Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 110, No. 1, 2009, pages 59–71

Local Productive Arrangements for Biodiesel Production in Brazil – Environmental Assessment of Small-holder's Integrated Oleaginous Crops Management

G. Stachetti Rodrigues [*1], **I. Aparecida Rodrigues** [2], **C. C. de Almeida Buschinelli** [3], **M. Antônio Ligo** [3] and **A. Moreno Pires** [3]

Abstract

Sustainability assessments were carried out in small-holders' farms in four territories where productive arrangements have been organized for production of minor oleaginous crops under the Brazilian biodiesel program. The study aimed at checking local impacts of the biodiesel productive chains at the rural establishment scale, and promoting the environmental performance of the selected farms, henceforth proposed as sustainable management demonstration units. Assessments were carried out with the APOIA-NovoRural system, which integrates 62 objective and quantitative indicators related to five sustainability dimensions: i) Landscape Ecology, ii) Environmental Quality (Atmosphere, Water and Soil), iii) Socio-cultural Values, iv) Economic Values and v) Management and Administration. The main results point out that, in general, the ecological dimensions of sustainability, that is, the Landscape Ecology and Atmosphere, Water, and Soil quality indicators, show adequate field conditions, seemingly not yet negatively affected by increases in chemical inputs and natural resources use predicted as important potential impacts of the agro-energy sector. The Economic Values indicators have been favorably influenced in the studied farms, due to a steadier demand and improved prices for the oleaginous crops. On the other hand, valuable positive consequences expected for favoring farmers' market insertion, such as improved Socio-cultural Values and Management & Administration indicators, are still opportunities to be materialized. The Environmental Management Reports issued to the farmers, based on the presented sustainability assessment procedures, offer valuable documentation and communication means for consolidating the organizational influence of the local productive arrangements studied. These productive arrangements were shown to be determinant

* corresponding author; Telephone: +33 (0)631133432; Fax: +33 (0) 467616590 e-mail: stacheti@cnpma.embrapa.br

[1] Geraldo Stachetti Rodrigues, Embrapa Labex Europe / UPR 34 Performance des Systèmes de Culture de Plantes Pérennes - CIRAD-PerSyst. Agropolis International, Avenue Agropolis, 34398 Montpellier, France

[2] Izilda Aparecida Rodrigues, Associated Researcher, Embrapa Environment. Pos-doctorate fellow, FAPESP. Cx.P. 069, Jaguariúna, São Paulo, Brazil CEP 13820-000

[3] Cláudio Cesar de Almeida Buschinelli, Marcos Antônio Ligo and Adriana Moreno Pires, Researcher, Embrapa Environment. Cx.P. 069, Jaguariúna, São Paulo, Brazil CEP 13820-000

for the selection of crop associations and diversification, as well as for the provision of technical assistance and the stabilization of demand - conditions that promote value aggregation and income improvements, favoring small-holders' insertion in the market. More importantly, these locally organized productive arrangements have been shown to strongly influence the valorization of natural resources and environmental assets, which are fundamental if sustainable rural development is to take place under the emerging agro-energy scenario.

Keywords: sustainable agriculture, environmental management, rural development, biofuels, family agriculture

1 Introduction

The insertion of small-holders dedicated to oleaginous crops into biofuel production chains represents a new opportunity for rural development in Brazil. Two main circumstances are influencing this agronomic and economic movement. First, a strong intensification in the demand for vegetable oils in the international market, either for food or energy purposes, which has improved both prices and the negotiating capacity of farmers. Second, the special provisions brought about by the 'Social Fuel Seal' policy of the Brazilian Agency for Petrol and Biofuels and the Ministry of Agrarian Development, which offers tax exemptions to biodiesel mills (but not to farmers directly) that acquire their feedstock from registered family farmers (Portal do Biodiesel, 2005). Influenced by these circumstances, particular productive arrangements have been organized in the different territories where oleaginous crops are being directed toward biodiesel production throughout the country, under varying institutional contexts, forms of farmers' involvement, and cropping systems (Bindraban and Zuurbier, 2007).

Even if specific regarding the institutional and geographical characteristics of these different territories, all local productive arrangements for biodiesel have been fashioned around productive chains involving on the one hand the farmers, and on the other the crushing mills and biodiesel transformation plants. Furthermore, these two main social actors of the biodiesel production chains are accompanied by their own representations (farmers' associations and entrepreneurs' cooperatives), as well as by a host of stakeholders (rural workers' syndicates, governmental and non-governmental organizations, social movements, scientific research and technology transfer institutions, consumers' representations, etc.). If indeed small-holders are to find insertion in these production chains, and whether this development is to be environmentally sound and sustainable (Hill *et al.*, 2006), all these social actors must be involved, having a say in the definition of their territorial development goals.

