Journal of Technology Management & Innovation

Received May 11, 2007 / Accepted June 12, 2007

SOCIO-ENVIRONMENTAL IMPACT OF BIODIESEL PRODUCTION IN BRAZIL

Geraldo Stachetti Rodrigues[1]*, Izilda Aparecida Rodrigues[2], Cláudio César de A. Buschinelli[3], Marcos Antônio Ligo[3], Adriana Moreno Pires[3], Rosa Frighetto[3], Luiz José Maria Irias[3]

Embrapa Labex Europe, Agropolis International. Montpellier CEDEX 5, France[1]
Embrapa Environment / Fundação de Amparo à Pesquisa do Estado de São Paulo. CP 069, Jaguariúna (SP), CEP 13820-000 [2]
Embrapa Environment. CP 069, Jaguariúna, São Paulo, CEP 13820-000, Brazil [3]

* Corresponding author. Tel.: +33.(0)4.67.04.37.43; Fax: +33.(0)4.67.04.75.90
E-mail address: stacheti@cnpma.embrapa.br (G.S. Rodrigues).

Abstract

Socio-environmental impact assessments were carried out on oleaginous crops for biodiesel production under the context of expanding demand in five regions of Brazil. The study brought together representatives of the main interest groups in Delphi-type workshops. Major impacts are related with increases in demand for inputs, resources, and energy, with potential risks on water quality and habitat conservation. In some instances, management practices may improve soil quality, favoring habitats recovery. Crop intensification is expected to bring important contributions for farmer capacitation, income generation and sources diversity, as well as improved management and administration. Institutional especially designed local productive arrangements offer the best options for fostering sustainable development and avoiding environmental degradation risks, under the scenario of expanding demand on oleaginous crops for biodiesel production.

Key words: socio-environmental impact assessment, technology appraisal and recommendation, biodiesel, sustainable rural development

Introduction

High anticipation has been deposited recently on the large scale production of biomass-derived biofuels. On the one hand, there are the hopes for abating some of the environmental impacts related with fossil fuels consumption, as well as with the shortage problem foreseen for not too distant a future (Pimentel et al., 1994). On the other hand, favorable opportunities arise with the technological improvements in biofuel production, from the diversifying choice of biomass raw materials, to the chemical processes and production scale of the transformation plants, to the fuel flexibility of the new

vehicle engines (Bournay et al., 2005; Hamelinck & Faaij, 2005).

In addition to these advances, high prospects are in place for associating the increasing demand for biomass crops with improvements in working and living conditions of rural producers and communities, taking advantage of propitious new productive arrangements, adequately adapted extension programs, and agricultural technology transfer and adoption. In order to tackle these issues, dedicated public policies must be devised and implemented (Monteiro et al., 2006; Haverkort et al., 2007).

The pressing demand for biomass is currently being confronted with a known long delay for the effective and widespread adoption of new technologies in the rural context, making it urgent to develop and validate viable production alternatives. Combined technologies for biomass (starch and oil grains, sugar tubers and grasses, and ligno-cellulosic materials) production and processing provide the best array of opportunities for tying the upcoming agro energy revolution to the sustainable development of rural communities (MacLaren, 2005).

Agro energy enterprises represent an excellent occasion for the Brazilian agricultural sector. Besides large expanses of land that could be incorporated into production, there are some 10 million hectares of sugar-cane plantations that must undergo a crop rotation every five years, making available countrywide around two million hectares for oleaginous crops every year. In addition, there are over 90 million hectares of pastures under some degree of degradation that could benefit from integration / rotation with annual crops (Peres et al., 2005).

Under this context, a federal policy (Act 11.097 of 13th January 2005) has instituted the National Program for Production and Use of Biodiesel (PNPB), determining the voluntary addition of 2% biodiesel into (mineral) diesel oil (a mixture named B2) before 2007 is over. Between 2008 and 2012 the 2% addition will be compulsory, with 5% voluntary (B5), being made compulsory from 2013 onward (ESALQ/USP, 2006; Lima Filho, 2006). The commercial use of B2 creates an 800 million liters of biodiesel / year market beginning in 2008.

Each link of the biodiesel productive chain shows peculiarities that differentiate the involved social actors, according with their particular opportunities for market insertion in the shaping agro energy market. Aiming at including the family farmers into the production of oleaginous crops for biodiesel, the National Agrarian Development Ministry (MDA) proposed the "Social Fuel Label" policy, which provides the engaged Biodiesel Transformation Plants with tax discounts, and farmers with special extension services and commercial priority. The MDA (2006) foresees the inclusion of 292,000 family farmers under the "Social Fuel Label" policy, growing oleaginous crops for biodiesel production in 830,000 hectares.

Reinforcing this National policy, the National Bank for Social and Economic Development (BNDES) currently contemplates 11 investment projects, reaching around US$ 350 million and 1.1 billion liters production capacity (Prates et al., 2007); a preview validated by the present 19 operating Biodiesel Transformation Plants, that reach 710 million liters production capacity / year. Other 13 Biodiesel Transformation Plants are built but not yet producing, adding a previewed 485.5 million liters / year (BiodieselBR, 2007).

One fundamental step for maximizing the opportunities and regional comparative advantages brought about by this shaping agro energy market, considering the several crops and productive arrangements possible; and to minimize potential socio-environmental threats, is the assessment of impacts. Environmental impact assessment procedures are instrumental tools for decision making, allowing the organization of the knowledge and experience of the social actors involved in the concerned biodiesel production chains (Rodrigues, 1998).

The present study brings a set of socio-environmental impact assessments carried out in five regional production centers of oleaginous crops in Brazil, under the context of expanding demand and changing arrangements for biodiesel production. The goal is to provide a basis for promoting territorial environmental management (Rodrigues et al, 2006a), relying on the sustainable development objectives of the main social groups of interest involved.

Methods

As a National policy for promoting the inclusion of family farmers, the PNPB imports potential dramatic changes onto the rural scenario of oleaginous crops production in Brazil, demanding urgent appraisal. Environmental impact assessment (EIA) systems provide an organized procedure to bring together and express the concerns and propositions of the social groups of interest involved in policy decision making. This is especially true when innovative technological and developmental programs are in place, aiming at both the (i) environmental management at the territorial scale, and (ii) the sustainable management of the production activities at the rural establishment scale.

In order to undertake the first aforementioned objective, a base system for socio-environmental impact assessment is warranted, to offer the procedural malleability and criteria and indicators adaptability, to conform with the definitions of the several social groups of interest. The Eco-cert.Rural System (Rodrigues et al,

2006b; Monteiro & Rodrigues, 2006) has being proposed as an adequate method for this purpose, providing a platform for raising the issues and debating the constraints of the social interest groups at the territorial / regional scale.

Once the rural territorial scenario has been constructed and critically analyzed regarding the socio-environmental impacts and technological constraints, an environmental management system can be applied at the rural establishment scale (second aforementioned objective). This research step allows checking the adherence of the socio-environmental impact assessment against the farmer reality, and to propose technology innovation adoption and productive activity best management practices. The APOIA-NovoRural System (Rodrigues & Campanhola, 2003; Rodrigues & Moreira-Viñas, 2007) has being proposed as an adequate method for this purpose, providing a procedure to offer a rural establishment sustainable management report, individually, to participating farmers.

EIA Systems descriptions

Eco-cert.Rural

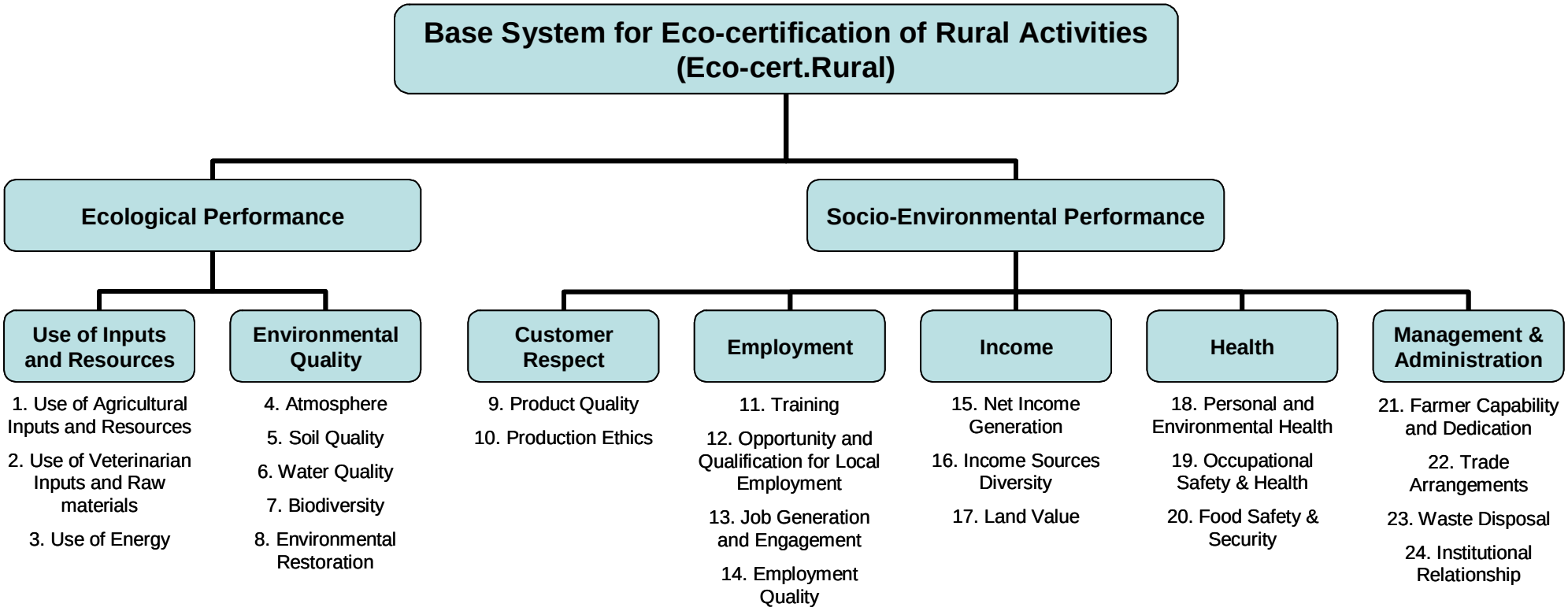

Figure 1. Dimensions and criterias for socio-environmental impact assessment of the Eco-cert.Rural system.

