EMBRAPA EXPERIENCE ON THE IMPACT ASSESSMENT OF AGRICULTURAL R&D: 15 YEARS USING A MULTIDIMENSIONAL APPROACH

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ABSTRACT

After decades doing sporadic studies on impact assessment and using diversified approaches focused on economic effects, Embrapa is now completing 15 years of an institutionalized system based in a common multidimensional approach measuring economic, social, environmental, political and scientific impacts of its main technologies. Since 2001, Embrapa is monitoring and evaluating more than one hundred technologies and around 200 cultivars originated from its 42 research centers.

An impact assessment team, located at the Embrapa Headquarters, by the Secretariat for Management and Institutional Development (SGI), coordinates the system. This central unit is responsible for the analysis and consolidation of the results, and to give feedback to local teams, as to continually improve their analysis. This process is completed with an official and annual publication reporting on the multidimensional impacts, named Embrapa's Social Report (http://bs.sede.embrapa.br/).

The impact studies include the estimation of economic surpluses generated by Embrapa technologies based on field data collected through a private national survey (for cultivars) and by local/regional research teams for surveys regarding the other technologies. Internal rates of return are estimated using benefits and costs data series.

To evaluate social and environmental impacts research teams in each center interviews a sample of technology adopters to measure their perception on the innovations' impacts, comparatively to the former technologies or practices replaced. A reference multicriteria method, named Ambitec-Agro, is applied to estimate multiple indices evaluating positive and negative impacts in a set of socioenvironmental indicators.

More recently, new impacts are being measured including the contribution of Embrapa to the formulation of public policies and its scientific impact to the advancement of science, measured by the publication of articles on refereed journals, citations and establishment of R&D networks.

It is important to note that the development of econometric and other more sophisticated impact assessment analyses continue to be developed at Embrapa's research centers. Always that an external viewpoint is needed, national and international

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consultants have developed aggregate impact studies, or specific R&D assessments for especial research areas, such as genetic breeding.

This continuous impact system has been extremely important to Embrapa's institutional sustainability. Certainly, the strong support received by the corporation from Brazilian society is due in large part to this institutionalized system that shows not only results (outputs), but also their use and application impacts.

KEYWORDS: impact assessment**,** multidimensional approach, public research centers

EMBRAPA EXPERIENCE ON AGRICULTURAL R&D IMPACT ASSESSMENT: 15 YEARS USING A MULTIDIMENSIONAL APPROACH

1. INTRODUCTION

Traditionally, public agricultural research performs fundamental roles in the development of the rural sector and the economy, around the world. In the Brazilian case, several examples of increased production and productivity gains due to new technologies developed by public institutions of research established predominantly at the state level (especially in the south and southeast regions), were realized in the 60 and 70s.

With the creation of the Brazilian Corporation for Agricultural Research - EMBRAPA, and, consequently, the improvement in the quality of human resources, the construction and modernization of federal research centers, and the strengthening of state research institutions throughout the regions of the country (Northeast, North and Center-West), has permitted the generation of many benefits in different crops and research areas.

Sources of productivity gains generated in the 80s and 90s include biological control of insects, biological fixation of nitrogen, rationalization of input use (fertilizers, pesticides, water, etc.), new technologies for occupation of the "cerrados" region (the savannas of the central plains), new and very productive pastures and generation of new varieties of grains, such as soybeans for tropical regions. These are some recent examples of the agricultural research contributions to economic development in Brazil.

In this initial period, Embrapa's experience on impact assessment was characterized by sporadic studies oriented to evaluate returns on investments. This focus was changed during the nineties, when Embrapa received strong demands to evaluate environmental and social impacts, besides the economic ones traditionally focused.

The impact team was expanded and other specialties were incorporated and dimensions of analysis were progressively introduced, arriving in 2001 at the first version of Embrapa's multidimensional and decentralized approach to impact assessment (Avila et al., 2001).

Parallel to this impact team effort to apply several approaches to measure the diversified effects of Embrapa's technologies, the institution decided to adopt and to release an annual Social Report, an initiative strongly influenced by the French experience in this regard. The first Social Report was released in 1998, covering the

year 1997 but innovating in its content to also focus on impact and not only on social actions and related activities.

As remarked, Embrapa is now completing 15 years of this institutionalized system based in this multidimensional approach measuring economic, social, environmental, political and scientific impacts of its main technologies, now supported by a common methodology improved along this period (Avila et al., 2008). Since 2001 the institution is monitoring and evaluating annually, more than one hundred technologies and around 200 cultivars originated from its 42 research centers.

This paper presents the evolution of this institutional system, its governance and some recent challenges faced by the impact assessment team.

2. THE INITIAL IMPACT EXPERIENCE FOCUSED ON PROFITABILITY

The impact studies at Embrapa started in the beginning of the eighties and were oriented to show returns on the investments in the institution as a whole and the individual research centers. The origin of this demand was a consequence of Embrapa's institutional model as a public state company, following private rules and more flexible to manage agricultural R&D investments relatively to the old model, linked directly to the Ministry of Agriculture. The characteristics of the new model, initially strongly dependent on international loans (IDB and World Bank), created a pressure to the Board to show evidences of returns to Brazilian society, which would compensate the high levels of investments from the central Government.

The impact studies included the estimation of economic surpluses generated by Embrapa's technologies, based on field data collected by a national private survey (for cultivars) and by local/regional research teams for surveys related to agricultural technologies. Internal rates of return (IRR) were estimated using benefits and costs data series. The results of these studies developed during the eighties are shown in Table 1.

Authors	Specification Area	IRR (%)
Cruz, Palma & Avila (1982)	Total Investment	22-43
Cruz & Avila (1983)	World Bank Project I	20 38
Avila, Borges-Andrade, Irias & Quirino (1984)	Human Capital: Research Training	22-30
Roessing (1984)	Soybeans Res. Center: Total Investment	45-62
Ambrosi & Cruz (1984)	Wheat Res. Center: Total Investment	59-74
Avila, Irias & Veloso (1985)	IDB Project I: EMBRAPA research Research of the South System	 27 38
Barbosa, Cruz & Avila (1988)	Total Investment: New Evaluation	34-41
Barbosa, Avila & Motta (1988)	World Bank Project II	43
Evenson & Cruz (1989) *	Brazil: Wheat Maize Soybeans	39 30 50
Kitamura et al. (1989)	EMBRAPA research: North Region	24
Santos et al. (1989)	EMBRAPA research: Northeast Region	25
Teixeira et al. (1990)	EMBRAPA research: Center-West Region	43
Lanzer et al. (1989)	EMBRAPA research: South Region	45

Source: Avila et al. (2008); (*) Marginal internal rate of return (MIRR).

Table 1 – Embrapa's experience on impact assessment during the 80s

The institution has been continually demanded to show evidences that the high investments in its activities were worthwhile and new impact studies were then developed. The new studies of economic impact evaluations developed during the 90s, in general, were a consequence of the international loans demand or due to isolate initiatives of Embrapa´s research centers, rather than an institutional nationwide effort as was the case during the eighties (Table 2).

