure in the region has diminished the fallow period and, therefore, the accumulation of biomass from the secondary vegetation has decreased over the last cycles of production. In function of this decrease, the successive burns provoke the decline of the productivity of the land, due to the nutrient losses from the fires, caused by the removal of nutrients in the products of the harvest and also by leaching. So, the continual extraction of mineral nutrients and organic material contributes to the decline of productivity and the degradation of the soil and constitutes the primary ecological problem of the traditional fallow land system of the region.

The ecological problems of the traditional fallow lands/bush system in the region are attributes of the reduction of the fallow period that significantly contribute to the unsustainable availability of nutrients, and along with this, the need to create incomes for the farmer family units. In the municipality of Jatoba do Piauí the farmers began to seek a solution to the sustainability crisis through the development of innovations to replace the practice of slash and burn by limiting the use of fire and also the introduction of new crops with a focus on commercialization, principally objectifying technical and economic stability of the production unit. The need, therefore, fomented farmer experimentation and innovation, based on the elements of sustainability of traditional systems (Sosa et al. 2010).

The integration of the results of the indicators, as much the qualitative as the quantitative, is presented below, and allows us to make a comparative analysis of sustainability between distinct systems. In the next section there is an integrated discussion of the different dimensions of these distinct systems.

Table 2 shows the equivalents and criteria for the optimal values of the indicators used in composing the integration graph of the results. The results of the indicators, expressed in percentages, are compared with an optimal value, which in this case was established by consensus between the perception of the farmers and the research team.

As the object of the methodology is to be able to use indicators that allow for periodic monitoring of the agroecosystem, it also includes a high level of participation on the part of the farmers. Perhaps the most important angle is that once the indicators are applied, each farmer can visualize the state of his or her farm by observing what aspects of the agroecosystem are coming along well or poorly in relation to a pre-established threshold for each (Altieri and Nicholls 2007; Beltrán 2010).

In measuring the different indicators, an AMEBA graph was created (Figure 4), as well as a table where all the indicators used in the study are concentrated (Table 3). As can be gathered in Figure 4, the system of reference presents less advantages when compared to the innovative system in practically every aspect that was evaluated. However, both cases present the
same results in so far as quality of production. In Table 3, the comparative results of the two systems are concentrated with respective comments.

All of this confirms that the innovative system is more sustainable, and that it is essential to take into account the sociocultural, community base that mitigates the degradation factors of the agroecosystems, and ameliorates production, which improves quality of life (Delgadillo and Delgado 2003).

### 4. INTEGRATED DISCUSSION

#### 4.1. Technical-Environmental Aspect

Results show that with intensification of land use for the last 15 years, the innovative system has gained productivity compared to the reference system, with a strong agroecological basis that preserves the main soil factors of organic matter and biota (flora and fauna).

The innovative system shows more advantages than the reference system, as the former keeps many aspects of ecological, soil sustainability; reduces loss of nutrients, enables incorporation of organic matter, and

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**TABLE 2** Indicators used in the AMOEBA for the two production systems, in original units as well as in optimum percentages (between brackets) of local circuit

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Innovative system</th>
<th>Reference system</th>
<th>Optimum (100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watermelon yield (t/ha)</td>
<td>41.92a (93.16)</td>
<td>18.17b (40.38)</td>
<td>45.00</td>
</tr>
<tr>
<td>Quality of product (TSS/TTA(^a) ratio)</td>
<td>94.97a (94.97)</td>
<td>91.4a (91.41)</td>
<td>100.00</td>
</tr>
<tr>
<td>Production costs ($)</td>
<td>1940.13 (80.77)</td>
<td>1567.18 (100.00)</td>
<td>1567.18</td>
</tr>
<tr>
<td>Net income ($)</td>
<td>2964.51 (100.00)</td>
<td>558.71 (18.88)</td>
<td>2964.51</td>
</tr>
<tr>
<td>Profit/cost ratio</td>
<td>2.53 (100.00)</td>
<td>1.37 (54.15)</td>
<td>2.53</td>
</tr>
<tr>
<td>Plague effects and diseases(^b)</td>
<td>9.00 (90.00)</td>
<td>1 (10)</td>
<td>10.00</td>
</tr>
<tr>
<td>Soil organic carbon (0–20 cm)</td>
<td>0.81a (100.00)</td>
<td>0.43b (53.04)</td>
<td>0.81</td>
</tr>
<tr>
<td>Soil total nitrogen (0–20 cm)</td>
<td>0.09a (100.00)</td>
<td>0.07b (77.78)</td>
<td>0.09</td>
</tr>
<tr>
<td>Soil microbial biomass (0–20 cm)</td>
<td>0.028a (100.00)</td>
<td>0.16b (57.11)</td>
<td>0.28</td>
</tr>
<tr>
<td>Carbon sequestration(^d)</td>
<td>10.00 (100.00)</td>
<td>1.00 (10.00)</td>
<td>10.00</td>
</tr>
<tr>
<td>Degree of innovation of farmers(^e)</td>
<td>80.00 (80.00)</td>
<td>30.00 (30.00)</td>
<td>100.00</td>
</tr>
</tbody>
</table>

\(^a\)Differences between systems are statistically significant for \(p < .05\).