The Eco-cert.Rural System integrates 24 criteria (Figure 1) and 125 indicators of the social and environmental performance of an agricultural technology or activity. The criteria and indicators are constructed in weighing matrices, ready for scoring in a field survey / interview with the farmer / administrator (or social actor at the territorial scale), who expresses a change coefficient for each indicator, according to his / her knowledge about the technology or rural activity effects. The change coefficients are weighed by factors related to each indicator's relevance toward effecting socio-environmental impacts and its scale of occurrence. This weighing procedure conform an artificial scale for the impact indices ranging between ±15. Finally, impact indexes are calculated for each indicator, criterion and technology innovation / activity studied. The output of this base socio-environmental performance assessment system allows the farmer / manager to inquiry which management practices and productive activities result in major impacts (either positive or negative), favoring the selection of best management practices according with local resources availability and environmental constraints. For decision makers and public managers the system permits the delineation of policies for rural activities performance improvement. Also, the Eco-cert.Rural System serves as a benchmarking scheme to guide the formulation of local / territorial sustainability objectives. For details of the methodology and access to the operational system, please refer to Monteiro & Rodrigues (2006).

APOIA-NovoRural

The APOIA-NovoRural System consists of a set of 62 sustainability indicators weighing matrices formulated toward the systemic assessment of a rural activity at the rural establishment scale, according to five dimensions: i) Landscape Ecology, ii) Environmental Quality (Atmosphere, Water and Soil), iii) Sociocultural Values, iv) Economic Values, and v) Management and Administration. The sustainability assessment is performed by quantitatively and analytically assessing the effects of the rural activity on each and every indicator constructed for these five dimensions, and automatically calculating the impact indexes, according to appropriate weighing factors. The impact indices are expressed as utility values (0-1, with the baseline sustainability conformity level defined at 0.7) in graphs for each indicator, the aggregated dimensions and a final sustainability index. For details of the methodology and access to the operational system, please refer to Rodrigues & Moreira-Viñas (2007).

Impact assessment workshops and participating groups of interest

The socio-environmental impact assessments were carried out in Delphi-type workshops conducted with social actors involved, in each region, with the oleaginous crops for biodiesel production chains. Four groups of interest were composed to accommodate the different social actors, namely (i) farmers and their representations, (ii) public and community management representatives, (iii) research and capacitation institutions representatives, and (iv) agro-industry representatives. The workshops and ensuing result transfer activities were conducted in five steps, as follows:

i. Meeting and short course on environmental management of oleaginous crops for biodiesel production, with detailed explanation of the Eco-cert.Rural methodology and presentation / discussion of applicable assessment indicators.
ii. Social actors debate concerning the management characteristics and context of expanding demand for the specific oleaginous crop in the region, emphasizing the particular views of the social groups of interest.
iii. Individual social actor filling out of the weighing matrices of the assessment system, under guidance of the workshop coordinator.

Post-workshop continuing assessment:

iv. General results statistical analysis and regional socio-environmental impact report formulation and distribution for critical analysis by all involved social actors.
v. Field study of typical rural establishments, for sustainability assessment (with the APOIA-NovoRural system) under the context obtained in the previous socio-environmental impact assessments.

Five oleaginous crops producing regions were selected for the study:

Figure 2. Regional distribution of oleaginous crops for biodiesel production areas involved in the socio-environmental impact assessment study

i. Region of Catanduva (São Paulo State): An important sugar-cane for ethanol production area in the ecological domain of semi-deciduous Atlantic rain forest. Here Fertibom Industries Ltda is producing biodiesel from animal fat, and proposing a project for establishing a *Jatropha curcas* production program with family farmers. Fertibom partook of the third biodiesel auction of the National Agency of Petrol, Natural Gas and Renewable Fuels (ANP)[1] on the 11th July 2006, selling 6.0 million liters. The assessment consisted of an *ex-ante* socio-environmental impact evaluation involving a farmer and a representative of the Rural Syndicate; three public management representatives of the Secretaries of Infrastructure and Environment, and Development and Employment; three representatives of research and capacitation institutions (SEBRAE/SP – Micro and Small Enterprises Support Service; APTA – São Paulo Agency for Agricultural Technology; and COOPERCITRUS – Cooperative of Citrus Producers of São Paulo State); and two agro-industry representatives (Fertibom Ltda).

ii. Region of Cássia (Minas Gerais State): A typical small farmstead region in the Atlantic rain forest ecological domain, mainly dedicated to coffee and feed grains, especially corn. Oleaginous rapeseed (*Brassica napus* or *Raphanus sativus* L. var. oleiferus) has been introduced for rotation with corn in a no-tillage agriculture program, enabling association of farmers with the Soyminas Biodiesel Derived from Plants Ltda, which also processes sunflower. The company partook of the first ANP auction on the 23rd November 2005, selling 8.7 million liters. The socio-environmental impact assessment addressed rapeseed production in rotation with corn under no-till management system. The workshop brought together two farmers and a representative of CEARCA (Cássia Rural Workers Associations Union); a public management representative (IMA – Minas Gerais State Institute of Agriculture); and an agro-industry representative (Soyminas Ltda).

iii. Region of Belém (Pará State): In the ecological domain of the Amazon rainforest, the region holds the

[1] All information regarding these auctions can be obtained on the websites: ANP - www.anp.gov.br/, Agrarian Development Ministry - www.mda.gov.br/ and BiodieselBR Bulletin - www.BiodieselBR.com/.

largest oil palm (*Elaeis oleifera*) plantations in the country, associated with important food agro-industries. The Agropalma Refinery of Amazonas Cia, with 24 million liters / yr capacity for biodiesel production from fatty acid from palm oil, partook of the first and third ANP auctions, selling 7.2 million liters. The perspective of expanding palm oil demand for biodiesel was the context for socio-environmental impact assessment, which involved seven public and community management representatives (three from the Bank of the Amazon; one of MAPA-Ministry of Agriculture, Livestock, and Supply; one from MDA-Ministry of Agrarian Development; one from SAGRI-State Secretary of Agriculture; and one from SEP-Especial Secretary for Production); 11 representatives of research and capacitation institutions (two from EMATER-State Agency for Technical Assistance and Rural Extension; one from Goeldi Museum; one from The Rural University of Pará; two from Embrapa Occidental Amazon-National Agency for Agricultural Research; and five from Embrapa Oriental Amazon), and one agro-industry representative (Marborges Agro-industry S.A.);

iv. Region of São Raimundo Nonato (Piauí State): Under the ecological semi-arid domain of the arboreal Caatinga, the region is characterized by extensive cattle and sheep husbandry, and low technology castor-oil plant (*Ricinus communis*) production in consortium with bush- and caupi-beans. All (small scale) production is collected through intermediaries by Brasil Ecodiesel Com. Ind. Ltda of Floriano (PI), which partook of the first and third ANP auctions, selling 78 million liters. The socio-environmental impact assessment workshop involved a representative of APSem-Association of Seed Producers; two public and community management institutions representatives (Bank of the Northeast of Brazil, and State Secretary of Rural Development); and four representatives of research and capacitation institutions (three of Embrapa Center-North, and one from SEBRAE/PI).

v. Region of Irecê (Bahia State): Under the ecological semi-arid domain of Caatinga, the region has been one of the most important bush-bean producers of the country, besides irrigated horticulture (mainly tomatoes and carrots), and castor-oil plant. The context for socio-environmental impact assessment consisted of expanding demand for castor-oil plant, which is produced in consortium with bush beans. Production is collected through intermediaries by Brasil Ecodiesel of Iraquara (BA), which partook of the fourth (12th July, 2006) and fifth (14 and 15th February, 2007) ANP auctions, selling 88 million liters. The workshop involved six farmers and two representatives (Small Farmers Territory of Irecê, and COOPAF-Familiar Farmers Production and Commerce Cooperative); a representative of public and community management institutions (Municipality of Lapão, BA); nine research and capacitation institutions representatives (six from EBDA-Bahia State Agency for Agricultural Development; and three from Embrapa Cotton); and three agro-industry representatives (Bom-Brasil Castor-oil Ltda).