One way to warrant and promote such a participatory involvement is to carry out environmental impact assessments (EIA), focusing the productive sector and dedicated public policies, and having the social actors partaking of the productive chains as mediators. EIA procedures can suitably support the development, selection, and transference of adequate management practices and technologies for the farmers, according to their availability of resources and technical capabilities (Rodrigues and Rodrigues, 2007).

The mediators involved in impact assessment procedures are here identified as social representations performing political roles for expressing the multiple objectives and interests of the local communities (CAMPANHOLA *et al.*, 2007). When considering oleaginous crops for biodiesel production, the definition *a priori* of a productive objective (that is, the agricultural dimension), within the context of the National Program for Production and Use of Biodiesel (PNPB, 2007), contributes for conforming the mediators' network, as well as for establishing their local sustainable development goals, in accordance with larger national objectives (WRIGHT, 2006) defined in the public policy.

In this sense, a series of Delphi-type Workshops were carried out in four territories in Brazil, with the objective of evaluating the main socio-environmental impacts of biodiesel production chains (RODRIGUES *et al.*, 2007). This research built upon the expertise and knowledge of the local mediators (in all four territories) about the observed and expected impacts of the increasing demand on oleaginous crops for biodiesel production. Based upon a set of 125 indicators encompassing agro-ecological and socio-environmental impacts (MONTEIRO and RODRIGUES, 2006), these EIAs pointed out that the increasing demand imposed by the biodiesel market would be linked to important management intensification in all studied territories, boosting consumption of inputs, natural resources, raw materials, and energy. These impacts were considered as negative consequences of productive intensification, with associated risks onto water quality and the conservation of natural habitats. On the other hand, concerning socio-economic and managerial indicators, this productive intensification would be associated with improved farmers training and professional dedication, income generation and distribution, investment levels and land valorization, better worker qualification, and improved working conditions and employment quality (RODRIGUES *et al.*, 2007).

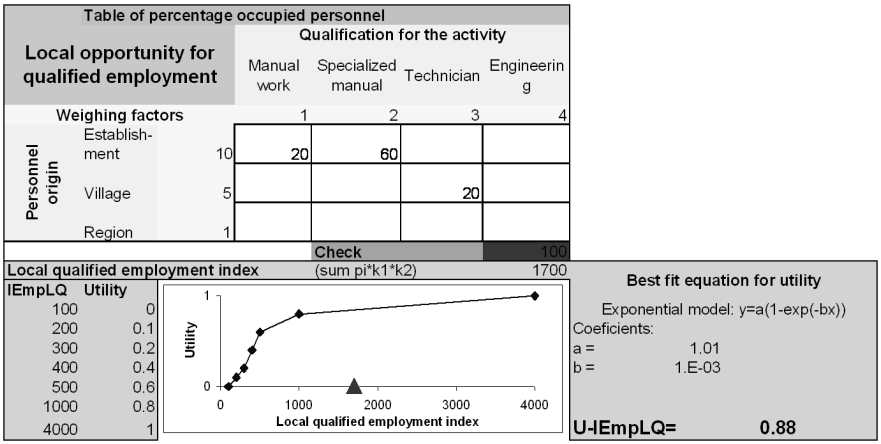
In the present study, these observed and prospective impacts at the production chain scale, whether negative or positive, are examined against the actual field situations observed in selected rural establishments, in the same territories and local productive arrangements. The objective is to verify the extension of those impacts, and to provide environmental management recommendations for promoting the sustainability of the involved small-holders. Additionally, and based on the detailed analysis of the environmental performance of the studied establishments, assess the role of the local productive arrangements for the insertion of small-holders in the agro-energy market.

2 Materials and Methods

The sustainability assessments were carried out in selected rural establishments with the 'System for Weighed Environmental Impact Assessment of New Rural Activities' (APOIA-NovoRural) (RODRIGUES and CAMPANHOLA, 2003; RODRIGUES *et al.*, 2008). The APOIA-NovoRural System consists of a set of 62 indicators scaling checklists, formulated toward the systemic assessment of a rural activity at the rural establishment scale, according to five sustainability dimensions: i) Landscape Ecology, ii) Environmental Quality (Atmosphere, Water and Soil), iii) Socio-cultural Values, iv) Economic Values, and v) Management and Administration.

