Evaluating social and environmental impacts at Embrapa

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Abstract

A strategic planning process has been implemented at the Brazilian Agricultural Research Agency (Embrapa) to introduce sustainable development objectives in all steps of agricultural Research and Development. An essential component of the institutional mission statement hence devised has called for the systematic assessment of social and environmental impacts (in addition to the traditionally studied economic ones) of all technology innovations resulting from R&D. The proposed approach emphasizes the interest of promoting close interaction between R&D teams and technology-adopting producers, under actual field contexts, in order to improve both the technology development and the demand probing processes. Given the multiplicity of technological applications ensuing from Embrapa's very broad research encompassment, and the variety of environmental and productive contexts involved, a customized impact assessment system has been proposed. Directed at the appraisal of agricultural technology development research projects (*ex-ante*) as well as their ensuing innovations (*ex-post*), the Ambitec-Agro System comprises a set of integrated socio-environmental indicators, constructed in modules suited to Agricultural, Animal husbandry, and Agro-industrial activities, besides a specific module for Social Impact Assessment. The system has been routinely applied in technology appraisal in all of Embrapa's Units, as a basis for their institutional performance evaluations, and toward the formulation of the annual Social Balance Report. Following the inception of this institutional technology appraisal initiative, several methodological innovations have

been proposed within Embrapa, including technical improvements and applicability adaptations of the Ambitec-Agro system, and approaches to further-reaching objectives, such as the sustainable development of rural communities, and the environmental management of agricultural activities.

1. Introduction

Current policies aimed at the science and technology sector have been increasingly oriented toward the organization of innovation systems, be these market-driven or directed at human interests in economic, social, and environmental developments. In order to instruct these policies and favor their efficacy, research organizations seek strategies to plan their resources allocation, the management of their capacities, and the transfer of their results. Technology appraisal and impact assessment methodologies comprise the toolkit required for consolidation of S&T innovation systems, as tools for orienting innovation demand probing, research priorities setting, research formulation and activities management (Bin et al., 2003).

Attentive to these planning tendencies, the National Institutes of Agricultural Research (NIARs) in the Southern Cone of South America have been committed to the design and systematic application of impact assessment tools to agricultural technology innovation, as attested by scientific meetings held (Puignau, 1998) and cooperative research developed on the subject (Rodrigues et al., 1998). The accorded approach has been to promote the Environmental (and Social) Impact Assessment with the declared objective of "promoting solutions for the sustainable development of rural spaces by generating, adapting and transferring knowledge and technology for the benefit of society" (Embrapa, 2004).

Additionally, in order to orient the assessment relative to specific local socio-environmental and productive contexts, the social actors must exert active role in the assessment process, thus facilitating the recovery and documentation of hands-on knowledge and expertise of farmers and other users of the innovations. Aiming at motivating farmers to wittingly promote technology conversion and adoption of sustainable management practices, as well as facilitating technology development project appraisal at the institutional R&D level, an integrated, expedite, reasonably inexpensive system/procedure for impact assessment of agricultural technological innovations was sought.

Among the methodological alternatives for socio-environmental impact assessment, the use of ecological and social indicators of sustainability has been a method of choice (Girardin et al., 1999). Ideally, the indicators are organized in Impact Assessment Systems that may span increasing levels of complexity and goal requirements for environmental management (Rodrigues, 1998; Payraudeau et al., 2004), being based on objective indicators constructed on a flexible platform, acceptable for application on the large diversity of rural activities, environmental situations, and their combinations.

A proposed solution is the "System for Environmental Impact Assessment of Agricultural Technology Innovations" (Ambitec-Agro) for the institutional context of R&D (Rodrigues et al., 2003). This system has been installed as a corporate impact assessment platform employed yearly by all Embrapa Research Centers to evaluate their technological contributions (Avila et al., 2005), besides being widely applied to support research project appraisals and technology innovation impact assessments (Irias, 2004a; Lanna et al., 2004; Rodrigues et al., 2006b; Almeida et al., 2007; Jacometi et al., 2008). Also, the impact assessment results obtained in this institutional assessment platform are instrumental for composing Embrapa's yearly Social Balance Report [1].