Authors	Specification Area	IRR (%)
Kahn & Souza (1991)	Manioc & Tropical Fruit Center: Manioc	29-46
Dossa & Contini (1994)	Embrapa Soybeans center	65
Avila e Evenson (1995)*	Embrapa (national programs)	56
	Embrapa (regional centers)	46
	State research	19
Evenson e Avila (1995)*	Embrapa grain research:	
	Wheat	40
	Soybeans	58
	Maize	37
	Rice	40
Oliveira & Santos (1997)	Embrapa Goats and Sheep center	24
Vilela et al. (1997)	Vegetables center (carrots)	36
Pereira e Santos (1998)	Cotton	15
Bonelli & Pessoa (1998)*	Embrapa	18-27
Almeida et al. (1999)	Soybeans	69
Ambrosi (2000)	Wheat	88-143
Almeida & Yokoyama (2000)	Rice	93-115

Source: Avila et al. (2008); (*) Marginal internal rate of return (MIRR).

Table 2 – Embrapa's experience on impact assessment during the 90s

During the 90s the number of economic impact studies developed at Embrapa was smaller than during the 80s. The theoretical basis adopted in these studies relied on the economic surplus approach, but other studies involving econometric models were also developed.

3. MULTIDIMENSIONAL APPROACH

The multidimensional approach is focused on four dimensions - economic, social, environmental and scientific impacts of its main technologies, a work that involves all Embrapa´s centers using a common reference methodology. More recently, impact on public policies, consumption and institutional impacts are also being analyzed. In this section, an overview of this methodology is presented.

3.1 ECONOMIC IMPACTS

The methodological approach used to estimate the economic impacts of Embrapa's research and development programs is the economic surplus, the most used

method to analyze economic impacts generated by agricultural research. In this approach the coefficients of price-elasticities of the demand and supply curves of the product under evaluation, the shift of the supply curve, price changes and the production values of the product area being used. The supply curve would be located to the left-hand side if there were no technological innovations generated by agricultural research. If the technological innovation occurs, the consumers benefit with the increase in the supply of products and, the producers benefit with a reduction in production costs.

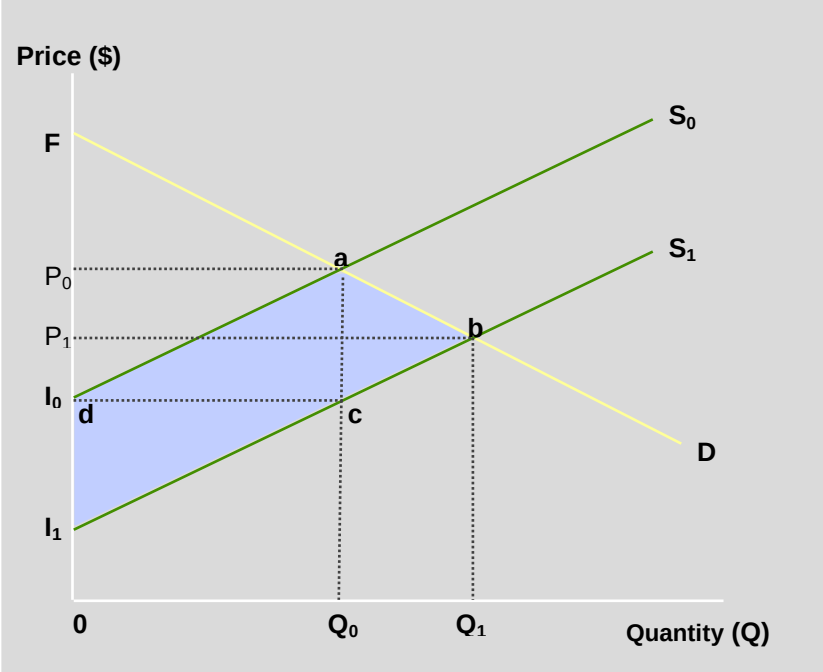

Figure 1- Economic surplus approach

In order to calculate this surplus it is necessary to know the rate of supply shift due to the new technology. This rate is calculated by comparing the traditional technology to the new technology (traditional variety vs. improved variety, for example). This rate of shift as a result of agricultural research is computed, in general, using yield increases due to new varieties compared with the traditional varieties and rate of adoption of new varieties, measured in percentage terms of the cultivated area.

Some authors have used a different approach to the measurement of the economic surplus concept (Tosterud, 1973; Kislev & Hofmann, 1978; Cruz et al., 1982, for example). Their approach is different due to different hypothesis about the coefficient of price-elasticity of the demand and supply curves compared to those presented in the literature. Such hypothesis assumes the existence of an aggregate horizontal demand curve for the agricultural production (D) perfectly elastic, and a supply curve (S_0) vertical, perfectly inelastic. In this case, the changes in economic surplus (Figures 2 and 3) are due to increment in production (varieties more productive, for example) or costs reduction (reduction in the use of agrochemical, for example).

In this approach, the economic surplus is computed considering the net additional economic benefits generated or to be generated (potential) for each one of the technologies identified as "product" of the institution or program under evaluation. The additional net benefits (additional income less the additional costs for the use of the new technologies) are taken at the producer level (farm conditions), and not the economic

benefits generated at the experimental station level. The information available at the agricultural research center (agronomic and economic results) only is utilized as a basis for the economic computation at the farm level.