Data analysis and presentation

The integrated analysis of the assessments obtained for the individual social actors involved in each territory consisted of graphic examination of the mean impact indices for each of the 24 criteria, as well as regarding data dispersion (±SD) within and among the represented groups of interest. Pending further refinement of statistical procedures, a correlation analysis (without data transformation for normality, considering first quartile of agreement as significance criteria) allowed the construction of social actors' convergence maps, facilitating the interpretation of tendencies among the social groups of interest. The results have been presented in Socio-environmental Impact Assessment Reports distributed for all participants, for critical analysis.

Results

The particular results for the different producing regions and crops, and the level of agreement of the social actors partaking of the study were as follows:

i. Region of Catanduva (SP), *Jatropha curcas* production: A moderate increase in the demand for inputs (criterion 1, Figure 3), raw-materials (2), and energy (3) may implicate increased emission of atmospheric pollutants (4). As indicated for cultivation in degraded and marginal areas of the establishment, the culture may contribute towards soils (5) and biodiversity conservation (7), favoring the quality of water (6) (due to erosion abatement), and habitats reclamation (8).

The agricultural intensification associated with production of *Jatropha* for biodiesel in the region may contribute for the socioeconomic indicators, especially farmer capacitation (criterion 11), to be provided by Fertibom under arrangements of the PNPB, income generation (15), and land value (17), improving the management and administration indicators (criteria 21-24, Figure 3). A moderate negative impact is expected on the occupational safety and health indicator (19), caused by increased exposure of workers in the input application operations.

The social actors whose assessments converged (considering a correlation >0.75 for all indicators) were represented by the farmer and his representation (the Rural Syndicate), this one with the representative of the Municipal Secretary of the Environment, and this one with the representative of the State Agency for Agricultural Technology, and one agro-industry representative (Figure 4).

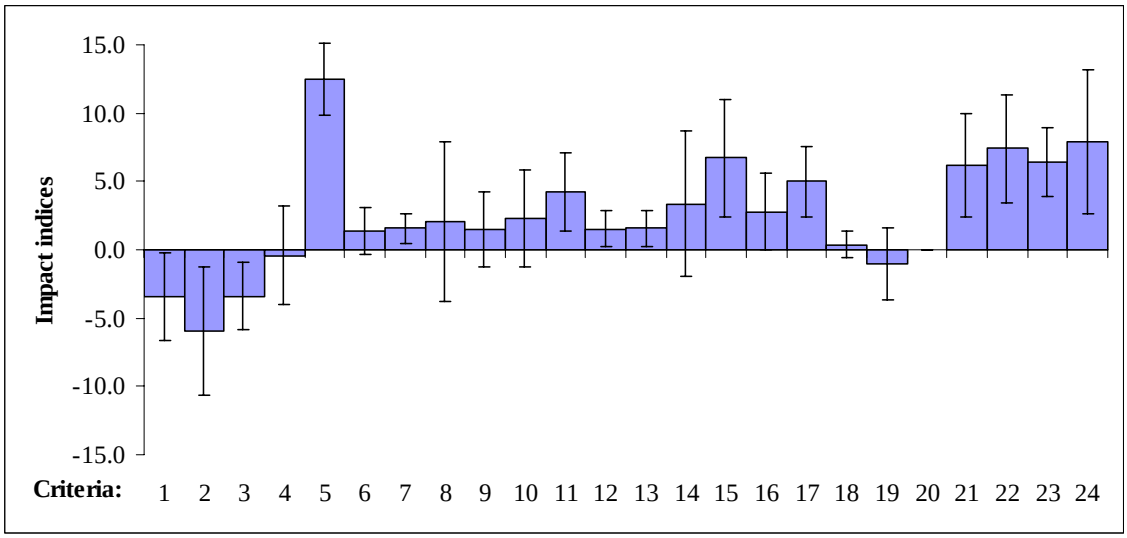

Figure 3. Mean and standard deviations of the Eco-cert.Rural impact indices applied to *Jatropha curcas* for biodiesel production, according with social actors' assessment in Catanduva (SP). Assessment criteria (1-24) labels in Figure 1.

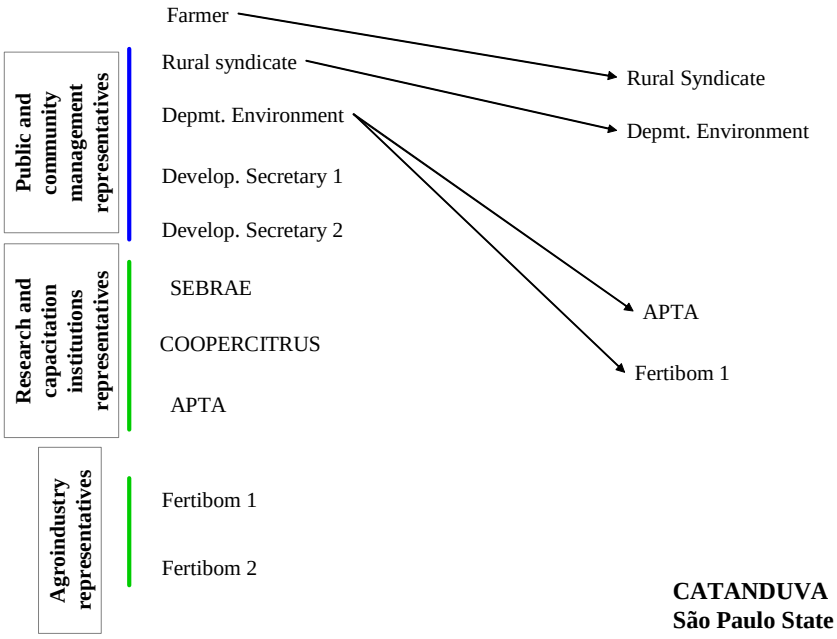

Figure 4. Convergence among social actors, for the set of 24 criteria of the Eco-cert.Rural System, for the assessment of socio-environmental impacts of *Jatropha curcas* for biodiesel production (correlation >0.75). Catanduva (SP).

ii. Region of Cássia (MG), rapeseed production in no-till rotation with corn: besides the important improvement in soil quality (criterion 5, Figure 5) resulting from the no-tillage management implemented for rapeseed in the region, the production system uses the same area and allows the recovery of soil nutrients left by the main crop, favoring a positive impact on the use of inputs and resources (criterion 1). Even then, there is increase in raw-material requirements (mostly seeds, criterion 2) and energy (3) for cultivation and harvest. The recovery of degraded soils also causes degraded habitats reclamation (8), with favorable impacts on biodiversity conservation, even if moderately (criterion 7, Figure 5).

The productive integration under no-till management reflects positively on the socioeconomic criteria, such as farmer capacitation (criterion 11), income generation (15) and income sources diversity (16), land value (17), and all criteria of management and administration (21-24). Aside from soil quality, all indicators' impact indices obtained in this region were only moderately favored (Figure 5), but with a high level of agreement among (the few) social actors involved. The agreeing actors in this territory were among the farmer and his representations (Figure 6).

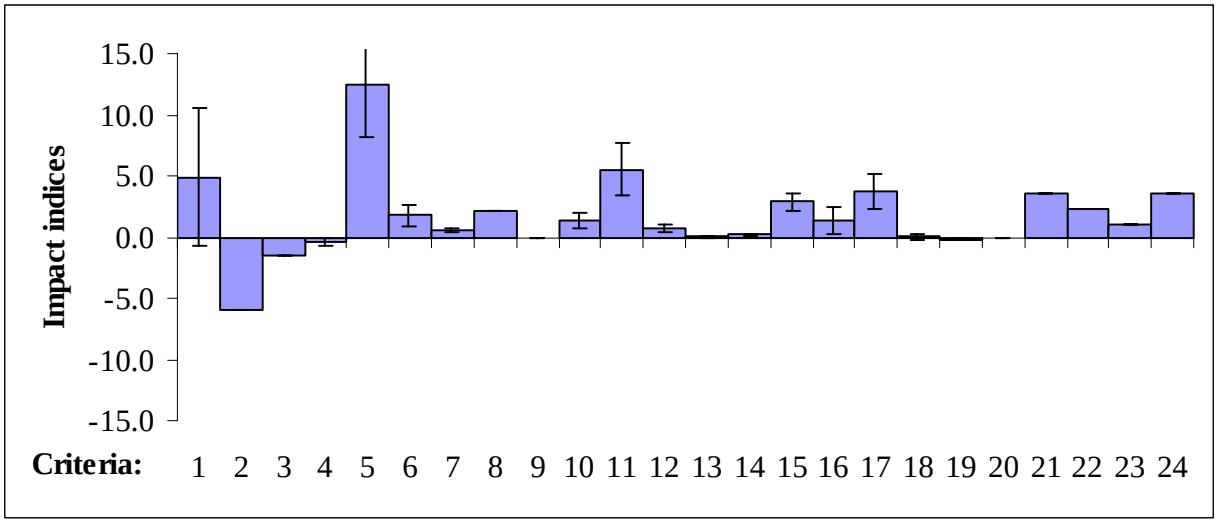

Figure 5. Mean and standard deviations of the Eco-cert.Rural impact indices applied to rapeseed for biodiesel production, according with social actors' assessment in Cássia (MG). Assessment criteria (1-24) labels in Figure 1.