Following the inception of this institutional R&D and technology innovation impact assessment procedure, numerous methodological advancements and alternative approaches have been proposed, not only as developments for improving and extending the applicability of Ambitec-Agro (Figueirêdo et al., 2007), but also as genuine methodological innovations. These developments reach beyond the impact assessment of technology innovations (Jesus-Hitzschky et al., 2006; Jesus-Hitzschky, 2007), furthering the assessment of sustainability of agricultural productive systems (Ferreira, 2007), the environmental management of agricultural productive activities (Rodrigues et al., 2006a) and the organization of terms of reference for the environmental settings of productive sectors (Rodrigues et al., 2008).

The present paper details the development of methodological innovations in environmental and social impact assessment systems at Embrapa, presenting a review on the applicability of these studies for research and technology management in the institution, and a referential summary of new approaches stemming from the strategic

[1] Embrapa's yearly Social Balance Reports are available at: http://bs.sede.embrapa.br/2007/.

initiative of extending technology appraisals and impact assessments as a routine procedure of the institutional R&D process.

2. A System for Environmental Impact Assessment of Agricultural Technology Innovations – Ambitec-Agro[2]

The aim of the Ambitec-Agro System is to provide a practical, expedite, reliable, and reproducible socio-environmental impact assessment platform for a wide range of agricultural technologies and rural activities. The system's hierarchical structure rely on a series of *Principles* of technology and rural activity performance, composed by *Criteria* of social and environmental sustainability, constructed by selected *Indicators* (Table 1), which were validated by prior experience and field trials (Irias et al., 2004a; Lanna et al., 2004; Rodrigues et al., 2006b). The indicators are scored in field surveys / interviews with farmers / administrators who express a *change coefficient* for each indicator, according to their 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* (Rodrigues et al., 2003). Finally, Impact indexes are calculated for each indicator, criterion and technology innovation studied.

[2] The files containing the Ambitec-Agro System (and its modules) are available for download via internet access through the Embrapa Environment homepage at http://www.cnpma.embrapa.br/forms/ambitec.html.

Table 1. Integrated Principles, Criteria and Indicators included in the several modules of the system for Impact Assessment of Agricultural Technological Innovations (Ambitec-Agro). Source: Monteiro and Rodrigues, 2006.

Ecological performance principle		**Socio-environmental performance principle**				
Use of Inputs and Resources Criterion and Indicators:	**Environmental quality criterion and indicators:**	**Customer Respect Criterion and Indicators:**	**Employment Criterion and Indicators:**	**Income Criterion and Indicators:**	**Health Criterion and Indicators:**	**Management & Administration Criterion and Indicators:**
1. Use of Agricultural Inputs and Resources 1.1. Use of Agrochemicals - Pesticides - Fertilizers - Soil amendments 1.2. Use of Natural Resources-Consumptive use of water-Water for processing- Land area	4. Atmosphere - Greenhouse Gases - Particulate material / Smoke - Foul smells - Noise	9. Product Quality - Chemical residues reduction - Biological contaminants reduction - Inputs suppliers availability - Input suppliers reliability	11. Training 11.1. Training Type - Local short course - Specialization short course - Regular education 11.2. Training Level - Basic - Technical - Superior	15. Net Income generation - Security - Stability - Distribution - Amount	18. Personal and Environmental Health - Endemic diseases sources - Atmospheric pollutant emissions - Water pollutant emissions - Soil contaminants generation - Restriction to sport and leisure practices	21. Farmer Capability and Dedication - Specialized training - Dedicated working time - Family engagement - Use of accountancy system - Formal planning - Certification / Labeling
2. Use of Veterinarian Inputs and Raw Materials 2.1. Use of Inputs- Veterinarian products- Hay / Fodder	5. Soil Quality - Erosion - Organic matter - Nutrient leaching - Compaction	10. Production Ethics 10.1. Animal Welfare & Health - Animal welfare - Access to water sources and forage supplementation - Sanitation and health conditions - Livestock density - Ethical handling, transportation and slaughtering	12. Opportunity and Qualification for Local Employment 12.1. Worker Origin - Farm - Local - Municipality - Region	16. Income Sources Diversity - Agriculture and livestock - Other rural activities - External jobs - Business branching - Financial investments	19. Occupational Safety & Health - Risk exposure - Noise - Vibration - Heat / Cold - Moisture - Chemical agents - Biological agents	22. Trade Arrangements - Direct / anticipated / cooperated sales - Local processing - Local storage - Transportation - Advertising / Trademark - Linkage to other product / service / activity - Cooperation with others local farmers
2.2. Use of Raw Materials - Basic raw materials - Raw materials for processing - Agroindustrial additives Feed / Supplements	6. Water Quality - Biological Oxygen Demand - Turbidity - Floating materials / Oil / Scum - Siltation		12.2. Worker Qualification - Untrained - Trained - Specialized - Technical	17. Land Value - Facilities improvement investments - Natural resources conservation - Products / services prices - Compliance to legal aspects - Public services / Tax policies etc.	20. Food Safety & Security - Production guarantee - Food quantity - Food nutritional quality	23. Waste Disposal 23.1. Domestic Residues Disposal - Selective collection - Composting / Reusables - Sanitary waste disposal 23.2. Production Residues Disposal - Reusables / Recyclables - Adequate waste disposal / Final treatment