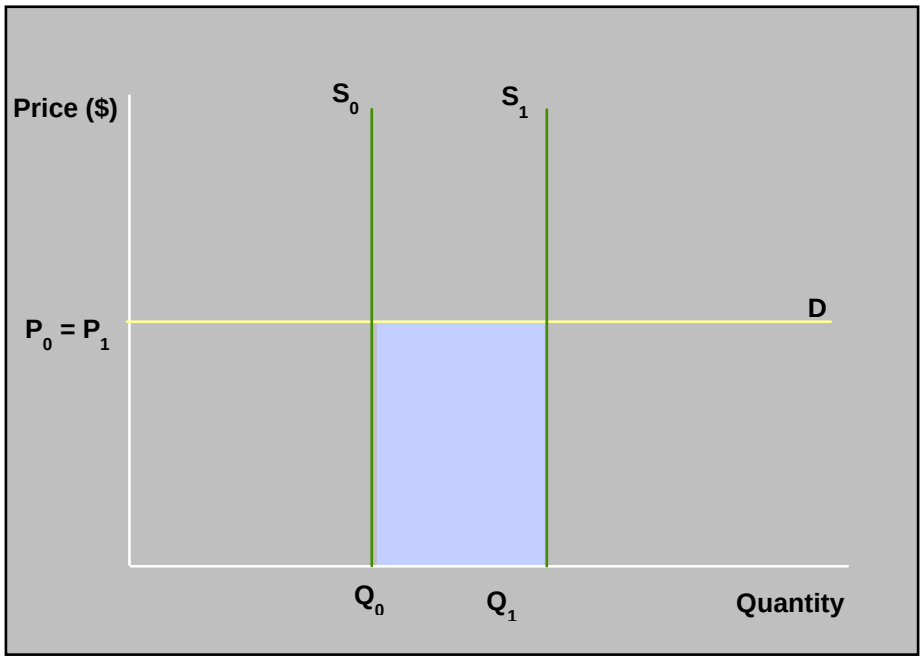

Figure 2 – Economic surplus: increment in production

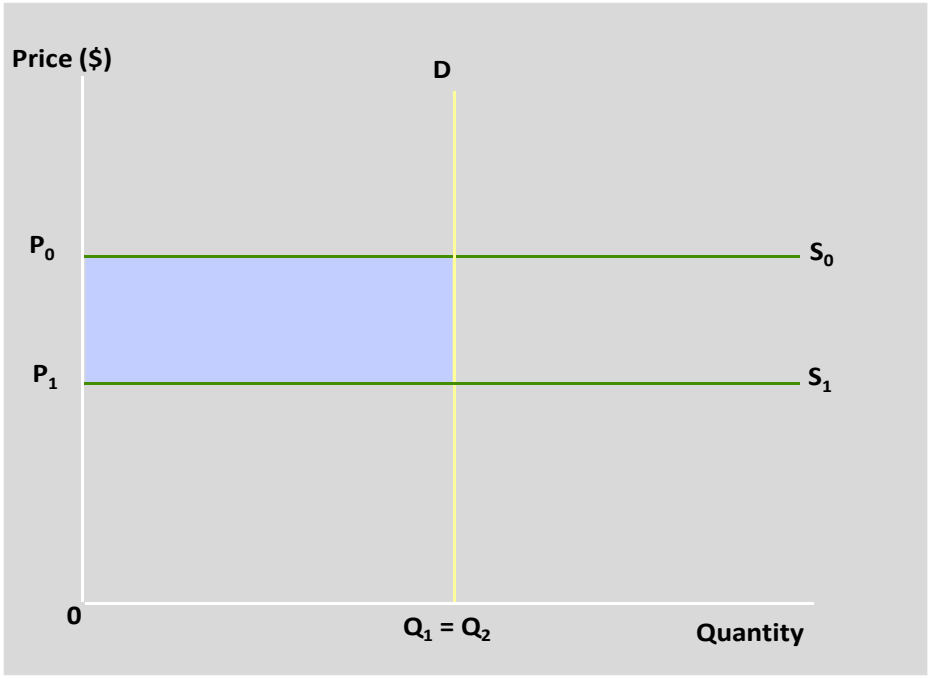

Figure 3 – Economic surplus: cost reduction

The additional net revenues at the adopting level are calculated at Embrapa using four types of impacts: increment in productivity, reduction in costs of production, value added (quality, processing, etc.) and expansion of the production in new areas.

At Embrapa, in especial during the last 15 years, each research center selected its main technologies generated and already adopted by the farmers or agribusiness. In this process, the benefits are computed in terms of additional net economic benefits obtained by the producers at farm level, for each one of the technologies discounting eventual additional costs. As the monitoring of these gains is carried out annually, this procedure reduces the risk of an overestimation of economic benefits of agricultural research, very high when the traditional economic surplus approach is utilized.

To compute the economic benefits at the producer level, farm surveys and qualified informants (public and private technical assistance workers, especially) were used. These annual surveys allowed knowing the real conditions of each technology being adopted (inputs used, technical coefficients, prices received and paid, etc.).

To estimate the net impact participation of Embrapa it is necessary to evaluate the role of the researchers in the development or adaptation of each one of the technologies under evaluation. Such estimation, computed in percentage terms, and allowed the authors to estimate the net economic benefits due to the research develop by Embrapa. They were isolated from other benefits due to investments in another national or international cooperating institution, as state agricultural research institutes or International Agricultural Research Center (CIAT, IRRI or CIMMYT, for example).

To calculate the research costs and then to estimate the returns on investments for each technology and at Embrapa as a whole, the impact team has been used as the main source of expenditure in each center or at the Embrapa headquarters. When the benefit/cost analysis is aggregated (Embrapa or by center), this process is relatively simple due the information system used by the institution. The complexity is larger when this calculation has to be made by technology, the case of the institutionalized system adopted by Embrapa. For each one of the technologies under monitoring all the generation costs are being estimated, including personnel (salaries and social benefits), direct and indirect costs (depreciation and management).

3.2. SOCIOECONOMIC AND ENVIRONMENTAL IMPACTS[6]

To evaluate socioeconomic and environmental impacts of agricultural technology innovations at Embrapa's institutional R&D level, a multi-attribute indicators system has been developed (Ambitec-Agro, Rodrigues et al., 2003a).

The Ambitec-Agro structure relies on a series of *Principles* of technology and rural activity performance, composed by social and environmental compliance *Criteria*, integrated by series of sustainability *Indicators* selected from prior experience and field trials (Irias et al., 2004a; Magalhães et al., 2006). The indicators are scored in field surveys/interviews with farmers/administrators, to obtain change coefficients according to technology or rural activity effects observed in the studied contexts. The change

[6] - This section is an excerpt of Rodrigues et al. 2010.

coefficients are weighted by factors related to each indicator's relevance toward effecting socio-environmental impacts and its scale of occurrence (Rodrigues et al., 2003b; Monteiro and Rodrigues, 2006). Finally, impact indices are calculated for each indicator and criterion, and also aggregated as a technology innovation socio-environmental impact index.

The Ambitec-Agro system comprises four modules, focused on the productive sectors of Agriculture, Animal husbandry, and Agro-industry environmental impact assessment (Irias et al., 2004b) and a specific module for social impact assessment (Rodrigues et al., 2005a), encompassing 24 criteria and 125 indicators, in an integrated platform to facilitate the application of the field surveys and analysis. The impact assessment of a given technology innovation with the Ambitec-Agro system is carried-out in three steps:

a) definition of technology innovation use magnitude, geographical area delimitation and users;

b) field survey/interview at the rural establishment scale, applied with innovation-adopting farmers and data filling out in the scaling checklists; and,

c) analysis, interpretation, and reporting of impact indices (in formatted templates), with proposition of alternative management practices and technology adaptation, focused on minimizing negative impacts and promoting positive ones.

The Ambitec-Agro system consists of integrated indicator scaling checklists, in which change coefficients checked in field surveys / interviews are related to quantitative measures of area, quantities, proportions, etc., and standardized. These indicators are then weighted according to their defined relevance to conform the assessment criterion and their scale of occurrence. The relevance weighting factors consist of a normalization step to equalize for different numbers of indicators that may comprise each assessment criterion.

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 relevance values and scale of occurrence, and then combined to express the impact index for the criterion (resulting range ±15, Figure 4).

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			-0,5	-0,25	-0,25	0	**-1**
Scale of occurence =	Non-applicable	Mark with X				X	
	Near	1	-1	-3			
	Proximate	2			-3		
	Surrounding	5					
Impact Coefficient = (change coefficients * weighing factors)			**0,5**	**0,75**	**1,5**	**0**	**2,75**

Figure 4– Example of scaling checklist, for the criteria Water quality – Ambitec-Agro impact assessment method.

The given example for the water quality criterion represents a field observation of moderate reduction in BOD at the proximate environment scale, a major decrease in turbidity also at the proximate environment, a moderate reduction in the presence of floating materials / oil / scum in the surrounding environment; and non-applicable context for siltation. Note that the weighting factor for siltation is zeroed, with corresponding weighting factor being transferred, in the given example, to BOD.