Evaluations were performed by quantitatively and analytically assessing the effects of oleaginous crop management on each and every indicator and automatically calculating impact indices, according to appropriate weighing factors (Figure 1). Impact indices are expressed as utility value (0-1.0 scale, with the baseline level defined at 0.7 - Bisset, 1987) for each indicator, then for the aggregated dimensions and the final sustainability index for the rural establishment.

Figure 1: Typical scaling checklist of the APOIA-NovoRural indicators system, showing the 'Local opportunity for qualified employment' indicator.



The utility functions built in the system express the environmental performance of the rural activity for each particular indicator, and were derived by probability and sensitivity tests, case by case, for each indicator (Girardin *et al.*, 1999). In the probability test, the indicator scale limits (maximum and minimum) and the baseline conformity value (0.7) are modeled, according to the numerical solution of the indicator variable (in the Figure 1 example, percent occupied personnel, according to origin and qualification). In the sensitivity test the indicator direction (whether positive or negative) and the meaning of the changes brought onto the indicator by the rural activity are modeled, according to the quantitative performance relationship defined in the sustainability baseline. These tests allow the construction of a correspondence table from impact indices to indicator utility values (in the Figure 1 example, IEmpLQ $= \sum$ pi*k1*k2 $= 1700$), which is presented graphically in the scaling checklist. This correspondence relationship is then algebraically effected by a best fit equation, resulting in the expression of the impact index (in the given example, U-IEmpLQ $= 0.88$; Figure 1).

Information required for filling out the APOIA-NovoRural scaling checklists are obtained in field surveys (aided by GPS, maps and satellite images) and data on the managerial and administrative history of the rural establishment provided by the farmer. Indicators related to water and soil quality are obtained in field and laboratory analyses. At the

conclusion of each assessment carried out with the APOIA-NovoRural System[1], an Environmental Management Report was issued to the farmer, for his/her decision making toward minimizing negative impacts and maximizing positive ones, contributing toward local sustainable development.

2.1 Study sites, local biofuels production programs, and institutional contexts

Study sites were chosen according to specific socio-environmental dynamics for oleaginous crops for biodiesel production in Brazil, considering two main aspects: (a) the organization of production associated with a well defined local market (industrial consumer), under a (b) consistent productive arrangement provided by some locally organized multi-lateral program or project, coordinated by local interaction among different social actors (or mediators). The enterprises (crushing mills and biodiesel transformation plants) perform an important role in determining the spatial reach of these local projects or programs, by promoting feedstock production and mechanisms for access to raw materials and inputs, as well as for final product distribution.

Four territories presenting these characteristics were selected for the proposed sustainability assessments, focusing small-holders' farms dedicated to crops that, even when considered secondary for biodiesel production, were managed under integrated energy-food crop associations, as follows: (i) Cássia (Minas Gerais State-MG) with integrated no-till forage turnip (*Brassica rapa* L.) / maize (*Zea mays* L.) rotation; (ii) São Raimundo Nonato (Piauí State-PI) and (iii) Irecê (Bahia State-BA) with integrated castor bean (*Ricinus communis* L.) / bush bean (*Phaseolus vulgaris* L.) production; and (iv) Belém (Pará State-PA) with oil palm (*Elaeis guineensis* Jacq.) production in a diversified context. Details of these studied establishments and their local productive arrangements are as follows.

2.1.1 Cássia

Located at 741 m altitude and 20°42'04" Latitude South and 46°52'24" Longitude West, in the ecological domain of the Atlantic Rain Forest, the municipality houses "Soyminas Biodiesel Derivado de Vegetais Ltda.", the industrial partner of the "Sowing Biodiesel Project" with the local Prefecture and associated family farmers. Two rural establishments were involved in the sustainability assessment field study in this territory. Establishment A (12 ha) was dedicated to maize production (10 ha) with forage turnip rotation in no-till integrated management. Establishment B (48 ha) produced maize (40 ha), half of which under no-till rotation integrated with forage turnip, besides some animal husbandry and a small orchard for self-consumption.

2.1.2 São Raimundo Nonato

Located at 403 m altitude and 08°56'18" Latitude South and 42°45'12" Longitude West, in the ecological domain of the semi-arid Arboreal Caatinga, the municipality supports the Project "Integrated and sustainable development of castor-oil agribusiness in the

[1] For details on the construction, validation, and usage of the APOIA-NovoRural indicators system see Rodrigues and Moreira-Viñas (2007), and for a copy of the operational spreadsheets, contact the authors.