3. Use of Energy - Fossil fuels - Biofuels - Biomass - Electricity	7. Biodiversity - Natural vegetation loss - Fauna corridors loss - Species / Varieties losses	10.2. Social Capital - Attention to local social needs - Rural technical assistance projects	13. Job Generation and Engagement - Temporary - Permanent - Partner - Family		24. Institutional Relationship 24.1. Organizational Influence and Reach - Technical assistance - Association / Cooperation - Nominal technological affiliation - Legal consultation / Inspection 24.2. Training - Manager training - Specialists training
	8. Environmental Restoration - Degraded soils - Degraded ecosystems - Legally-defined Preservation Areas - Mandatory Protection Areas		14. Employment Quality 14.1. Work Legislation - Underage work prevention - Workweek < 44 hs. - Formal contract - Social Security 14.2. Fringe Benefits - Housing assistance - Food assistance - Transportation assistance - Health care assistance		

2.1. Ambitec-Agro: Principles, Criteria and Indicators scaling checklists

The Ambitec-Agro System consists of a platform of integrated indicator scaling checklists, combined meaningfully to compose assessment modules according to the productive sector (agriculture, animal husbandry, agro-industry) and assessment dimension (environmental or social). Change coefficients checked in the field surveys / interviews are related to quantitative variables of area, weight, or proportions, then standardized as varying from –3 (meaning a major decrease in the indicator) to +3 (meaning a major increase in the indicator), reflecting the effects of the studied technology or rural activity, contingent to each particular assessment.

The indicators are then weighed according to their defined *relevance* to conform the assessment criterion and their *scale of occurrence*. Once the change coefficients resulting from the field survey / interview are introduced in the scaling checklists, the impact index for each indicator is calculated, according to the given scale of occurrence and relevance value, and then combined to compose the impact index for the criterion (Figure 1).

Table of change coefficients for variable						
Water Quality		**Water quality variable**				weighing factor check
		Biochemical Oxygen Demand	Turbidity	Floating materials / Oil / Scum	Siltation	
Weighing factors k		-0,25	-0,25	-0,25	-0,25	**-1**
Scale of occurence = No-effect	Mark with X					
Near	1				-1	
Proximate	2	-1	-3			
Surrounding	5			-3		
Impact Coefficient = (change coefficients * weighing factors)		**0,5**	**1,5**	**3,75**	**0,25**	**6,0**

Figure 1. Typical scaling checklist of the Ambitec-Agro system. The given example represents the field observation of a moderate reduction in BOD at the proximate environment scale, a major decrease in turbidity also at the proximate environment, a major reduction in the presence of floating materials / oil / scum in the surrounding environment; and a moderate reduction in siltation at the near environment scale.