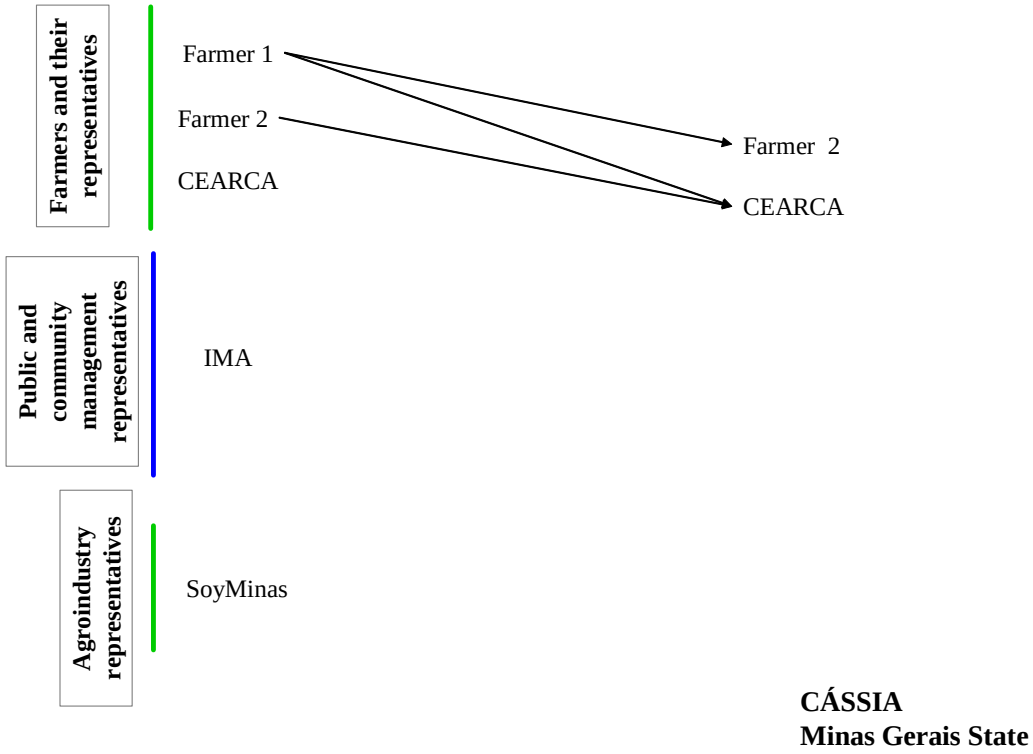

Figure 6. Convergence among social actors, for the set of 24 criteria of the Eco-cert.Rural System, for the assessment of socio-environmental impacts of rapeseed for biodiesel production (correlation >0.75). Cássia (MG).

iii. Region of Belém (PA), palm oil production: The increase in the demand for palm oil for biodiesel production is expected to bring a strong pressure for the expansion of cultivated areas and application of chemical fertilizers, now practically not used in the culture. This trend implicates negative ecological impacts on the use of inputs and resources, including soil for the plantations (criterion 1, Figure 7), use of raw-materials (2), and risks for water quality (6), due to inputs runoff. Regarding energy impacts, a high level of discrepancy occurred among actors, as shown by the large deviation bars seen in Figure 7 (criterion 3), which is also true for the indicators of impact on the atmosphere (4) some social actors considering the negative impacts of area expansion and machinery operations, others considering the substitution effect of the biofuel. The improvement on soil quality indicators (5), caused by the highly perennial aspect of the crop and the conservation practices associated (nitrogen fixing cover crop, no-till management, incorporation of large amounts of organic matter residues from the processed coconut bunches) contribute toward biodiversity conservation (7). With these results, there is a negative balance for the ecological indicators of the expansion of palm oil cultivation for biodiesel production (Figure 7).

Regarding the socio-environmental performance indicators, the productive intensification resulting from the expanding demand reflects positively on the integration between agro-industries and farmers, favoring the indicators of productive ethics (criterion 10), capacitation (11), and especially income generation (15), income sources diversity (16) and land value (17), a result of the investments for establishing palm oil cultures. The criteria of job positions generation (13) and employment quality (14) are also favored, given the intensive recruitment of personnel for the management and harvest operations in palm oil plantations.

Two slightly negative criteria are related with personal (18) and occupational health (19), caused by the increased use of chemical inputs and exposure of workers. The expected improvements in farmers' capacitation and income bring positive effects on the criteria of management

and administration (21-24), concerning farmers profile and dedication, commercialization conditions, waste disposal, and institutional relationship. Interestingly enough, the social actors with agreeing assessments in this territory were within the group of public and community management representatives, and between these and within the research and capacitation institutions representatives (Figure 8).

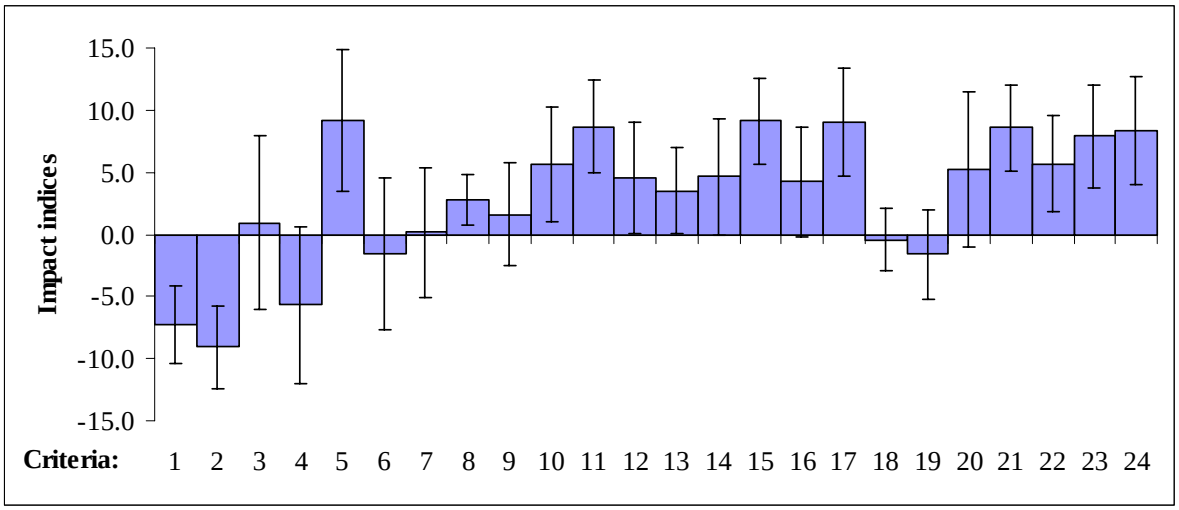

Figure 7. Mean and standard deviations of the Eco-cert.Rural impact indices applied to palm oil for biodiesel production, according with social actors' assessment in Belém (PA). Assessment criteria (1-24) labels in Figure 1.

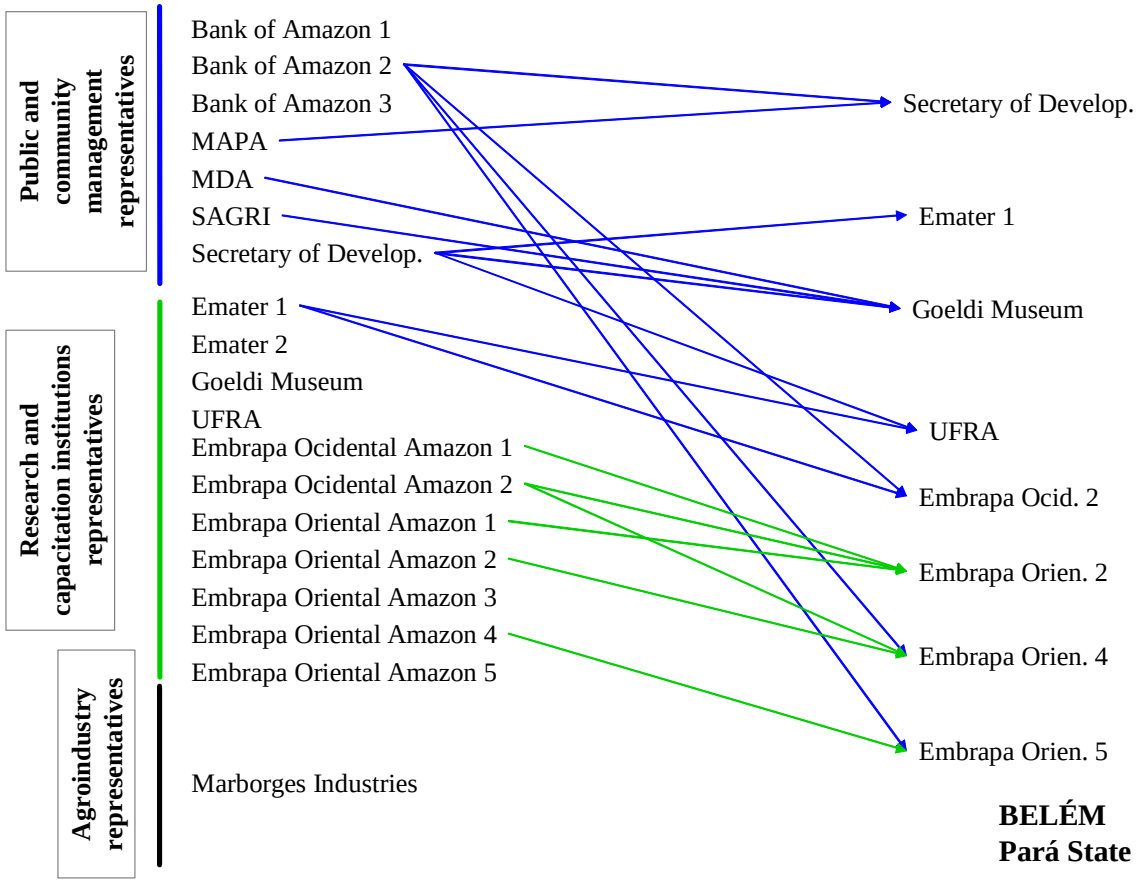

Figure 8. Convergence among social actors, for the set of 24 criteria of the Eco-cert.Rural System, for the assessment of socio-environmental impacts of palm oil for biodiesel production (correlation >0.75). Belém (PA).

iv. Region of São Raimundo Nonato (PI), castor bean production in consortium with bush or caupi-bean: The expected pressure on oil demand for biodiesel, much alike in the other regions and crops, is associated with increases in castor-bean cultivated area in this region. However, given the very low technological level of agricultural practices, only minor effects have been observed on the use of inputs and resources (criterion 1, Figure 9), some effect on raw-materials (mostly seeds, criterion 2), and energy (3) used to brake open the fruits and transport the beans.