Piauí semi-arid". The project is coordinated by Embrapa Meio Norte and involves the family farmers of a Bank of Northeast's rural colonization project, and the Micro and Small Enterprises Support Service of Piauí (SEBRAE-PI). Most of the castor-bean production from this area is destined to Brasil Ecodiesel Ltda. in Floriano (PI) and Crateús (Ceará State). The rural establishment (C) selected for the sustainability assessment (23 ha) cultivated castor beans integrated with bush beans in 3 ha as the main activity, with some maize and cattle raised in the collective area of the colonization project. Most of the area consisted of fallow and Caatinga secondary growth, without economic production.

2.1.3 Irecê

Located in the América Dourada district at 798 m altitude, 11°21'48" Latitude South and 41°33'42" Longitude West, in the ecological domain of the semi-arid Arboreal Caatinga, the rural establishment studied is a 50 ha tenancy (under long term, shared production and risk contract) without any infrastructure. The establishment (D) was sown to castor bean integrated with bush beans, under the "Castor Bean Varieties and Crop Rotation / Association Coordinated Program", carried out by Embrapa Cotton, CODEVASF-BA, and the "Cooperativa de Produção e Comercialização da Agricultura Familiar" (COOPAF). Most of the regional castor bean production is sent to Brasil Ecodiesel Ltda. in Iraquara (BA).

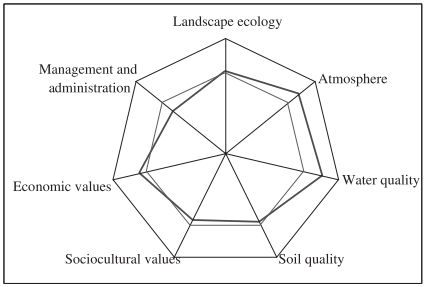
2.1.4 Belém

This study area focused the palm oil production chain, under the institutional arrangement of the "Programa Paraense de Incentivo à Produção de Biodiesel – Parábiodiesel". The sustainability assessment was carried out in a diversified rural establishment (E) located in Santo Antônio do Tauá, at 54 m altitude, 01°06'13" Latitude South and 48°07'34" Longitude West, in the ecological domain of the Equatorial Amazonian Rain Forest. The rural establishment studied (275 ha) had 192 ha under oil palm plantation, with a diversified productive base, including black pepper (28 ha), açaí palm (28 ha), lemon (5 ha), papaya (5 ha), cupuaçu (2 ha), pineapple (2 ha), noni (5 ha), and trees for plywood (5 ha). Only 2.5 ha corresponded to native forests in the establishment, notably occupying the permanent preservation areas shoring a small stream. Some small animal production was carried out for self-consumption.

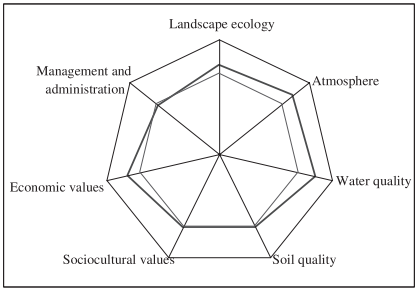
3 Results and Discussion

The field results obtained in the sustainability assessments in all rural establishments and studied territories, and concerning all oleaginous crops comprised in the present study were shown to be in contrast with the tendencies pointed out in the impact assessments carried out at the biofuels production chain scale (Rodrigues *et al.*, 2007). With results equal to or above the conformity sustainability level defined by the APOIA-NovoRural System (Figure 2), all establishments showed important contributions of the oleaginous crops management to sustainability, as well as evident opportunities for improvement, regarding the several sustainability dimensions and indicators evaluated.

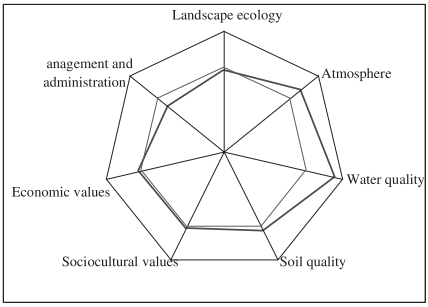
Figure 2: Sustainability assessments of rural establishments dedicated to oleaginous crops for biodiesel production, according to the evaluation dimensions of the "System for Weighed Environmental Impact Assessment of New Rural Activities" (APOIA-NovoRural).