\(^b\)1 = susceptible to diseases, more than 50% of plants with symptoms; 5 = between 20% and 45% of plants with symptoms from mild to severe; 10 = hardy, less than 20% of plants with mild symptoms;

\(^c\)1 = powdery and nude soil; 5 = loose soil, few granules and less than 50% covered by wastes; 10 = friable, granular soil, and more than 50% dead covered.

\(^d\)1 = emission; 5 = neutral; 10 = sequestration; original data for sequestration or emission of C-CO\(_2\) (mg ha\(^{-1}\)), are: 0–10 cm = innovative S. = 16.18, reference S. = −13.03; 10–20cm = innovative S. = 3.12, reference S. = −2.75.

\(^e\)0–33% = low; 33–66% = medium; 66–100 = high.
protects physical, chemical, and biological attributes, apart from controlling weeds and conserving humidity.

Adopting this system is a definite contribution to agriculture and society as it develops independence from the agribusiness model based on purchased and imported resources (fertilizers and pesticides) and fossil fuel. It also improves air quality, lessens the degree of deforestation, and mitigates the greenhouse effect through carbon fixation in soil and straw. In this way, farmers are providing several environmental services to the larger society.

Atmospheric carbon fixation in soil, which this system favors, is a very relevant additional contribution to global climate change, an advantage this system provide toward the possibility of creating a more environmental sustainable agriculture.

4.2. Economic Aspects

Using innovative technology allows peasant families to choose the sowing date according to their needs, taking into account work distribution during the agricultural cycle and market demand for local products. The agronomic
### TABLE 3 Comparison between the different crop system of family farms in the territory of Carnaubais—Piauí, Northeast Brazil

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Indicator of sustainability</th>
<th>Innovative system</th>
<th>System of reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>Yield and quality of product</td>
<td>High yield and high quality product</td>
<td>Low yield and high quality product</td>
</tr>
<tr>
<td></td>
<td>Economic profitability</td>
<td>High, generating surplus and capitalization of the peasant family</td>
<td>Low, covering only basic necessities of the peasant family</td>
</tr>
<tr>
<td>Stability, resilience and reliability</td>
<td>Soil cover</td>
<td>Unexposed soil; vegetable cover (<em>bagana of carnaúba</em>); weeds suppressed by cover (especially grass); shoots remain intact</td>
<td>Soil exposed; ash; superficial weed seeds and regrowth destroyed; grasses are stimulated</td>
</tr>
<tr>
<td></td>
<td>Organic matter and carbon</td>
<td>Slow microbiological respiration</td>
<td>Rapid loss by oxidation; emission of CO2</td>
</tr>
<tr>
<td></td>
<td>Soil: chemical characteristics</td>
<td>Temporary immobilization prolonged availability; essential nutrients from the soil remaining in the system, high cation exchange capacity (nutrient retention)</td>
<td>Nutrients that remain in the ashes are readily available to the plants; risk of leaching; most essential nutrients are lost by volatilization (nitrogen, 96%)</td>
</tr>
<tr>
<td></td>
<td>Soil: physical characteristics</td>
<td>Good soil structure (aggregates); lower temperature range; surface soil horizon usually damp</td>
<td>Soil compaction; heat peaks at noon; surface soil horizon usually dry</td>
</tr>
<tr>
<td></td>
<td>Floristic biodiversity</td>
<td>High; dominated by broadleaf plants; rehabilitation is expected of the community of species</td>
<td>Low; dominated by grasses; community adapted to frequent burning</td>
</tr>
<tr>
<td></td>
<td>Pests and diseases</td>
<td>Persistent biological balance</td>
<td>Temporary soil surface sterilization from the heat of the fire</td>
</tr>
<tr>
<td></td>
<td>Period and planting date</td>
<td>Flexible; long planting period because of the mulch that conserves water</td>
<td>Fixed, after the burning, and short planting period due to rapid drying in summer</td>
</tr>
<tr>
<td>Adaptability</td>
<td>Capacity for change and innovation</td>
<td>High capacity for innovation with intense socioeconomic transformations</td>
<td>Worsening socio-environmental crisis</td>
</tr>
<tr>
<td>Equity</td>
<td>Environmental costs and benefits</td>
<td>Maintenance of biodiversity, soil protection, reduced risk of forest fires, climate change mitigation</td>
<td>Danger of accidental fires damaging adjacent crops and forests, accumulation of greenhouse gases</td>
</tr>
<tr>
<td>Autonomy</td>
<td>Self-sufficiency and control</td>
<td>Need for income that can be obtained locally without any financial requirement; use of more local knowledge and skills</td>
<td>Low dependence on external inputs; traditional knowledge</td>
</tr>
</tbody>
</table>
advantage of this system helps to obtain significant economic results for peasant families.