The substitution of fossil fuels by biodiesel in the context of the production chain reflects positively on the atmosphere (4), but with a high dispersion among the individual assessments, since many may have considered the locally usual practice of burning the vegetation for establishing the crop. The consortium with edible bush beans improves soil quality (5), which in turn favors water (6), biodiversity (7) and habitat (8) conservation, even though these last indicators show high level of dispersion (see deviation bars). This is true also for the productive ethics criterion (10).

The productive intensification driven by increased demand has brought important improvement in farmers' capacitation (criterion 11, with Embrapa Cotton and institutional partners extending training courses), some level of betterment in job qualification (12), generation (13), and employment quality (14), and high expectancy for income generation (15) and land valorization (16). All criteria of management and administration performance (21-24) are also improved (Figure 9).

Only three of the eight social actors partaking of the workshop panel converged on their impact assessments, pointing out the not consolidated status of castor bean production still present in the region (Figure 10).

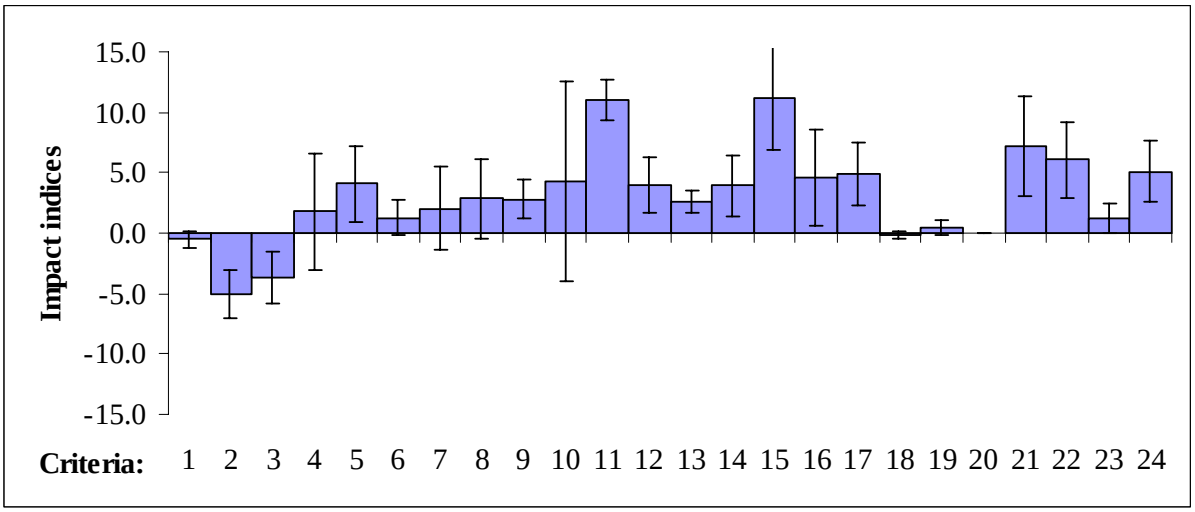

Figure 9. Mean and standard deviations of the Eco-cert.Rural impact indices applied to castor bean for biodiesel production, according with social actors' assessment in São Raimundo Nonato (PI). Assessment criteria (1-24) labels in Figure 1.

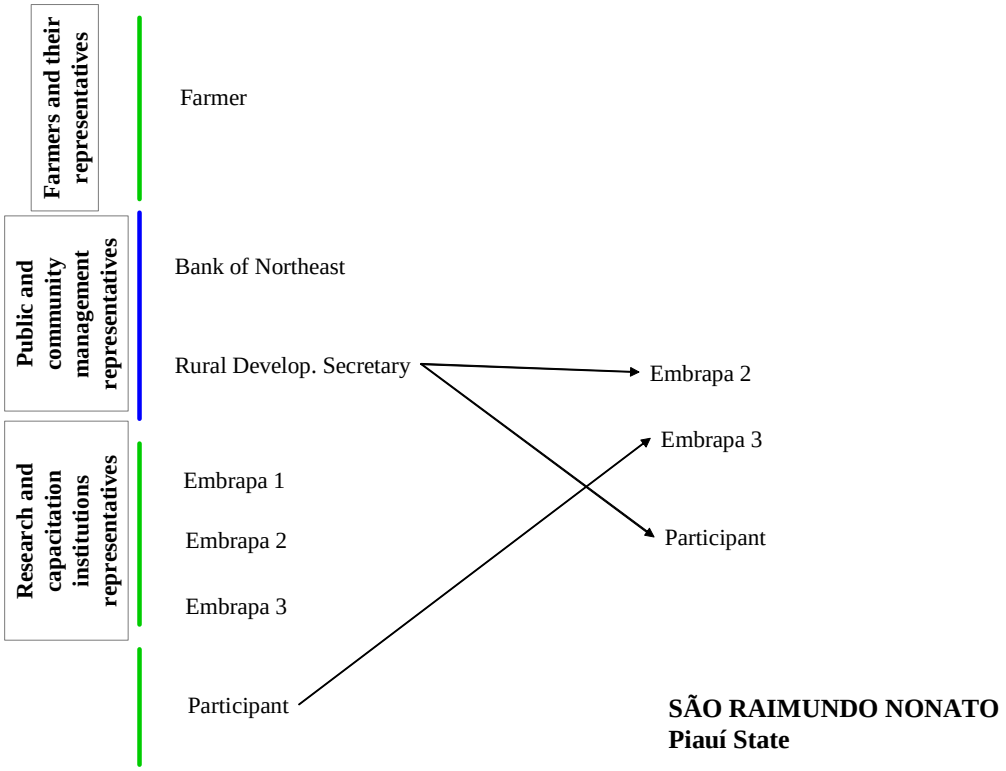

Figure 10. Convergence among social actors, for the set of 24 criteria of the Eco-cert.Rural System, for the assessment of socio-environmental impacts of castor for biodiesel production (correlation >0.75). São Raimundo Nonato (PI).

v. Region of Irecê (BA), castor-oil production in consortium with bush bean: The strong demand expansion being posed onto this comparatively technologically intensive productive region has being associated with important impacts on the use of inputs and resources (criterion 1, Figure 11), even for the eutrophic regional soils. Also, important increase in materials (criterion 2, such as seeds, machinery, and implements), and energy (3) was pointed out. The substitution of fossil fuels by biodiesel in the production chain context implies positive impact on the atmosphere (4), but this result is very dispersed among social actors, since many consider increased demand for (mineral) diesel oil for the field operations.

The productive intensification, even under consortium, is importing high pressures on soil quality (5), with negative effects on water quality (6), biodiversity conservation (7, with expected incorporation of new areas), and habitat reclamation (8). Thus, according with the mean values for the impact indices among social actors, for the criteria of the ecological performance dimension, the increased demand on castor bean for biodiesel production has brought negative consequences in the Irecê region.

On the other hand, regarding the socio-environmental criteria, the productive intensification reflects positively on most indicators, such as farmers' capacitation (11), local job opportunities (12) and job generation (13, given manual harvesting operations), but not in employment quality indicators (14, Figure 11). This result refers, on the one hand, to the precarious type of worker engagement typical for the culture (in management as in harvest), and on the other, to increased exposure to chemical inputs (see criterion 1), which reflects on occupational safety and health impacts (criterion 19). Some improvement in income generation (15) and income diversity (16) is apparent, but with large dispersion among assessments. The competing trend between castor bean and food crops (even when considering cultivation under consortium) appears as divergent results for the food security criteria (20). As observed in all other regions, the criteria regarding management and administration (21-24) show positive trends.

A characteristics of the set of assessments obtained in Irecê is the agreement of results among social actors, be it related with indicator direction (whether positive or negative), or with impact indices amplitude for the criteria. This agreement attests a quite leveled knowledge about the socio-environmental impacts of castor bean production in the region, as shown in Figure 12. It is evident the assessment convergence among farmers and their representatives; between this group of interest and the representatives of the research and capacitation institutions, as well as within this group; and between all those with the agro-industry representatives.