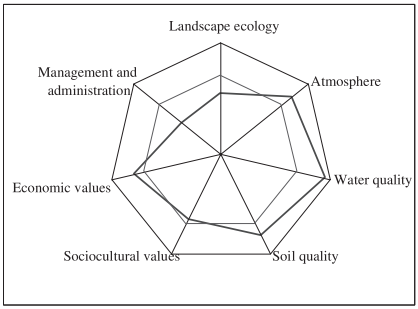
Establishment A, Cássia (MG)



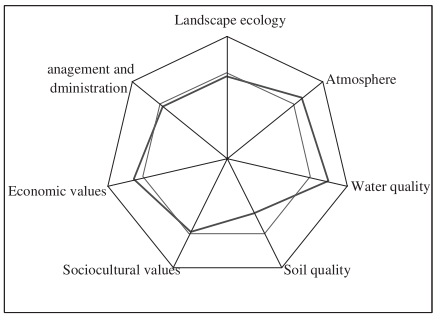
Establishment B, Cássia (MG)



Establishment C, São Raimundo Nonato (PI)



Establishment D, Irecê / América Dourada (BA)



Establishment E Belém / S A Tauá (PA)

Rural establishment location, oleaginous crop assessed	Mean sustainability index, all dimensions
Establishment A, Cassia (MG), forage turnip (*Brassica rapa*)	**0.73**
Establishment B, Cassia (MG), forage turnip	**0.77**
Establishment C, São Raimundo Nonato (PI), castor-oil plant (*Ricinus communis*)	**0.73**
Establishment D, Irecê (BA), castor-oil plant	**0.72**
Establishment E, Santo Antônio do Tauá (PA), oil palm (*Elaeis oleifera*)	**0.70**

Note: Results are mean values of indicators for each dimension. Thin lines represent the (0.70) sustainability conformity level, thick lines represent assessment result indices, in a utility values (0 – 1.0) scale.

The general mean sustainability index obtained when all establishments are considered (0.73) resulted from (a) near absence of negative impacts on the atmosphere, (b) quite adequate water quality and (c) generally favorable soil fertility improvements, as well as (d) overall positive economic indicators. On the other hand, the Management and Administration indicators were below the sustainability conformity level for all establishments, pointing out where there are major opportunities for sustainability performance improvement (Figure 2).

3.1 Establishment level analysis

3.1.1 Cássia, establishments A and B

Both establishments studied in this territory reached favorable final sustainability indices, with 80 and 88% of the 62 APOIA-NovoRural indicators showing results above the baseline conformity level defined in the method, respectively for establishment A (sustainability index = 0,73) and B (sustainability index = 0,77 - Figure 2). The local productive arrangement constructed under the 'Sowing Biodiesel Project' has been providing, on the one hand, improvements at the field level, contributing to productive efficiency by lowering the dependence on external inputs and resources, and favoring the recovery of soils and habitats, thus abating water contamination risks, while raising the living standards and economic security of participating farmers. On the other hand, by providing the institutional setting for cooperation among the several links of the local biodiesel production chain, from the farmers to the agro-industry, the Project has strengthened the relationship of the different groups of interest, fostering the territorial sustainable development. Adding to these results, three general difficulties have been pointed out by the farmers, concerning their productive capacity: i) severe wild bird attack onto germinating seeds; ii) lack of certified turnip seeds; and iii) severe losses (up to 30 - 40%) during harvest, due to inadequate machinery.

3.1.2 São Raimundo Nonato, establishment C

The association of castor bean with the bush bean crop traditionally grown by the farmer, brought about by the "Integrated castor bean agribusiness Project", has contributed most favorably (and perhaps most importantly) for improvement of the Economic performance indicators (mean index = 0.73) of this very modest producer. With a whole 40% of the 62 indicators below the conformity sustainability level (general index = 0.71), however, many opportunities are in place for improving this farmer performance, especially concerning the Management and Administration set of indicators (mean index = 0.60 - Figure 2), with special reference to the Farmer profile and dedication indicator components (index = 0.50). Namely, the implementation of accountability (to manage resources and finances) and planning practices should be emphasized in the technology transfer actions of the Project. Three main difficulties were named by the farmer: i) low value and excessive fringe costs (for minimum processing of the harvested beans) of the product; which engendered ii) inaccessibility to mechanization; and iii) to temporary workers for cultivation and harvest. An adequate solution could be access to credit directed toward acquisition of implements for animal traction, to be offered under the Project.