The *weighing factors* related to the *relevance* of each indicator (k in Figure 1) are defined on an *ad hoc* basis according to user criteria in order to better reflect specific situations and add up to ±1 (according to the indicator impact direction, either positive or negative). Hence, the relevance weighing factors consist of a normalization step to equalize the different number of indicators that make up each assessment criterion. The factors for *scale of occurrence* are related to the geographic scale in which the indicator change coefficient occurs in any studied case, as follows:

i. *near environment* when the innovation / rural activity effect on the indicator is restricted to the crop area, productive field or facility where the studied activity is being conducted / innovation is being adopted;

ii. *proximate environment* when the innovation / rural activity effect on the indicator extends beyond the productive unit, but within the limits of the property or farmstead;

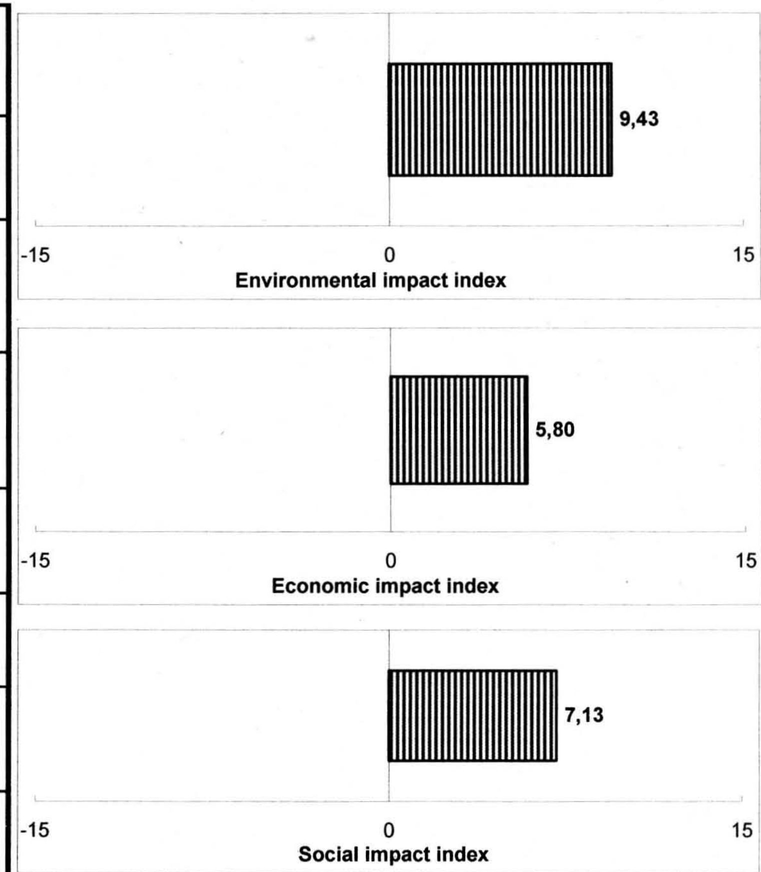
iii. *surrounding environment* when the innovation / rural activity affects the indicator in an area or environment beyond the limits of the property or farmstead.

Once the indicators change coefficients are inserted into all scaling checklists, a *Technological Innovation Impact Index* is calculated for the specific conditions studied, by averaging all the normalized impact coefficients for the criteria considered (Figure 2). As included in each scaling checklist for the numerous indicators, this normalization procedure allows new adjustment of relevance values, this time for the different criteria considered in the impact assessment system. With this definition of relevance weights for indicators and criteria, assessments may be better adapted to specific evaluation contexts, by emphasizing local relevant aspects or evaluation objectives, or even by excluding certain aspects that may not appropriately represent meaningful consideration for particular cases.