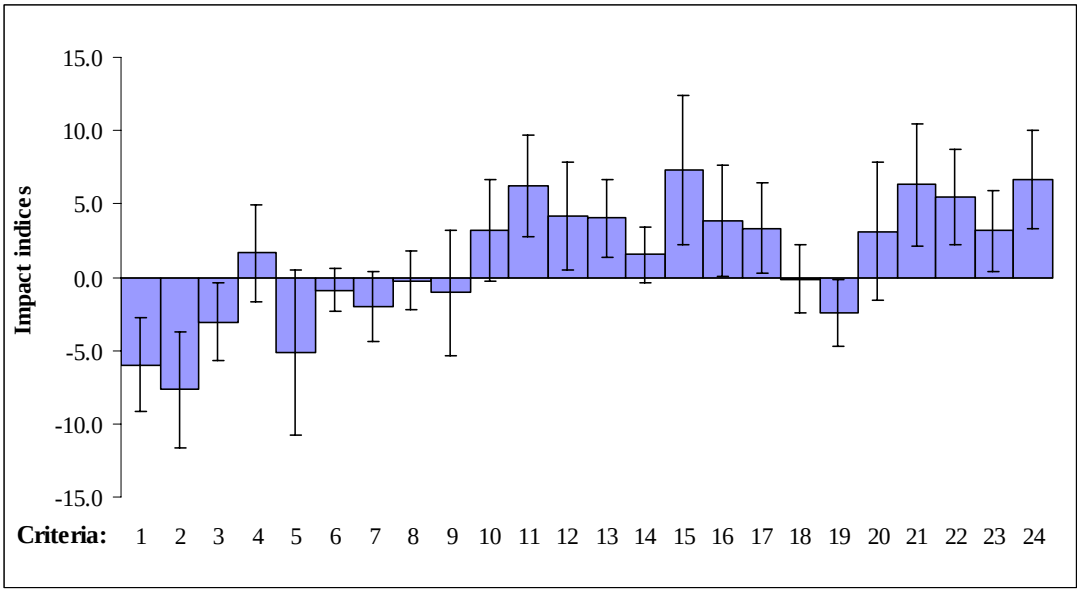

Figure 11. Mean and standard deviations of the Eco-cert.Rural impact indices applied to castor bean for biodiesel production, according with social actors' assessment in Irecê (BA). Assessment criteria (1-24) labels in Figure 1.

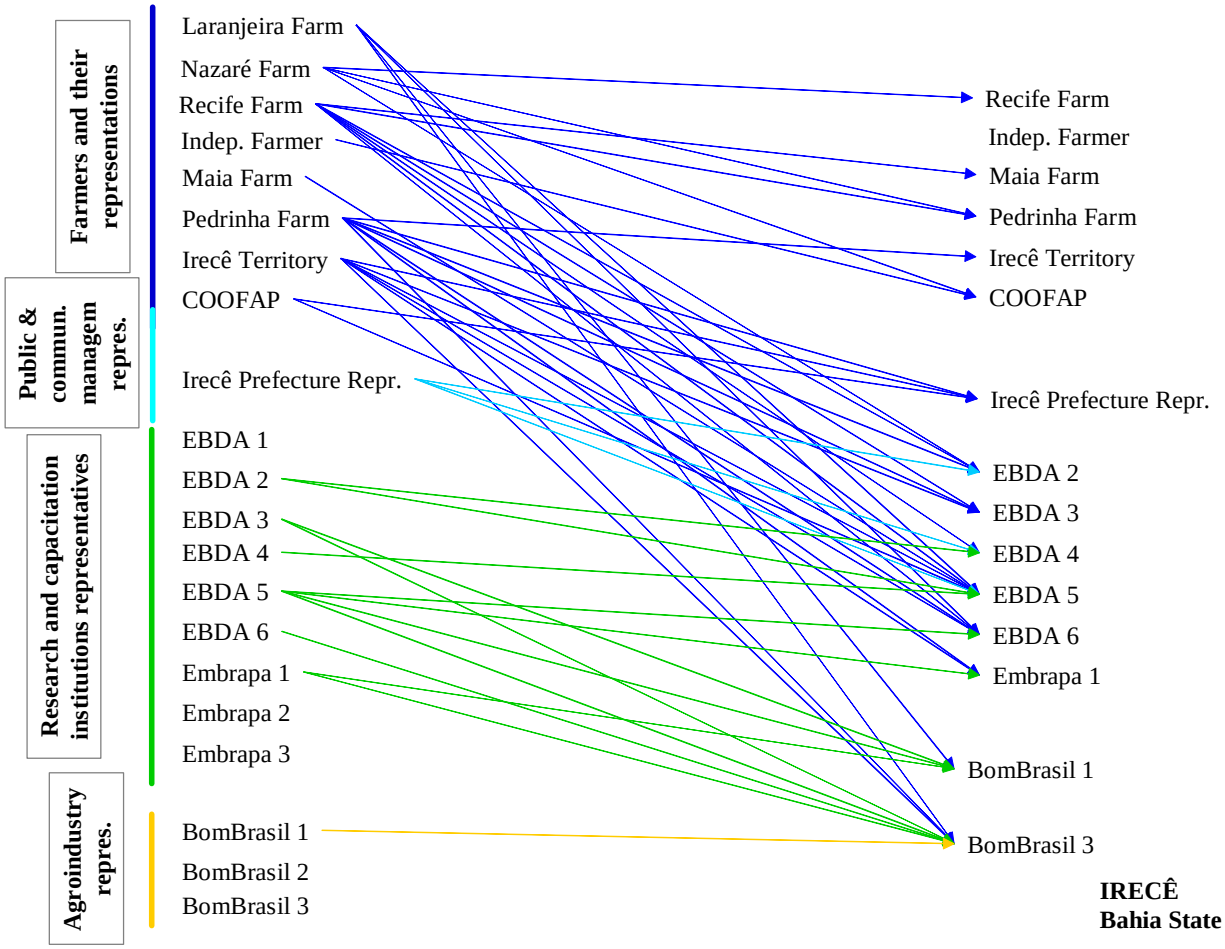

Figure 12. Convergence among social actors, for the set of 24 criteria of the Eco-cert.Rural System, for the assessment of socio-environmental impacts of castor for biodiesel production (correlation >0.75). Irecê (BA).

Integrated regions and crops analysis

When all regions results are integrated, combining all the socio-environmental assessments for oleaginous crops under the context of expanding demand for biodiesel production, a similar trend is evident for the set of 24 criteria, especially when the direction of impacts (whether negative or positive) is concerned (Figure 13). Exceptions comprise only (i) a positive impact on the use of inputs and resources (criterion 1) for rapeseed production in Cássia (due to rotation integration in no-till management system); (ii) some divergence regarding impacts on the atmosphere (criterion 4), due to varying consideration among social actors, contrasting the context of field intensification, against fossil fuel usage substitution by biofuels; (iii) and a negative impact on soil quality (criterion 5) in Irecê, due to the higher level of input application already in place in this technologically more intensive region.

The general trend for all regions and crops obtained in the present study is corroborated in the literature, following the argument that, more than a matter of which crop or environmental setting is concerned, the local productive arrangement defines the tendency of impacts caused by integration of oleaginous crop for biodiesel production (Haverkort et al., 2007). In this sense, the following section brings a sustainability assessment of one particularly promising local productive arrangement, organized with all social groups of interest involved with biodiesel production in the Cássia (MG) region.

Sustainability assessment of a local productive arrangement for rapeseed production in no-tillage system with rotation with corn.

Looking for exemplifying where viability may be laid for the production of biodiesel, this section details the collaborative local arrangement constructed in the Cássia (MG) region, presenting a sustainability assessment at the rural establishment scale, bearing out the favorable results obtained in the socio-environmental impact assessment for the region on the biodiesel production chain scale. The collaborative local arrangement for rapeseed production in no-till rotation with corn in Cássia has been celebrated under the "Sowing Biodiesel"[2] Project, put together in 2005 by the Municipal Prefecture and Soyminas Biodiesel de Óleos Vegetais Ltda.

In order to verify the effective contributions of the 'Sowing Biodiesel' Project in the field, a sustainability assessment of two participating rural establishments was carried out, by the application of the APOIA-NovoRural System (Rodrigues & Campanhola, 2003; Rodrigues & Moreira-Viñas, 2007, refer to the Methods section). The field survey / samplings occurred on 7th and 8th November 2006, with individual environmental management reports being issued to the farmers and presented for critical analysis at the territory's socio-environmental assessment workshop[3].

Both studied establishments reached positive final sustainability indices, with 80 and 88% of the 62 APOIA-NovoRural indicators showing results above the baseline conformity level established in the method, for establishments A and B, respectively (Figure 14). With the exception of a slightly lower than conformity index (0.64) for the Sociocultural values (lower than conformity public services, consumption standards, and employment quality indicators) and Management and administration (0.57 – with lower than conformity farmer dedication and profile, and commercialization conditions) dimensions, the other dimensions showed favorable results in establishment A. These few lower than conformity results were caused by the situation of urban residence of the farmer, and his having an additional, non-rural occupation, that implicated sub-contracting the farm business, with negative effects on the mentioned indicators. Even under this constraint, good sustainability indices were obtained for the Landscape ecology (0,72), Atmosphere (0,82), Soil quality (0,67) , and Economic values, with excellent result for the Water quality (0.87) dimension of sustainability.