Once all indicator change coefficients are inserted into the scaling checklists, a Technological Innovation Impact Index is calculated for the specific conditions studied, by averaging all the normalized impact indices for the criteria considered. Similarly, to the weighting factors included in each indicator scaling checklist, this normalization step allows a 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 (Figure 5), assessments may be better adapted to specific evaluation contexts, by emphasizing relevant local aspects or evaluation objectives, or even by excluding certain aspects that may not appropriately represent meaningful consideration for particular cases (non-applicable).

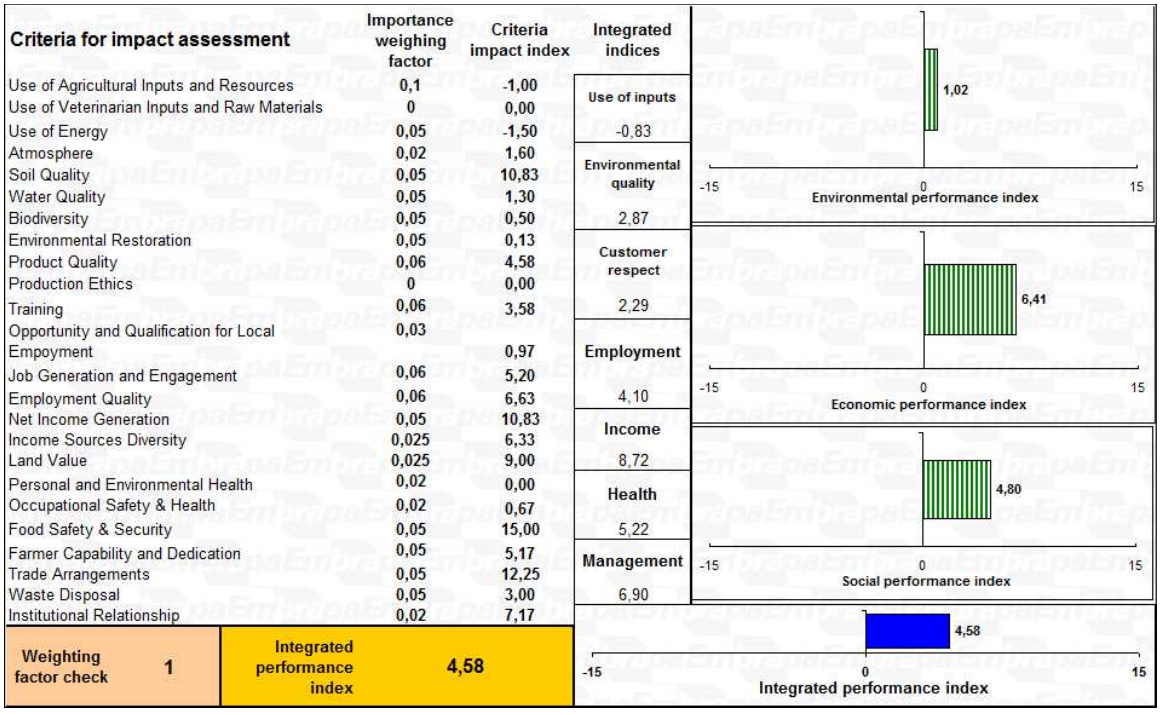

Figure 5 - Example of results presentation graphs – Ambitec-Agro impact assessment method.

The aim of Ambitec-Agro is to provide a practical, expeditious, low cost, and reproducible socio-environmental impact assessment procedure for the wide range of agricultural technologies and rural activities concerned in Embrapa's research program. These particular technology innovations, made available through the numerous R&D

projects in the decentralized Research Centers, comprise the basic units of Embrapa's impact assessment platform.

Evaluations are carried out by appointed teams in the Research Centers, normally comprised by dedicated socio-environmental researchers; and the members of the group responsible for the development of the selected technology innovation. A budgetary allowance is made available through the Secretariat for Management and Institutional Development (SGI) for this task, estimated as a minimal amount sufficient to fund interviews / field surveys in a sample of ten technology-adopting rural establishments.

3.3 IMPACTS ON SCIENTIFIC ADVANCES

One of the ways to access, measure and compare scientific productivity is by the large scientific articles databases such as Scopus from Elsevier and Web of Science from Thomson Scientific. By this way one can have statistics of its own rganization and compare it with other organizations, such as: number of articles and number of citations, the partnerships established to do these articles, its evolution over the years and many other dimensions. For that one must make use of bibliometric techniques.

As Penteado and Boutin (2008, pag. 40) described, "they deal with many different aspects of information and its quality, their main raw material being words. A word can represent between many other things, a concept or theme, an individual, an organization or even a group of themes, individuals, or organizations. The methods of analysis involve one-dimensional statistics (sum and meaning of the values/words), two-dimensional statistics (how it is and how much measures the relationship among two values/words), multidimensional statistics (how they are and to measure relationships between several variables/values/words) and, finally, probabilistic (to detect emerging or atypical behaviors, or even to determine how these variables/values/words will behave)".

The bibliometric analysis always starts with a question. To answer it, we apply the necessary technical statistics. For example: to answer the question: "what is the total output of articles and their evolution" was created the matrix "Embrapa research centers," whose information was drawn from the fields "Author Affiliation" and "Publication Year" registered in the last ten years. To answer the question "What are the main partners and how it has evolved this cooperation by major geographic areas of the world?" was created a matrix "Affiliation Author and Publication Year", targeted by regions of the world and for the last ten years of publication.

A search was conducted on August 08, 2015 in the databases known as Web of Science, covering a period from 1973 to 2015, for all records, in every language and all types of documents, with mention of "Embrapa" and its many variations in the authors' address. From this, 9.505 articles were located. The analysis gathers documents described as articles and reviews.

The Embrapa research centers are very diversified when it comes to mission, customer demands, number of researchers, infrastructure, support staff and budget. We must therefore pay attention to these factors in evaluating the company's scientific production. The production of each center is analyzed on all above and other complementary indicators.

Scientific production

The scientific production of Embrapa based on the database of the Web of Science (WoS) has been growing at high rates. Figure 6 shows this evolution.