Agricultural income from watermelon cultivation in both systems shows significant differences. They are mainly related to quantitative increase in the innovative system, with higher values for gross production value and added value due to family labor. Because of technical and productive vulnerability of the reference system when faced with the impact of natural phenomena or decrease in market value, harvest values are reduced so greatly that they become exclusively used for personal use.

In both systems, most production is marketed directly to intermediaries, who carry out distribution to wholesale and retail markets, or rarely, farmers sell at fairs in medium-sized towns in the center and north of the country. Generally, the harvest product is acknowledged and assessed as organic and of high quality by the market network, however, the producer does not receive any corresponding bonus for quality.

According to S. G. Almeida (2001), and within the aim of this research, the main factor of system sustainability that stands out is the way profitability is incorporated into family finances. In fact, the main question would be about the economic capacity of the innovative agricultural system to meet basic biological reproduction and social family needs autonomously.

It can be observed that the reference system shows critical structural vulnerability, with all agricultural income obtained being directly consumed by family for purchasing food.

In the innovative system, agricultural income is obtained mainly with watermelon cultivation, and results in a relatively high level of productive capitalization. Therefore, it becomes one of the main components of productive and financial capital for investments, focused on strengthening the productive capacity of the system, and has proven vital to its stability, resilience, and autonomy.

The application of the system is based, in accordance with van der Ploeg (2009a), on the self-controlled and self-managed strengthening of resources, such as the progressive creation of efficient infrastructures; in investment capital aimed at increasing productivity and to lessening the intensity of agricultural work conditions. It was also used to improve the quality of domestic life thanks to house alterations and additions, and the purchase of technology equipment and furniture, clothes, and such, helping to create a higher level of autonomy.

4.3. Social Aspect

Production of technical-productive innovations lies in changing social relationships. Those relationships produce innovations such as new organizations, practices, or opportunities. These innovations contribute to
a greater degree of participation, as well as distinct forms of participation, among producers, in ties between producers and technicians, in gender relationships, and so on. (Calle Collado and Gallar 2010).

Progressive technical-productive change of farms imposes new demands in division and management of family work, stimulating the emergence of new social practices. An example is the emergence of an agricultural cooperative of watermelon farmers at the municipality of Jatobá do Piauí. Another example includes new cultural relationships among family members themselves and toward nature.

In a year, the innovative system has achieved relevant improvements related to employment and worker wages compared to the reference system. These results highlight differences in the ability of both systems to generate wealth, leading to very disparate work productivity.

Labor retention in the innovative system is mainly related to its strategy of increasing productivity and keeping system stability through investments and an influx of technology to the productive system. Introducing innovations in the system management creates new working demands in periods with reduced agricultural activity. Besides, the increase of agricultural capital allows the expansion of productive capacity, leading to bigger demands on subsystem management in rainy periods, creating new opportunities for employment and work intensification.

The rationale, which creates more employment stability in the innovative system, is not present in the reference system. This is due to its inability to provide investment and its simpler way of managing the agricultural subsystem, creating idle periods for family labor.

In most of the productive units analyzed, we identified some strategies for better autonomy in the agricultural social environment (J. Almeida 2009; van der Ploeg 2009b). Farmers research new production methods that can be added to the traditional system. They also seek diversification of production and self-organization. Therefore, they are headed toward a legitimate system of solidarity and identity to confront the increasing difficulties in production, marketing and life in a socio-rural environment. These strategies assure reasonable family income for family reproduction, while also assuring some autonomy and promoting a considerable integration among some production units.

These behavior strategies of the production unit are headed, almost always, toward an integration of agricultural activities in family life. Women get to play a more active role (besides her responsibilities within the family unit, which are usually greater than the responsibilities of the men). They play a diversified and appreciated role in economic and technical management of the productive unit. Women also get to participate more in family exchange, training and several social organization programs.

One factor limiting relationships in social environments within Carnaubais region is a deficiency in formal organizations. We found some
organizational presence around the Trade Unions for Rural Workers, the association of rural producers and inhabitants of the region. Thus, actions with the purpose of proposing and planning issues that address family agriculture, are dispersed. NGOs and several institutions at a federal or state public level perform these actions, but it is the authority of the municipality that is challenged to arrange these actions and to encourage and appreciate local organizations.