Technological Innovation Performance Indicators	Importance weighing factor	Indicator impact coefficient
Use of Agricultural Inputs and Resources	0,05	8,0
Use of Veterinarian Inputs and Raw Materials	0,05	5,0
Use of Energy	0,05	13,0
Atmosphere	0,02	5,0
Soil Quality	0,05	10,0
Water Quality	0,05	6,0
Biodiversity	0,05	15,0
Environmental Restoration	0,05	15,0
Product Quality	0,05	7,5
Production Ethics	0,05	7,0
Training	0,05	8,5
Opportunity and Qualification for Local Empoyment	0,02	2,7
Job Generation and Engagement	0,05	3,2
Employment Quality	0,05	7,0
Net Income Generation	0,05	7,5
Income Sources Diversity	0,025	7,5
Land Value	0,025	3,8
Personal and Environmental Health	0,02	7,0
Occupational Safety & Health	0,02	3,3
Food Safety & Security	0,05	3,5
Farmer Capability and Dedication	0,05	5,5
Trade Arrangements	0,05	6,8
Waste Disposal	0,05	13,0
Institutional Relationship	0,02	13,0

Weighing factor check	1	Technological Innovation Impact Index	7,97

Integrated indices	
Use of inputs	8,67
Environmental quality	10,20
Customer respect	7,25
Employment	5,35
Income	6,25
Health	4,58
Management	9,56



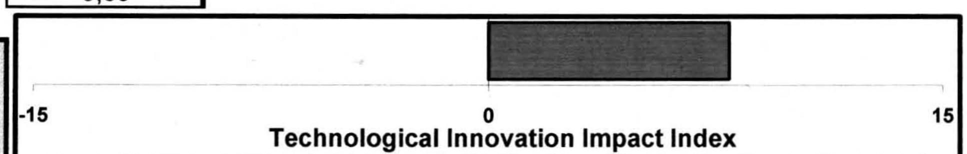


Figure 2. Final environmental impact assessment display of the Ambitec-Agro system.

2.2. Ambitec-Agro Assessment Modules

The Ambitec-Agro System is composed by four modules, designed to application focused on the productive sectors of Agriculture, Animal husbandry, and Agro-industry environmental impact assessment (Irias et al., 2004a) and a specific module for Social impact assessment (Rodrigues et al., 2005), encompassing, when integrated, 24 criteria and 125 indicators (Table 1). The evaluation process is developed in three steps: 1. data surveying about the technology use magnitude, geographical area delimitation and users; 2. field survey / interview applied to the establishment manager and system filling out; and 3. indices analysis, interpretation, and proposal of alternative management practices and technology adoption, focused on minimizing the negative impacts and stimulating the positive ones, contributing to the local sustainable development.

3. Ambitec-Agro Applications and contributions for technology management

The Ambitec-Agro System is currently applied at Embrapa's institutional context for performing the socio-environmental impact assessment of technology innovations made annually available through the National Agricultural R&D Program (Avila et al., 2005). After integration with the economical return rate estimates for all technological innovations studied, the generated technology appraisal reports constitute the basis for constructing the institutional Annual Social Balance Reports. These technology evaluations contribute as a feedback for society about the governmental investments in agricultural R&D, as well as provide a tool for researchers to program new research initiatives and to assess the relevance of their research contributions (Irias et al., 2004b).

For instance, the Social Balance Report 2005 includes over 30 new technological innovations transferred by Embrapa's Research Centers, which span a broad application spectrum, from forestry management software to alternative production systems for selected crops, pastures and their integration systems; from integrated pest management to new seed varieties and animal breeds; and from agro-industrial processing to technology for water treatment and sanitation in rural establishments (Embrapa, 2006). In general, technological innovations associated with the proposition of production systems' intensification show lower amplitudes or negative environmental impact indices, whereas technological innovations linked to managerial improvements, such as integrated production systems and resource conservation technologies, reach larger positive impact indices.