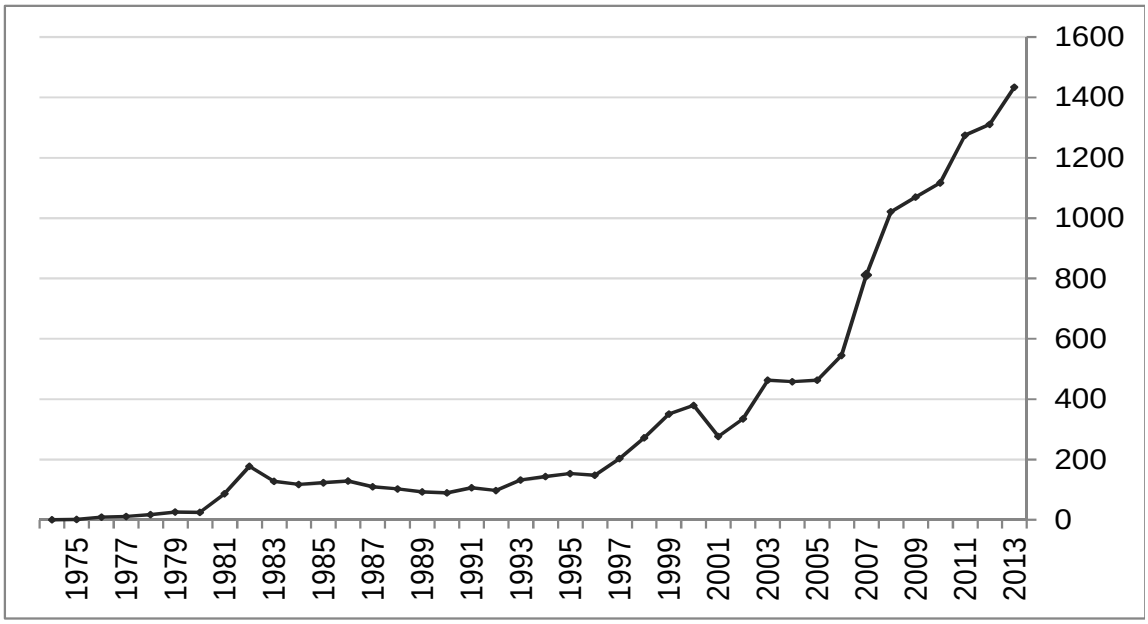

Figure 6: Embrapa's articles production 1974-2013.

The production of articles at Embrapa is concentrated 76,15% with Brazil partners as showed at Table 3.

Table 3. The first 30 country in partnerships to produce articles from 2004-2013.

Class.	Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total	%	%cum
1	Brazil	453	454	543	808	1018	1064	1107	1275	1305	1429	9456	76,15	76,15
2	USA	70	65	47	80	77	87	94	107	103	137	867	6,98	83,13
3	France	18	17	15	16	31	30	56	46	29	51	309	2,49	85,62
4	UK	12	14	15	18	11	25	10	20	32	36	193	1,55	87,18
5	Netherlands	8	5	12	9	6	11	14	12	23	29	129	1,04	88,21
6	Germany	16	7	7	12	18	13	6	13	15	18	125	1,01	89,22
7	Spain	3	6	7	6	9	13	18	13	16	27	118	0,95	90,17
8	Australia	4	5	7	5	3	7	12	9	24	23	99	0,80	90,97
9	Argentina	3	3	11	2	13	7	10	15	12	19	95	0,77	91,73
10	Canada	3	6	6	8	15	12	6	9	12	16	93	0,75	92,48
11	Italy	4	3	2	6	6	6	6	4	13	12	62	0,50	92,98
12	Mexico	5	1	6	2	1	5	2	8	14	11	55	0,44	93,42
13	Colombia	8	3	4	2	5	6	5	5	7	7	52	0,42	93,84
14	Japan	4	3	5	1	4	8	5	8	3	10	51	0,41	94,25
15	Uruguay	1	3	1	1	3	4	13	3	9	6	44	0,35	94,61
16	Portugal			1	3	1	4	5	8	7	12	41	0,33	94,94
17	China			2	2		5	7	7	7	6	36	0,29	95,23
18	Switzerland			1	2	6	1	2	3	6	11	32	0,26	95,49
19	Belgium	3	4	2	3	1	3	5	2	3	5	31	0,25	95,74
20	India	1	1	1		1	5	2	2	11	4	28	0,23	95,96
21	South Africa	1	2	3	2	2	1	3	2	7	5	28	0,23	96,19
22	Denmark	2	1		2	1	1	2	3	5	5	22	0,18	96,36
23	New Zealand		2	1	1	2	7	1	2	4	2	22	0,18	96,54
24	Ireland	1		3	2	2	4	4	1	2	1	20	0,16	96,70
25	Venezuela	2		1	3		5	1	1	4	2	19	0,15	96,86
26	Chile	1		3	1		2	2	3	4	2	18	0,14	97,00
27	Austria	1		2	1	1	1	3	1	4	3	17	0,14	97,14
28	Ecuador	2		1		3	3		1	1	6	17	0,14	97,27
29	Peru	2		1			5	1	2	1	5	17	0,14	97,41
30	Costa Rica			2		2	2	5	3	1	1	16	0,13	97,54

During the last 10 years the production of articles at Embrapa was concentrated 64,49% in English, 34,56% Portuguese and 0,95% in other languages. This production is published mainly in national journals (56,22%) although they represent only 7,74% of the total number of journals in the article corpus.

The Figure 7 presents the main research partners of Embrapa. The acronym OIRAs represents International Organizations of Agricultural Research.

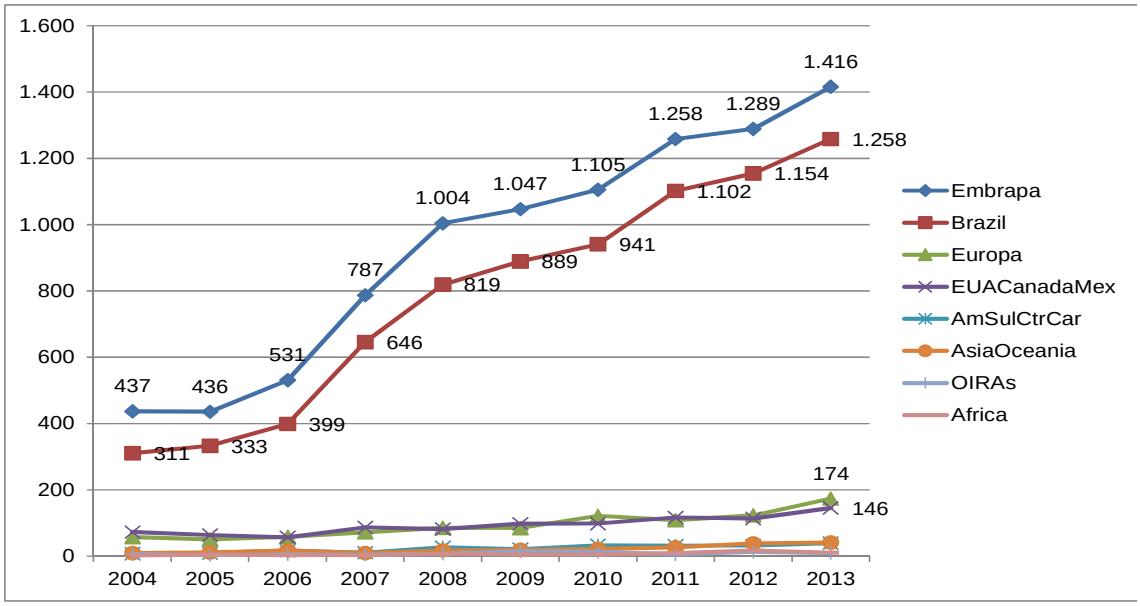

Figure 7 - Embrapa's articles by regions of the world.