4.4. Understanding the Developmental Trajectory of the Innovative Alternative

In this section, we present a theoretical-practical effort to try to understand the dynamics, which favored the appearance and development of the innovative system as a technological alternative to slash and burn peasant agriculture in the Carnaubais territory, in order to reach a deeper understanding of the local society’s relations with the environment. This is based on data obtained from documentary research, along with reports and publications and open interviews addressed to regional farmers and technicians. We carried out interviews to learn implicit reasoning (purpose) and technological evolution and, therefore, try to set possible connections between the ecological crisis and the emergence of the innovative system as a new technological option.

Empirical evidence is presented that points to the emergence of these new socio-productive practices as a response to farmers’ demands. We stated that the emergence of these innovations is linked to the innovation ability of peasants, trying to intensify production in an agroecosystem, on an autonomous and sustainable basis, and to assure social functioning of production systems.

We can infer that the shortage of production factors (land and work) of peasant units was crucial to the emergence of “mulch technology,” highlighting the fact that peasant units are headed now toward intensification of land use (Freitas 2005). This statement is consistent with the assumptions of our work related to the fact that the socio-environmental crisis is prompting a technical change in slash and burn family agriculture in the Carnaubais territory.

4.5. Innovations by Farmers as a Basis of the Agroecological Transition Process in the Territory

The notion of transition indicates a long-term change in a comprehensive system that fulfills a basic social function (e.g., production and consumption of food, etc.). In a transition, just as much as the technical dimensions, the sociocultural dimensions require a radical change in the system. This emphasis on coevolution of technical and social changes distinguishes from
incremental transition processes, which are mainly characterized by technical change (through successive generations of technology) with relatively minor changes in society by incorporating these technologies. (Elzen and Wieczorek 2005).

We also recognize agroecological transition as a central concept. This is understood as a gradual and multilinear process of change that occurs over time, in the approach to appropriation and management of natural resources and systems of conventional and traditional production, for a model that is more socio-environmentally sustainable (Ministério do Desenvolvimento Agrário 2006; Caporal and Costabeber 2007).

Through the concept of agroecological transition, the science of agroecology (Guzmán Casado et al. 2000; Sevilla Gusmán 2006) attempts to evaluate those incentives that might support and strengthen the processes of reorganization and transformation of traditional systems of production without creating some type of socio-environmental conflict, primarily due to the fact that it is not possible to balance out the intensity of cultivation and the regeneration capacity of the ecosystem’s fertility, which compromises long term sustainability.

The results presented and discussed here shed light on the central importance of farmer innovations, which represent local contribution to policies promoting sustainability in family-based systems and also in the transition toward agroecology (S. G. Almeida and Fernandes 2002).

It is worth noting that the knowledge of the farmers (tacit knowledge) is the basis on which agroecological innovations develop. Accordingly, through the advance of experimentation farmers will gather more knowledge, such as contextual and scientific knowledge to support and develop their experiences around innovation. With the union of the knowledge from farmers with other fields of knowledge, and by means of a “knowledge dialog” (Leff 2002; Petersen and Dias 2007; Toledo and Barrera-Bassols 2008), a great deal of innovations\(^3\) could occur (Wiskerke and van der Ploeg 2004) and would allow the development of strategies to confront economic crisis and other current problems.

5. CONCLUSIONS

Innovations by family farmers, along with the introduction of a new cropping system focused on the market and associated with mulch technology, which uses bagana of carnauá, favor improvements in constituent elements of system sustainability. These innovations make possible a sustainable land use thanks to improvement of chemical, physical, and biological soil properties, assuring a rise in income, investment ability, maintenance of family jobs and farm structuring. These factors cast light on the relevance of local knowledge as a key factor in policies for promoting
the sustainability of family systems, and as a basis for a transition process using agroecology.

Innovations by family farmers, through the development of the new system of production with the introduction of the watermelon crop, have contributed to productive restructuring of slash and burn peasant agriculture of the Carnaubais territory, while helping with mitigation of global socio-environmental crises, and making possible the combination of environmental preservation with valuation of capital.

The assessment reveals that farmers take into account other kinds of profit in addition to monetary profit. Effects of fertilization, weeds suppression, and positive impacts on soil moisture conditions, in the innovative system, are factors that strongly favor confidence, stability, resilience and productivity, in accordance with the results of the indicators studied.

Finally, it can be deduced that the shortage of production factors (land and work) of peasant units were crucial to the emergence of “mulch technology,” highlighting the fact that peasant units are now headed toward intensification of land use, but in a more sustainable way.

NOTES

1. For a discussion of participatory research and “science with people” see, respectively, Kindon et al. (2007) and Funtowicz and Ravetz (1993).
2. For the discussion of general attributes concerning sustainable approaches to food production see Rivera-Ferre et al. (2010) and Rivera-Ferre (2008).
3. The farmers innovations can be defined here as a particular combination of practice and new discoveries through which farmers can increase technical efficiency in their production process (van der Ploeg 2008).

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