For establishment B, a deficiency on the commercialization conditions, resulting from the lack of any local processing, lack of organized storage and transport means, lack of a brand name and product advertisement, and lack of sales cooperation (index = 0.25) caused a slightly lower than conformity index (0.68) for the Management and administration dimension of sustainability. All other dimensions resulted above the baseline conformity level of the APOIA-NovoRural method, with 0.77 for Landscape ecology, 0.82 for Atmosphere, 0.86 for Water quality, 0.71 for Soil quality (with marked improvements in the soil contents of P, K, Mg, and base saturation as a result of the no-till management), and quite favorable 0.81 for Economic values (Figure 14).

[2] "Plantando Biodiesel" in the original Portuguese conception.

[3] Similar rural establishment sustainability assessments were carried out in all regions comprising the present study, as a constituent element of the territorial environmental management methodology. Our presenting only the two mentioned cases in the present paper is due to the particular objective of exemplifying the especially successful local arrangement of the 'Sowing Biodiesel' productive arrangement being developed in Cássia.

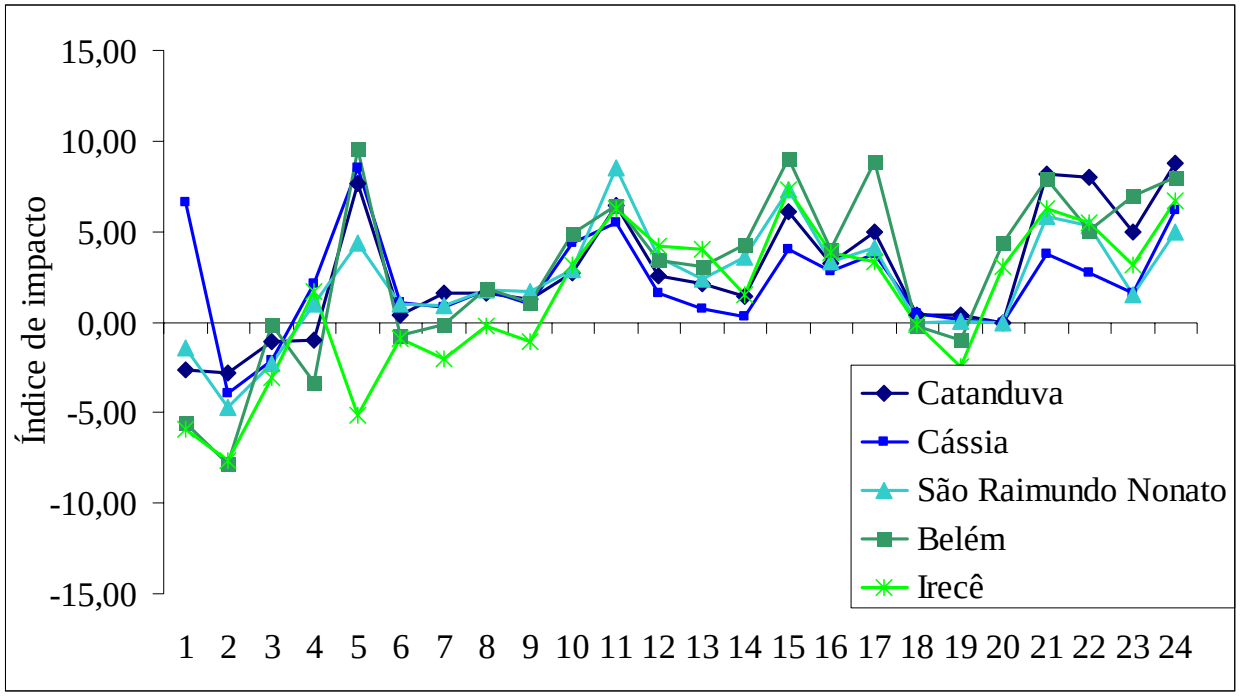

Figure 13. Means of the Eco-cert.Rural socio-environmental impact indices, for oleaginous crops for biodiesel production, according with social actors' assessments in all studied regions. Assessment criteria (1-24) labels in Figure 1.

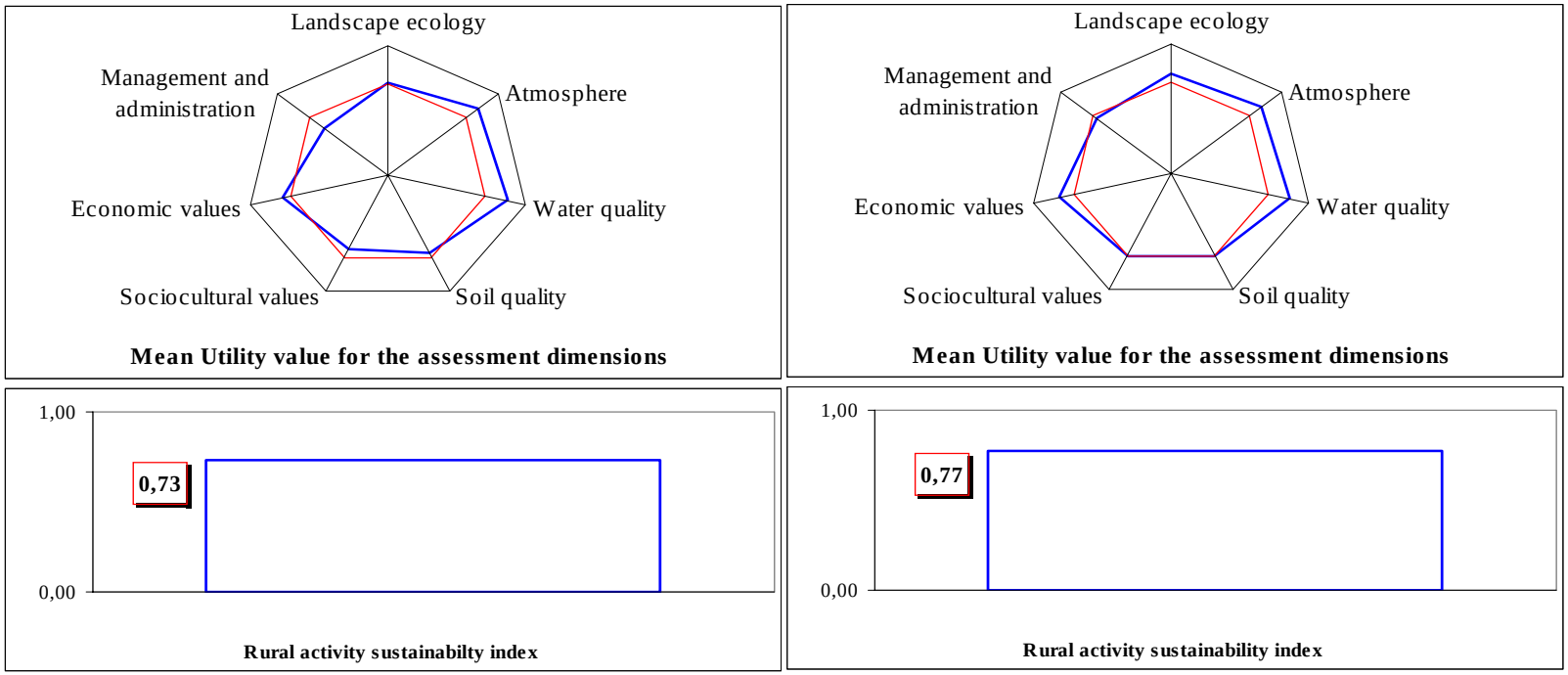

Figure 14. Aggregated dimensions results and final sustainability indices reached by two rural establishments participating in the 'Sowing Biodiesel' Project, dedicated to rapeseed production in no-till rotation with corn in the Cássia (MG, Brazil) region. Results of the APOIA-NovoRural sustainability assessment system, baseline conformity sustainability level defined at 0.70.

These results for both establishments come to strongly corroborate the socio-environmental assessments carried out with the social actors, regarding the regional scale and the biodiesel production chain context. The local productive arrangement constructed under the 'Sowing Biodiesel' Project has been providing, on the one hand, improvements at the field level, contributing to the 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 biodiesel production chain, from the farmers to the agro-industries, the Project can strengthen the relationship of the different social groups of interest, fostering the territorial development.

Discussion

Concerning the ecological performance dimension of impacts, the general context of expanding demand on oleaginous crops for biodiesel production, expressed by the mean impact indices obtained in the assessments, denoted expectation for productive intensification, implicating increase in the use of inputs and natural resources (with associated risks on water quality), raw-materials, and energy. A high level of controversy occurred regarding impacts on the atmosphere in all studied regions and crops. On the one hand, negative impacts are expected from greenhouse gases emission at the rural establishment level, due to increased machinery operation; and on the other hand, positive impacts are associated with the substitution of fossil fuels, considering the biodiesel production and use chain.

According with the assessments, an important trend toward soil quality improvement is expected with the implementation of all oleaginous crops, associated with the proposed integrated / rotational management practices, potentially fostering environmental reclamation of degraded areas and biodiversity conservation. It should be emphasized, however, that both the incorporation of new areas (marginal or not) and the recovery of degraded areas by oleaginous crops should be conditioned by acceptable productivity, warranted by technological improvement. Special attention is to be paid on the demand for inputs, both industrial and natural, required for acceptable productivity, as well as on the ensuing risks posed for soil, water, and habitats degradation (Giller et al, 2007).