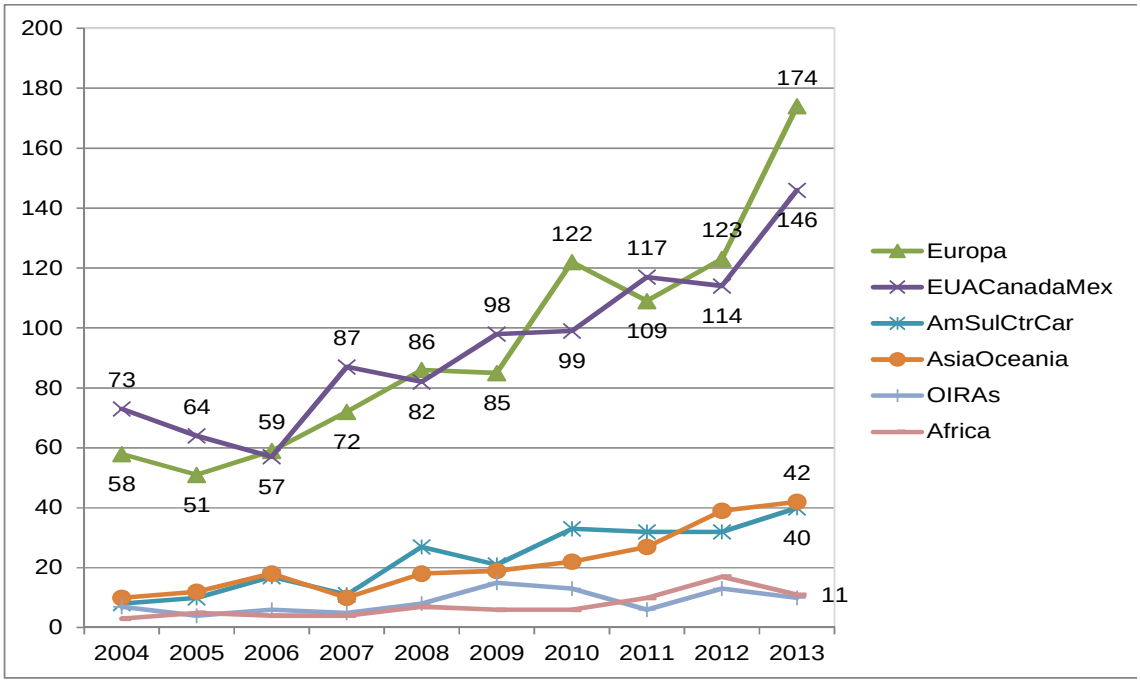

Figure 8 - Embrapa's international article production cooperation.

Embrapa's main partners in Europe during the 2004/2013 period is showed below (Table 4).

Class.	Partner	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
1	Cirad/IRD/Orstom	11	12	8	8	24	18	36	26	22	28	193
2	Univ Agr Wageningen	5	4	10	8	5	9	13	7	15	21	97
3	INRA-FR	7	5	3	6	4	11	24	14	8	13	95
4	Agr Res Org-England		4	3	1	2	4	3	6	8	4	35
5	Agr Res Ctr-Germany	6	1	2		5	4	2	4	5	5	34
6	Univ Edinburg	5	1	4	2	1	8		1	2	5	29
7	CSIC-SPA				1	4	4	3	4	2	6	24
8	Royal Bot Garden-UK	2	1				3		5	4	6	21
9	Univ Oxford			1		1	7	1	3	4	4	21
10	Agr Res Org-Netherlands	1	1	1		3	3	1	2		4	16
11	Syngenta		1		3	3	2	1	2	1	3	16
12	Univ Pol Valencia			1	1	1		4	1	3	5	16
13	CNRS-FR	1				1	1	3	4	2	3	15
14	Univ Gottingen	4	2	1	3		1	2		2		15
15	Univ York-UK		2	1	2	1		2	2	1	4	15
16	Univ Complutense Madrid	1	2	1	1	1	1		2	2	3	14
17	Univ Sant Compostela-SPA				2	2	1	4	2	1	2	14
18	Univ Dundee		1	1	3	1		2	2	1	2	13
19	ECT_Tox-GER	3		2	1	2	2		1		1	12
20	Univ Leeds	2		1			4		1	1	3	12
21	Univ Limerick-IRL			1	2	2	1	2	1	2	1	12
22	Agr Res Org-Scotland		1	1			1	2	2	1	3	11
23	Conservat Int	2	1	1		1	3	2		1		11
24	ETH Swiss Fed IT				2	5		2	1	1		11
25	Univ Cardiff	1	1		3	1	3	1		1		11
26	Univ Ghent	1	1	1	2	1	2	2			1	11
27	Univ Utrecht	1					1		3	4	2	11
28	Univ Cat Louvain	1	2	1			1	2	1		2	10
29	WWF					1	2		2	2	3	10

The citations

Embrapa's articles citations present a constant growth but have declined in the last five years. We are studying these phenomena and believe that this could be due to a delay of five years for the citations to attain their climax.

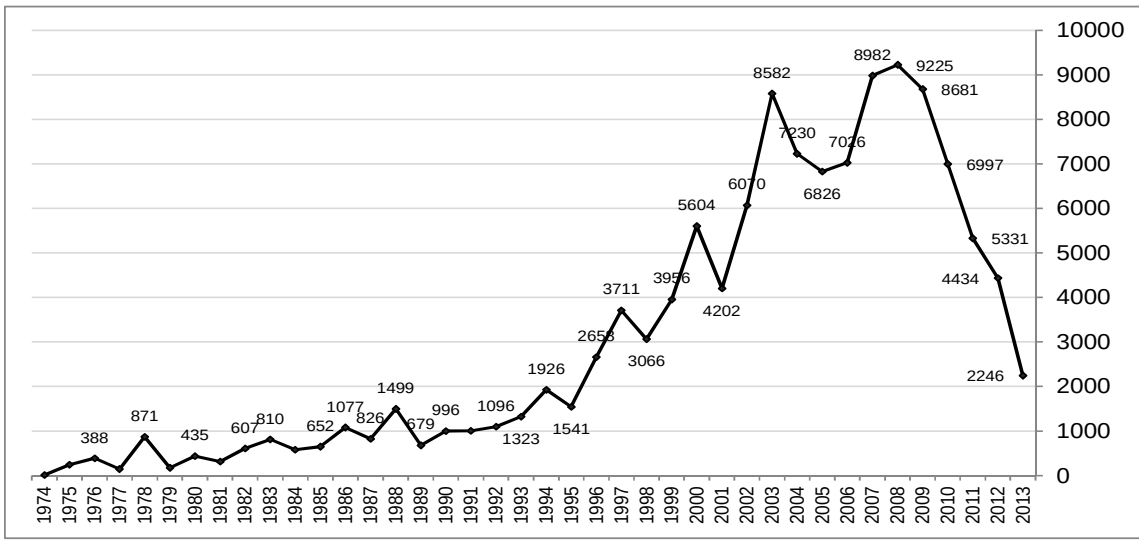

Figure 9 - The citations by year from 1974-2013.

Embrapa's articles in Portuguese receive more citations in the classes of until 4 citations and lesser in the classes above that ceiling. The classes of citation and the number of articles contained are organized from the higher citation articles, 100 or more to the lesser citations articles. As expected the Embrapa's articles citations in National journals present a weakness on the citations classes of 10 or more citations.

Table 5 The citations by language by classes of citation.