3.1.3 Irecê (América Dourada), establishment D

The crop situation studied consisted of castor bean only, with atypical spacing, because the bush bean crop had been lost to the season's severe drought. With 71% of the 62 indicators above the conformity sustainability level of the APOIA-NovoRural System, this establishment presented important limitations regarding the Landscape Ecology dimension (mean index = 0.54), owing to its lack of any natural habitats and null productive diversity (castor bean production only); and the Management and Administration dimension (mean index = 0.44), bringing the mean general sustainability index to a 0.72 value (Figure 2). Both of these dimensions' feeble performances were constrained by the land tenancy situation found in place, which discouraged the farmer's engagement to solve those particular deficiencies. This situation also influenced negatively some important Socio-cultural Values indicators (mean index = 0.65), such as deficient Employment quality (informality and lack of any fringe benefits, index = 0.30). These negative impacts were offset by excellent Soil quality and Economic performance indicators (mean indices = 0.82 and 0.79, respectively). Two main difficulties were pointed out by the farmer: i) the uncertainties of the regional climate and ii) complete absence of credit.

3.1.4 Belém (Santo Antônio do Tauá), establishment E

This establishment presented the most homogeneous performance among the assessed sustainability dimensions (mean index = 0.70), with the smaller amplitude of variation among indicators. Even though a whole 40% of the 62 indicators were below the conformity level of the Apoia-NovoRural System, no less than six of the 10 Soil quality indicators were well below the conformity level, biasing the results downwards (Figure 2). This result owed itself to the comparison between orchards and oil palm plantation for soil quality indicators assessment, which was justified because it is onto these orchards that oil palm is to be eventually expanded in the farm. High Productive areas management (0.97) and Productive diversification (index = 0.67) followed not from equitability of land use (70% under oil palm plantation) but from a valuable complement of other perennial crops (with a high Shannon-Wiener diversity index = 0.48), which favored other Landscape Ecology indicators, such as Natural habitats, Permanent Preservation Areas, and Threatened species protection. That same diversification was associated with good Economic Values performance (0.78). The farmer listed two important productive difficulties: i) very high costs for oil palm implantation, compared with current product value; and ii) severe losses imposed by the heart-of-palm-rotting disease.

3.2 Integrated sustainability dimensions analysis

When considering the environmental performances for the whole set of studied establishments, results show indices above or very close to the conformity level for the Landscape Ecology dimension of sustainability, except for establishment D (Figure 2). Most favorable indicators for those other establishments were related with 'Conservation of natural habitats' and 'Permanent Preservation Areas' (APP), 'Productive areas management', and 'Degraded land reclamation'. On the other hand, mandated 'Legal Preserve' (RL) conservation was a problem for all except establishment C, for the Legal Preserve in its case is collective, legally defined for the whole colonization project. Also, 'Land-

scape diversity' and 'Productive diversity' were low for all except establishment E. This latter indicator is a measure of the farmers' capacity to face prices instabilities, in the potentially volatile market of vegetable oils.

Regarding Atmosphere and Water quality indicators, quite favorable results were obtained in all establishments, while Soil quality indicators were mostly adequate, and improving under oleaginous crops management, for all except establishment E. All these indicators immediately concerned with ecological performance (Landscape Ecology and Environmental Quality dimensions of APOIA-NovoRural) attested to an adequate field situation (for the selected sample), opposed to the expectancy obtained in the socio-environmental impact assessments carried out at the production chain scale, which pointed out increased use of inputs and natural resources, with potential negative environmental consequences (Rodrigues *et al.*, 2007). This apparent favorable situation observed in the present set of environmental assessments calls for attentive management, in order to avoid eventual materialization of those expected negative impacts.

The feeble results for the Socio-cultural indicators pointed out the quite modest living conditions observed in most studied territories and establishments, only two showing results just similar the sustainability conformity level (0.70). 'Access to education', especially for the farmers; 'Opportunities for local employment', even if for non skilled workers; 'Employment quality', especially due to formality and social security observance; and 'Access to public services' weighed favorably for this general result, while 'Consumption standards' were very modest.

The Economic Values dimension showed quite favorable results for all studied establishments, especially due to good performance relative to 'Income generation' (considering income security, stability and amount), 'Income sources diversity', and 'Land value', which concerned improvements in productive conditions and infrastructure, even if associated with increased 'Indebtedness level', the main negative indicator for the studied establishments in this sustainability dimension.

Contrarily to social actors expectancies raised in the socio-environmental impact assessment at the production chain scale in all territories (Rodrigues *et al.*, 2007), the Management & Administration dimension of sustainability showed the main performance weaknesses in all studied establishments, strongly so for A, C, and D. Here rest the most valuable opportunities for improvements to be brought about by increased demand for oleaginous crops under the agro-energy context, for in general no heavy cash investments are required to obtain solutions – potentially low cost managerial, capacity building, and organizational ameliorations suffice.