On the other hand, when the social impacts are concerned, the very technological intensification innovations usually related with negative environmental impacts often effect highly positive social improvements, be these due to employment generation and quality of workers recruitment, or to product quality ameliorations, or to income increases that reflect positively in quality of life for farmers and rural communities.

The usage of Ambitec-Agro in the impact assessment of technology innovations throughout Embrapa's Research Centers, favored by the institutional platform of the System for Units Evaluation (SAU), is generating a valuable database of technology appraisals, not only as internal documents and project mid-term reports, but also as specialized publications (e.g., Lanna et al., 2004; Ferreira et al., 2005; Tupy et al., 2006a,b,c,d,e,f,g; Vinholis et al., 2006; Canto et al., 2007; Galharte, 2007; Holanda Filho, 2007; Miele et al., 2008).

The scope, applicability and encompassment of the Ambitec-Agro system has been critically analyzed in a comparative review of several available impact assessment methods (Payraudeau et al., 2005). The analysis pointed out the need for the methods to be transparent in order to facilitate farmer participation, simple to allow uncomplicated field application, and sufficient in number and scope of indicators to avoid gaps in the assessments. All these features may be regarded as adequately met by Ambitec-Agro. In addition to the critical analysis of the methodological approach, a recent independent study on the practice of impact assessment at Embrapa and its role in modifying the praxis of innovation has been carried out. The study pointed out both "*perfectioning* and funneling tendencies [caused by the impact assessment platform and proposed methodology], under which creativity, aptitude and normativeness must coexist... with room for pondering about the many impacts of this institutional culture on the quotidian of technical innovation" (Andrade, 2008).

4. Beyond technology appraisal - methodological innovations for agricultural impact assessments and environmental management

Several methodological developments have been ensuing from the adoption of impact assessments as an institutional practice at Embrapa. One immediate objective has been to improve the scope the current assessments, for instance by including life cycle analysis (LCA) and environmental vulnerability considerations in multi-criteria impact assessment of technology innovations (Figueirêdo et al., 2007). The *Ambitec-Life Cycle* model proposed includes four life cycle phases to evaluate the environmental performance of an agro-industrial innovation: raw material production, innovation production, innovation use and residues final disposal. Also, a set of indicators is applied to evaluate the vulnerability of the watersheds where each phase of the innovation life cycle takes place. This proposed framework provides the decision maker a broadened view of an innovation environmental performance, shedding light on technological improvements needed to benefit its entire life cycle (Figueirêdo et al., 2008).

Another amendment on the applicability of the Ambitec-Agro methodology has been directed at the evaluation of ecosystems functions, in a proposal to support the 'Proambiente Program'. The Eco-cert.Proambiente environmental services assessment method is a tool to check for environmental services and promote their improvement, resulting in a 'conversion factor' applicable to the definition of compensations to small farmers for environmental services rendered by their conservative agricultural management practices (Medeiros et al, 2007).

Especial attention has been devoted also to alternative methods, appropriate for innovative agricultural technological sectors, such as those related to advanced biology and nanotechnology. For instance, given the specific research requirements and the need for licensing field experiments with genetically modified organisms (Rodrigues et al., 2005), a dedicated risk assessment methodology has been proposed. The 'Risk Assessment Method for Genetically Modified Plants' and associated software (GMP-RAM, Jesus-Hitzschky, 2006) rely on the involvement of experts for the composition of the 'Index of Risk' (based on aspects of damage, exposure, and precedent) and the 'Index of Significance' (extent and reversibility) related with the release of a genetically modified organism in the field. Regulators are called upon in order to ascertain the chosen parameters as best to define potential impacts as well as quantifiable variables, warranting that subjectivity can be decreased in the proposed analyses.

One additional alternative method for technology innovations impact assessment, originally conceived as a general tool and currently addressed for nanotechnology assessment, is the INOVA-tec System, also accompanied by dedicated software (Jesus-Hitzschky, 2007). This proposition includes indicators related to the economical, environmental, social, ethical and institutional capacity-building aspects of technology development and adoption, according to innovation policies and demands. Relying also on sets of scoring procedures performed by experts and stakeholders of technology development and adoption, this method compiles the analyses in 'significance' and 'magnitude' indices, then expressed as general recommendations for technology management.