Language	0	1	2a4	5a9	10a14	15a24	25a49	50a99	100+	Total	%
English	1066	812	1482	1162	571	496	375	126	40	**6130**	**64,65**
Portuguese	1061	626	878	483	138	76	19	4		**3285**	**34,64**
Others	31	13	23	15	8					**90**	**0,95**
% English	**17,39**	**13,25**	**24,18**	**18,96**	**9,31**	**8,09**	**6,12**	**2,06**	**0,65**	**100**	
% Portuguese/Others	**32,36**	**18,93**	**26,70**	**14,76**	**4,33**	**2,25**	**0,56**	**0,12**	**0**	**100**	
% WoS	**47,71**	**8,76**	**12,93**	**10,20**	**5,52**	**5,83**	**5,26**	**2,49**	**1,30**	**100**	

Table 6 presents the citations of the Embrapa's articles by regions of the world.

Table 6. The citations by regions of the world by classes of citation.

Class.	Partners	0	1	2a4	5a9	10a14	15a24	25a49	50a99	100+	Total
1	Embrapa	2113	1428	2351	1618	693	554	386	128	39	9310
2	Brazil	1864	1238	2033	1349	574	418	281	74	21	7852
3	Europa	87	90	177	200	110	118	102	37	18	939
4	EUACanadaMex	92	88	172	172	105	124	104	53	27	937
5	AmSulCtrCar	37	33	46	39	19	24	18	6	9	231
6	AsiaOceania	10	17	36	41	29	23	34	18	9	217
7	OIPAs	4	9	10	16	13	9	12	5	9	87
8	Africa	5	6	15	15	12	4	10	2	4	73

Embrapa's articles citations by partner institutions. The institutions in gray are the reminiscent of the institutions partners by articles list

Table 7. The citations by main 50 partner institutions by classes.

Class. # cit.	Class. # art.	Partners	0	1	2a4	5a9	10a14	15a24	25a49	50a99	100+	Total
1	14	USDA-ARS	17	22	38	54	35	31	23	17	10	247
2	177	Univ Columbia-US					4		3		6	13
3	79	CSIRO-AUS	1	1	2	3	4	11	10	3	5	40
4	69	Univ Cornell	5	1	5	11	4	4	9	3	5	47
5	111	Univ Texas A&M	3	2	2	3	1	1	5	2	5	24
6	99	Univ Edinburg		2	6	1	3	4	7	1	5	29
7	76	Mus Goeldi-BR	4	2	7	10	6	1	6	1	5	42
8	158	Smithsonian			1		2	1	4	1	5	14
9	32	INPA-BR	20	14	33	19	13	4	9		5	117
10	184	Univ Leeds		1			1		5		5	12
11	136	USDA-FS			3	1	3		2	5	4	18
12	20	Cirad/IRD/Orstom	13	20	32	42	22	31	25	4	4	193
13	41	INRA-FR	4	6	13	21	14	15	14	4	4	95
14	191	Conservat Int					1		4	2	4	11
15	169	CGIAR_CIFOR				1	3	1	3	1	4	13
16	167	Agr Res Ctr-India		2	1			2	4		4	13
17	218	Univ Duke					1	1	4		4	10
18	260	Mus Noel Kempff M-BOL							4		4	8
19	234	Max Planck RI		1		1		1	2		4	9
20	22	Univ Cat Brasilia	12	18	38	37	28	20	26	8	3	190
21	2	UNESP	173	126	162	119	53	40	24	8	3	708
22	6	UFRGS	78	54	103	78	21	14	12	6	3	369
23	4	UnB-BR	98	99	155	106	74	42	38	4	3	619
24	25	USP-SP*	23	18	45	29	16	17	11	4	3	166
25	87	Agr Res Ctr-Germany	3	3	5	5	2	3	6	4	3	34
26	152	Univ New Hampshire-US	1		1	1	1	1	4	3	3	15
27	92	Univ Georgia	3	1	6	6	6	2	3	3	3	33
28	166	Univ Stanford	1	1	2		1		3	3	3	14
29	150	Univ Missouri			4	2		1	3	2	3	15
30	125	Woods Hole RI	2		1	2	6	2	3	1	3	20
31	119	Royal Bot Garden-UK	1	3	3	1	1	6	2	1	3	21
32	270	Univ Maryland	1					2	1	1	3	8
33	120	Univ Oxford	1	2	2	2	4	2	5		3	21
34	299	Univ Natl S AA Cuzco					1		3		3	7
35	353	Agr Res Inst-Peru							2		3	5
36	230	European Commiss			2	2		1	1		3	9
37	226	CGIAR_BIOVERS		2	1	1	1		1		3	9
38	7	Unicamp	45	46	84	65	33	22	19	8	2	324
39	13	UFRJ	43	26	65	43	26	24	26	7	2	262
40	42	Univ Florida	5	8	17	19	10	10	17	7	2	95
41	39	Univ Agr Wageningen	3	13	17	18	13	15	10	6	2	97
42	154	Univ York-UK	1		2		1	2	2	5	2	15
43	90	Univ Wisconsin	5	5	2	5	4	4	3	4	2	34
44	71	Univ Calif Davis	6	4	6	7	5	3	9	3	2	45
45	10	UFMG	63	45	79	65	18	19	11	2	2	304
46	163	Univ Iowa State		1	1	1		1	6	2	2	14
47	168	Agr Res Org-New Zealand			1	4	1	1	2	2	2	13
48	196	Univ Calif Berkeley		1		2	1	1	2	2	2	11
49	146	CNRS-FR	1		2	3	2	2	1	2	2	15
50	193	ETH Swiss Fed IT	1	1	2		1	2		2	2	11

Main Findings

The bibliometric analysis about its scientific production has allowed Embrapa to know the outcomes of its work and redirect its performance. At large, according Penteado et al. (2015), Embrapa is among the top scientific institutions in Brazil and has extensive international network of scientific production involving 98 countries. However, much of this international production is concentrated in six countries (USA, France, UK, Netherlands, Germany and Spain). Most of them are headquarters of Embrapa's Virtual Laboratories Abroad - Labex. This performance is not only quantitative but also qualitative. The last four years about 36% of the papers produced by Embrapa´s researchers have been published in most prestigious international journals, classified by the Brazilian Ministry of Education as level A.

The evaluation of its scientific production is also allowing the Embrapa redirect its performance evaluation system to contemplate some fundamental questions:

Valorization of diversity – The scientific and technological production of Embrapa´s research centers do not have the same performance because they have different profiles and work in economic contexts, social and environmental very diversified. Hence, the present results not only point to the existence of that diversity but also induce to propose a more skilled work performance evaluation.

Institutional performance evaluation improvement - In this study it was found the need to improve Embrapa's performance evaluation system to tune it to the concerns of the international community on the use of indicators in S & T, the guiding documents of the Company and the profile of its units. In order to establish this profile is necessary to consider several factors, such as type of research center, knowledge areas in which it operates synergy with other units, insertion in supply chains etc.

Publishing policy-setting papers - The production of scientific articles must come to meet the needs of Embrapa, adopting for it not only the mission, vision and overall goals of the institution but also the agenda of its unit's priorities. The adoption of this policy seeks to reduce distortions such as publication in journals that are not in tune with public and research topics of each research center, just to get better scores in databases.