For example, the 'Farmer profile and dedication' indicator showed deficiencies as basic as total lack of any accountability and of any planning systems, indispensable items if small-holders are to find their insertion into market settings. The 'Commercialization conditions' indicator pointed out deficiencies regarding widespread dependence on middlemen, and lack of processing, storage, and productive integration conditions in the studied establishments. The 'Residues management' indicator showed common prob-

lems, mostly for domestic wastes; while residues from production are, for the best cases, just incorporated as soil amendments, without treatment, composting, or conditioning.

The 'Institutional relationships' indicator showed as main deficiency the absence of continuous professional training for the farmers, possibly where the best potential for a performance shift lies. This is especially confirmed by the main positive results obtained in this same indicator, attesting to the presence of technical assistance and extension, as well as research and development institutions with close ties with all farmers studied, registering the presence of several local Producers Associations, Municipal Secretaries, and the institutions Embrapa, Emater, and Sebrae.

4 Conclusions

Regarding production of forage turnip, the positive socio-environmental impacts were corroborated by several known attributes of the plant: (i) fast and abundant growth even under winter conditions, out-competing weeds; (ii) extensive, acidity-resistant root system (up to 2 m long), favoring deep recovery of soil nutrients (especially N and P); (iii) good acceptability as forage and fodder for ruminants, as well as early and abundant flowering, excellent for bee feeding; and (iv) tolerance to most pests and diseases (Pereira, 1998).

In what concerns castor-oil, the high value for the fine chemistry industry and the relatively low level of technology still present in Brazilian producing areas are important constraints to make the crop viable for biodiesel production (de Mendes, 2005; Severino, 2006). Even with these constraints, castor-oil is still to be considered an important crop under the Biodiesel Program, due to its role as a value-adding cash-crop usually cultivated in association with food-crops such as maize and beans, as well as a means for small-holders to obtain access to technical assistance and training, when associated with biodiesel producing companies under the provisions of PNPB.

All favorable conditions contributed by the oil palm crop expressed by the social actors are also fully corroborated in the literature (Monteiro *et al.*, 2006), whereas the positive points regarding degraded lands occupation and recovery by oil palm plantations must be resolved, in conjunction with solutions to the problems of incorporation of new areas and native forest felling in many regions of the world (Annevelink *et al.*, 2007).

Even though each specific assessment overviewed in the present study has been constructed under its own environmental, managerial, and productive context - abating the meaningfulness of comparisons - the mean Sustainability Index obtained for the sample, above the conformity level defined in the assessment methodology, is a measure of the positive influence of the organized local productive arrangements and territorial projects to the environmental performance of the studied farms. This general conclusion, applicable to all regions and crops studied, has been corroborated in the literature (Haverkort *et al.*, 2007) by the argument that, more than a matter of specific crop or environmental setting, it is the local productive arrangement that defines the tendency of impacts caused by the integration of oleaginous crops into agro-energy production chains.

The insertion of small-holders into the biofuels market has also been shown to follow a similar trend, with all sustainability criteria and indicators being influenced by the local productive arrangements that determine favorable opportunities for crops association and diversification, the provision of technical assistance, and the certainty of a steady demand for production. These conditions may promote value aggregation and income improvements, security and stability over time, and most importantly a valorization of natural resources and environmental assets, under the frame of local development initiatives and community involvement. Sustainability assessment procedures, such as the one exemplified in the present study, offer valuable documentation and communication means for consolidating such initiatives.

Acknowledgements
We thank the institutional support provided by the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), Embrapa (Units Environment, Center-North, Cotton, Occidental Amazon and Oriental Amazon) and Codevasf/BA. The contributions of the enterprises Soyminas, Fertibom, and Dentauá, and the Municipality of Cássia (and CEARCA) are gratefully acknowledged. Special gratitude is addressed to all participants of the Workshops and to the farmers, who dedicated their time and knowledge for the consecution of this research.

References

Annevelink, B., Elbersen, W., de Jong, E., Koops, A., Kuikman, P., Langeveld, H., van Loo, R. and Slingerland, M.; Biomass production for bioenergy: opportunities, threats and required actions; in: *Food, Fuel or Forest: Opportunities, Threats and Knowledge Gaps of Feedstock Production for Bio-energy*, edited by Haverkort, A., Bindraban, P. and Bos, H.; 47–55; Plant Research International, Wageningen University; Holand; 2007.

Bindraban, P. S. and Zuurbier, P. J. P.; Sustainability of feedstock for biodiesel; in: *VI International PENSA Conference – Sustainable Agri-food and Bioenergy Chains/Networks, Economics and Management, Ribeirão Preto, Brazil*; 2007.