Regarding the socio-environmental dimension of impacts, the productive intensification reflected favorably on the expectation of farmer capacitation, income generation, land value improvement, and betterment on the opportunities, qualification, and quality indicators of employment. The same intensification and demand on input use raised concerns about the personal and occupational safety and health for workers. Especially beneficial results were related with the management and administration indicators, such as farmer profile and dedication, commercialization conditions, and institutional relationship, for rural establishments and production chains alike.

Considering *Jatropha* production for biodiesel, the income generation and income sources diversification expected is due, mostly, t its proposition as a secondary crop, to be planted as field borders and hedges, not to compete with food crops (Openshaw, 2000). Such condition has been established, for example, in India, under incentive of governmental programs, to promote small farmer inclusion (Subramanian et al., 2005). Careful consideration, however, must be exercised on this proposition, for marginal lands show productive potentials as low as 0.5 ton. ha^{-1} yr^{-1} (Giller et al., 2007), so requiring larger areas, then offsetting the aforementioned advantages. One other important restriction for large scale adoption of *Jatropha* is the paucity of adequate agricultural data on this plant. Scientific, field validated information is needed from genetic variability to cultivar quality and stability, from nutrient requirements to pest control, from plant field stand to pruning, making it currently risky for farmers to invest on the crop (Beltrão et al., 2007).

Regarding production of rapeseed, the positive socio-environmental impacts are 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), favoring deep recovery of soil nutrients (especially N and P); (iii) good acceptability as forage and fodder for ruminants, and early and abundant flowering, excellent for bee feeding; and tolerance to most pests and diseases (Pereira, 1998; BiodieselBR, 2007).

All favorable conditions contributed by the palm oil crop expressed by the social actors are also fully corroborated in the literature (Monteiro et al., 2006). Finally, the high value of castor-oil for the fine chemistry industry, and the relatively low level of technology still present in Brazilian producing areas are important constraints to be circumvented to make the crop really viable for biodiesel production (Severino, 2006).

In conclusion, especially designed local productive arrangements offer the best options for fostering sustainable development and avoiding environmental degradation risks, under the scenario of expanding demand on oleaginous crops for biodiesel production in Brazil.

Acknowledgements

We thank the institutional support of FAPESP, Embrapa (Units Environment, Center-North, Cotton, Occidental Amazon and Oriental Amazon) and Codevasf/BA. The contributions of Soyminas, Fertibom, Dentauá, and the Municipalities of Cássia (and CEARCA) and Catanduva 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

Abramo, V. (2007) BR antecipará para julho adição de 2% ao óleo diesel que comercializa. *Revista Brasileira de Tecnologia e Negócios de Petróleo, Gás, Petroquímica, Química Fina e Indústria do Plástico*. Retrieved from the Web 09/05/07 http://www.tnpetróleo.com.br/.

ANP, Agência Nacional do Petróleo, Gás Natural e Biocombustíveis. Rede de Notícias, Superintendência de Planejamento e Pesquisa. Retrieved from the Web 10/05/07. http://www.anp.gov.br/.

Beltrão, N. E. M. de, Severino, L. S., Suinaga, F. A., Veloso, J. F., Junqueira, N., Fidelis, M., Gonçalves, N. P., Saturnino, H. M., Roscoe, R., Gazzoni, D., Duarte, J. de O., Drumont, M. A. & Anjos, J. B. dos. (2007). Recomendação técnica sobre o plantio de pinhão manso no Brasil. Embrapa Algodão, Retrieved from the Web 08/05/07 http://www.cnpa.embrapa.br/publicações/2007/folder.

Bindraban, P.& Conijn, S. (2007). Land, water and nutrient requirements for sustainable biomass production. In: Haverkort A., Bindraban, P. & Bos H. (Eds). *Food, Fuel or Forest: Opportunities, Threats and Knowledge Gaps of Feedstock Production for Bio-energy*. *Plant Research International*. *142*, 31-35.

BiodieselBR, Retrieved from the Web 03/04/07. http://www.BiodieselBR.com.

BiodieselBR, Retrieved from the Web 08/05/2007. http://www.BiodieselBR.com.

Bournay, L., Casanave, D., Delfort, B., Hillion, G., Chodorge, J. A. (2005).New heterogeneous process for biodiesel production: A way to improve the quality and the value of the crude glycerin produced by biodiesel plants. *Catalysis Today, 106,* 190-192.

ESALQ/USP. Pólo Nacional de Biocombustíveis. Retrieved from the Web 05/08/2006 http://www.polobio.esalq.usp.br/biocombustíveis.html.

Giller, K., Vem, G. van der & Ittersum M. van. (2007) Competing Claims on Natural Resources: Food, Fuel, Fibre or Forest. In: Haverkort A., Bindraban, P. & Bos H. (Eds). *Food, Fuel or Forest: Opportunities, Threats and Knowledge Gaps of Feedstock Production for Bio-energy*. *Plant Research International*. *142*, 37-42.

Hamelinck, C. N. & Faaij, A. P. C. (2005). Outlook for advanced biofuels. *Energy Policy*, 1-16.

Haverkort, A., Bindraban, P. & Bos H. (Eds). (2007). Food, Fuel or Forest: Opportunities, Threats and Knowledge Gaps of Feedstock Production for Bio-energy. *Plant Research International*. *142*, 60 p. Proceedings of the Seminar.

Lima Filho, G. (2006). Alternativa que vem do campo. *Revista Brasileira de Tecnologia e Negócios de Petróleo, Petroquímica Fina, Gás e Indústria do Plástico*. 18-30.

McLaren, J. S. (2005). Crop biotechnology provides an opportunity to develop a sustainable future. *Trends in Biotechnology, 23 (7),* 339-342.

MDA – Ministério do Desenvolvimento Agrário. *Seminário sobre biocombustíveis reúne países sul-americanos.* Retrieved from the Web 07/08/06 http://www.mda.gov.br/.

Monteiro, R.C. & Rodrigues, G.S. (2006). A system of integrated indicators for socio-environmental assessment and eco-certification in agriculture – Ambitec-Agro. *Journal of Technology Management and Innovation. 1 (3),* 47-59.

Monteiro, K. F. G., Silva, A. R. F. da & Conceição, E. R. da. (2006). Inserção da agricultura familiar na cadeia do biodiesel no Estado do Pará: possibilidades de emprego e renda com o cultivo do dendê. In: Monteiro, D. M. C. & Monteiro, M. A. (Org.). *Desafios na Amazônia: uma nova assistência técnica e extensão rural*. UFPA: Belém. 233-246.

Openshaw, K. (2000). A review of *Jatropha curcas*: an oil plant of unfulfilled promise. *Biomass & Energy. 19,* 1-15.

Pereira, J. O. F. (1998). Nabo Forrageiro – AL1000 Adubação Verde para o Inverno. *CATI Responde*. Retrieved from the Web 08/05/07 http://www.cati.sp.gov.br/novacati/tecnologias/catiresponde/cr25naboforr.html.

Peres, J. R. R., Freitas J. R. E. & Gazzoni, D. L. (2005). Biocombustíveis: uma oportunidade para o agronegócio brasileiro. *Revista de Política Agrícola. 14 (5),* 31-42.

Pimentel, D., Rodrigues, G., Wang, T., Abrams, R., Goldberg, K., Staecker, H., Ma, E., Brueckner, L., Trovato, L., Chow, C., Govindarajulu, U. & Boerke, S. (1994). Renewable energy: Economic and environmental issues. *BioScience. 44,* 536-547.

Prates, C. P. T., Pierobon, E. C. & Costa, R. C. da. (2007). Formação do Mercado de Biodiesel no Brasil. *BNDES Setorial*, Rio de Janeiro. *25,* 39-64.

Rodrigues, G. S. (1998). *Avaliação de Impactos Ambientais em Projetos de Pesquisas - Fundamentos, Princípios e Introdução à Metodologia.* Jaguariúna (SP): Embrapa Meio Ambiente, Documentos 14. 66 p.

Rodrigues, G. S. & Campanhola, C. (2003). Sistema integrado de avaliação de impacto ambiental aplicado a atividades do novo rural. *Pesquisa Agropecuária Brasileira*. *38(4),* 445-451.

Rodrigues, G.S., Campanhola, C., Rodrigues, I.A. & Frighetto, R. T. S. (2006a). Gestão ambiental de atividades rurais: estudo de caso em agroturismo e agricultura orgânica. *Agricultura em São Paulo*. *53 (1),* 17-31.

Rodrigues, G. S., Buschinelli, C. C. de A., Rodrigues, I. A., Monteiro, R. C. & Viglizzo, E. (2006b). *Sistema base para eco-certificação de atividades rurais.* Jaguariúna: Boletim de Pesquisa e Desenvolvimento-Embrapa Meio Ambiente, *37,* 1-40.

Rodrigues, G. S. & Moreira-Viñas, A. (2007). An environmental impact assessment system for responsible rural production in Uruguay. *Journal of Technology Management and Innovation. 2(1),* 42-54.

Severino, L. S. (2006). Como a Índia tornou-se líder mundial na produção de mamona. BiodieselBR 267. Retrieved from the Web 06/12/06 http://www.biodieselBR.com.

Subramnian, K. A., Singal, S.K., Saxena, M. & Singal, S. (2005). Utilization of liquid biofuels in automotive diesel engines: Na Indian perspective. *Biomass & Energy***.** *29,* 65-72.