Extending the scope of these approaches on technology innovations, a cooperative project dedicated to the assessment of technology development programs proposed an integrated 'Economic, Social, Environmental and Capacity-building' (ESAC) methodology and assessment software (Bin et al., 2003; Paulino et al., 2003). The model includes tools for constructing appropriate 'impact structures' (related indicators), each assessed in field surveys and consultations and obtained scorings, and an 'attribution coefficient', explicative of the measure in which the indicators are impacted in the given case studies. The methodology has been employed at higher institutional levels, for the assessment of Programs in State agencies of foment for technology research.

Interesting developments in impact assessment methods can also be mentioned as regarding the sustainability of agricultural production systems, bringing a social interest beyond that of the impact of agricultural research, while still spanning from the institutional learning process so far dealt with in the present text. The objective of such developments has been to enable the dialogue among stakeholders, providing management and decision-making tools for a sustainable agriculture – immediately in accordance with Embrapa's enunciated mission statement. One such development is the 'Perception Method of Upland Rice Cropping System Sustainability (Ferreira, 2007). The declared strength of this method is that data generation and analysis are developed in a participatory way, and the results are easy to visualize, enabling a qualitative assessment and favoring comprehension, reflection and prioritization of critical points.

Also pursuing the sustainable development of agricultural activities, a "System for weighed environmental impact assessment of rural activities" (APOIA-NovoRural) has been proposed as an objective, quantitative and analytical environmental management tool (Rodrigues & Campanhola, 2003). Constructed for the systemic encompassment of sustainability dimensions, including (i) Landscape Ecology, ii) Environmental Quality (Atmosphere, Water and Soil), iii) Socio-cultural Values, iv) Economic Values, and v) Management and Administration indicators, this system has been extensively applied toward the environmental management of rural establishments (Rodrigues, 2007), rural territories (Rodrigues et al., 2006a), countrywide rural developments programs (Rodrigues and Moreira-Viñas, 2006), and for the organization of terms of reference for sustainable development of agricultural production sectors (Rodrigues et al., 2008). The objective, systemic nature of APOIA-NovoRural represents a stride to comply with the quantitative fundamentals of the environmental impact assessment science intended in ecology.

The broad spectrum of impact assessment methodological approaches ensuing from research at Embrapa, briefly presented in this section, can be deemed as a valuable spillover of the strategic institutional practice of systematically carrying out impact assessments, regarding both research projects and technological innovations. Perhaps still more important, the practice of impact assessment (and the simultaneous sustainability evaluation) is being brought to the fields, as a tool for farmers to promote the environmental management of rural activities. This bold research objective and development movement may be the most effective way to promote the consolidation of a sustainable rural sector, as forwarded in the institutional mission statement.

5. Conclusion

Hundreds of evaluations, of a myriad of technological innovations have been produced and gathered since the inception of systematic impact assessment practice at Embrapa. The strategic objective of extending impact evaluations beyond the economic internal rate of return or benefit/cost analyses, introducing social and environmental evaluations, has been crucial for the critique of the institutional role in agricultural development. This process, however, has not been always smooth, and while the provision of a basic methodological approach may have facilitated the internalization of the impact assessment practice, it seems to be now fostering new, innovative developments.

The consolidated database obtained with these many technology assessment reports in the last seven years show the magnitude of research results and technological innovations made available, and allow a shift in the critical analysis of these contributions, from the naïve speculation to the educated elaboration. Aspects regarding employment generation and quality, income, health, product quality and food security, inputs use and environmental conservation, among many other indicators can be pondered upon, with reference elements obtained in real field contexts, together with technology adopters. Researchers, technology transfer agents, and research planning committees have, from this database, the knowledge to correct negative impacts and promote positive ones. These are valuable institutional learning processes and informational assets provided by Embrapa's impact assessment platform.

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