Bisset, R.; Methods for environmental impact assessment: a selective survey with case studies; in: *Environmental Impact Assessment for Developing Countries*, edited by Biswas, A. K. and Geping, Q.; 3–64; Tycooly International, London; 1987.

Campanhola, C., Rodrigues, G. S. and Rodrigues, I. A.; Gestão ambiental territorial; in: *Gestão Ambiental na Agropecuária*, edited by Gebler, L. and Palhares, J. C. P.; 13–31; Embrapa Informação Tecnológica, Brasília; 2007.

Girardin, P., Bockstaller, C. and van der Werf, H.; Indicators: tools to evaluate the environmental impacts of farming systems; *J. Sust. Agric.*; 13(4):5–21; 1999.

Haverkort, A., Bindraban, P. and Bos, H., (Eds.) *Food, Fuel or Forest: Opportunities, Threats and Knowledge Gaps of Feedstock Production for Bio-energy*; Plant Research International, Wageningen University; Holand; 2007.

Hill, J., Nelson, E., Tilman, D., Polasky, S. and Tiffany, D.; Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels.; *Proc*

Natl Acad Sci U S A; 103(30):11,206–11,210; 2006; ISSN 0027-8424 (Print).

DE MENDES, R. A.; *Diagnóstico, Análise de Governança e Proposição de Gestão para a Cadeia Produtiva do Biodiesel da Mamona: o caso do Ceará*; Master's thesis; Universidade Federal do Ceará, Fortaleza, Brazil; 2005.

MONTEIRO, K. F. G., DA SILVA, A. R. F. and DA CONCEIÇÃO, E. R.; Inserção da agricultura familiar na cadeia do biodiesel no Estado do Pará: possibilidades de emprego e renda com o cultivo do dendê; in: *Desafios na Amazônia: uma nova assistência técnica e extensão rural*, edited by MONTEIRO, D. M. C. and MONTEIRO, M. A.; 233–246; Universidade Federal do Pará, Belém, Brazil; 2006.

MONTEIRO, R. C. and RODRIGUES, G. S.; A system of integrated indicators for socio-environmental assessment and eco-certification in agriculture – Ambitec-Agro; *Journal of Technology Management & Innovation*; 1(3); 2006.

PEREIRA, J. O. F.; Nabo Forrageiro – AL1000 Adubação Verde para o Inverno; CATI Responde São Paulo, no. 25; 1998; URL `http://www.cati.sp.gov.br/novacati/tecnologias/catiresponde/cr25naboforr.html`.

PNPB; Biodiesel: o novo combustível do Brasil; Programa Nacional de Produção e Uso de Biodiesel; 2007; URL `http://www.biodiesel.gov.br/docs/Folder_biodiesel_portugues_paginado.pdf`.

PORTAL DO BIODIESEL; Selo Combustível Social; 2005; URL `http://www.biodiesel.gov.br/index.html`.

RODRIGUES, G. S., DE A. BUSCHINELLI, C. C. and MUNIZ, L. R.; Ostrich farming and environmental management tools: an overview; *Australian Journal Experimental Agriculture*; 48:1308–1313; 2008.

RODRIGUES, G. S. and CAMPANHOLA, C.; Sistema integrado de avaliação de impacto ambiental aplicado a atividades do novo rural; *Pesq. Agrop. Bras.*; 38(4):445–451; 2003.

RODRIGUES, G. S. and MOREIRA-VIÑAS, A.; An environmental impact assessment system for responsible rural production in Uruguay; *Journal of Technology Management & Innovation*; 2(1):42–54; 2007.

RODRIGUES, G. S. and RODRIGUES, I. A.; Avaliação de impactos ambientais na agropecuária; in: *Gestão Ambiental na Agropecuária*, edited by GEBLER, L. and PALHARES, J. C. P.; 285–310; Embrapa Informação Tecnológica, Brasília, Brazil; 2007.

RODRIGUES, G. S., RODRIGUES, I. A., DE A. BUSCHINELLI, C. C., LIGO, M. A., PIRES, A. M., FRIGHETTO, R. and IRIAS, L. J. M.; Socio-environmental impact of biodiesel production in Brazil; *Journal of Technology Management & Innovation*; 2(2):46–66; 2007.

SEVERINO, L. S.; Como a Índia tornou-se líder mundial na produção de mamona; BiodieselBR 267; 2006; URL `http://www.biodieselbr.com/colunistas/liv/india-lider-mundial-producao-mamona.htm`.

WRIGHT, L.; Worldwide commercial development of bioenergy with a focus on energy crop-based projects; *Biomass and Bioenergy*; 30:706–714; 2006.