3.4. IMPACTS ON CONSUMPTION AND INTANGIBLE EFFECTS

3.4.1 Consumption

The most recent methodological challenge where Embrapa has directed its efforts has been to assess the impacts of their technologies from the point of view of the consumption. After identifying the impacts on the farmer's income, the social impact of technology on rural property and the chain in which the product is inserted, including the verification of the environmental impacts of these technologies. The need to assess impacts on consumption technologies and the perception of consumers also becomes essential.

Checking impacts of this nature is important because consumption is of great value for Brazilian family farmers where this sector represents 4.3 million production units (84% of the total), and up to an 80,250,453 hectares or 25% of the total area harvested, (Herbelê, 2014). Grisa and Shineider (2008) stress that current research is linking consumption to food security and rural poverty. These same authors, citing the work of Buainain, Romeiro and Guanziroli (2002) and Leite (2004) emphasize that the home consumption means, on average 20% of the product generated in the production unit. The construction method for assessing the consumer impacts has been made in the context of the development of biofortified cultivars to reduce hidden hunger in Brazil.

In addition to an extensive literature review and interaction with other research centers in Latin America, the development of the method has also considered the experience of field indicators and tested through surveys of rural farmers in pilot projects.

Table 8 - The list of consumption used at Embrapa.

Acceptability - physical properties	Color
	Flavor
	Odor
	Texture
New product acceptance	Acceptance in the family
	Acceptance in the neighborhood
	Market acceptance
Culinary quality	Time for preparation
	Quality after preparation
	Preparations options
Preservation quality	Storage capacity
	Time for preparation after storage

Source: Authors.

The list of indicators presented in Table 8 is in the process of incorporation into the Ambitec-Agro, methodology developed by Embrapa Environmental Studies. The aim is that the assessment of the impacts of the consumption dimension is to prepare it to be incorporated into the annual process of technologies of Embrapa.

In the same way as in the other dimensions of impact assessment, it is expected that the consumer attitudes will be incorporated into future research projects conducted by Embrapa to evaluate technologies developed in the institution in terms of outreach increasingly tailored to the needs of consumer.

3.4.2 Intangible Impacts

The improvement of ways to measure, evaluate and improve the effectiveness of agricultural research is important. In recent years, Embrapa has focused its efforts on assessing the impacts of some of the intangibles that generates more precisely the effects of development and adoption of its technologies on issues related to knowledge, training and other political and institutional impacts. This is because a part of what

Embrapa researchers developed can be considered the main input for further generation of new knowledge.

In Embrapa indicators of intangible impacts considered in the evaluation method can be seen in Figure 10 and are an adaptation by the institution's experience Geopi / Unicamp (Brazil) in developing the methodology ESAC (acronym of the economic, social, environmental and training). The method Esac Impact Assessment Research is the ex post measurement of the intensity of the transformations of the adoption of a technology. ESAC is integrated assessment of economic, social, environmental dimensions and training. To assess the impacts on the knowledge, capacity and institutional policy in Embrapa, a variation of the dimension " capacity" the ESAC is used.

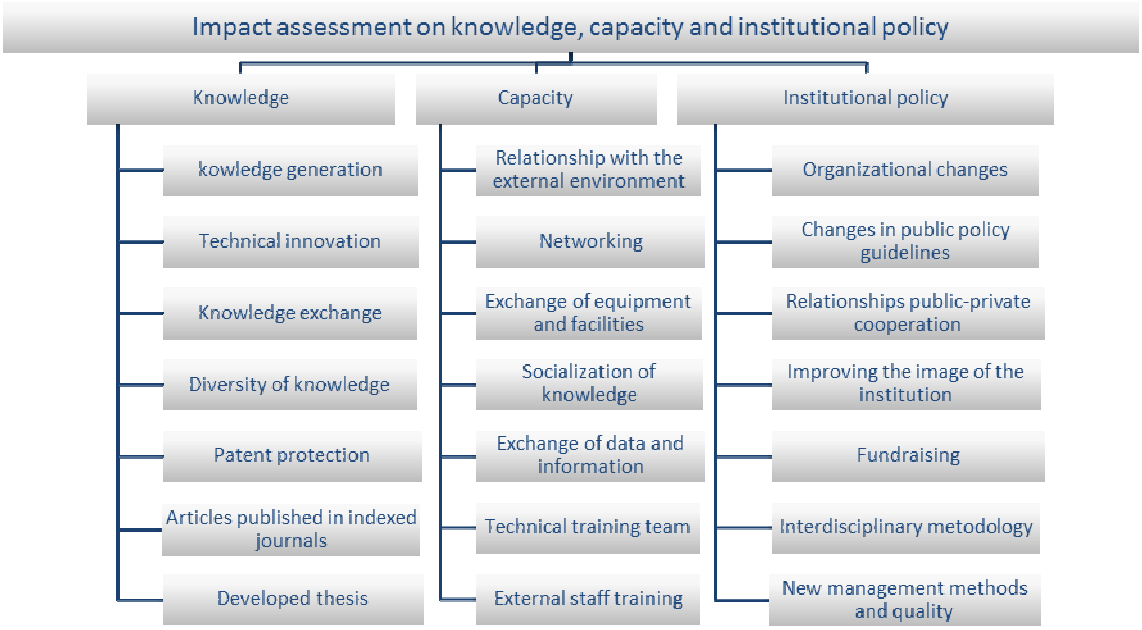

Figure 10 - Intangibles used for evaluation at Embrapa

This method began to be used in Embrapa in 2006. Initially it was being planned especially for evaluating the impacts of each research centers basics of the institution but has finally shown to demonstrate efficient intangible impacts estimates for all centers.

After nearly a decade, the use of this method has been able to assess the impacts on the knowledge providing results that allow researchers to assess how far the research is taking the right direction, and if it is fulfilling its role in promoting social welfare or to develop new research tools. In many cases, in addition to the results from the evaluation of impacts on the knowledge also serve for the development and change of orientation of public policies for the agricultural sector

4. ECONOMETRIC IMPACTS STUDIES

It is important to note that the Embrapa experience is not limited to the use of the economic surplus approach to measure impacts. Several studies using econometric approaches have been developed during the last decades, involving its own researchers and in many cases international experts. This external involvement has underwritten the validity of its own impacts research.

The use of foreign researchers, as those from Yale University, International Food Policy Research Institute (IFPRI) and the University of California-Davis, in the development of impact assessments and using diversified methodological approaches, has played a vital supporting role in EMBRAPA's accountability reports. In this regard are presented below some examples of this rich experience on international collaboration.

Avila, Evenson, Silva and Almeida (2003) analyzed the impact of adoption of new varieties in the Brazilian agricultural productivity has used a model with different specifications. The results obtained showed that the improved varieties had played an important role in the increase of the productivity of the Brazilian selected commodities analyzed in this study. The results also showed the importance of the varieties based on CGIAR genetic material on this increase of productivity. The improved varieties developed by the public sector have been an important in the gains of productivity in Brazil, measured with a construction of the pool of variety variable. Embrapa's varieties have the leadership in wheat, irrigated rice, upland rice and soybeans, at the same time of the varieties developed by the state institutions were more important for beans and cotton.

Pardey et al. (2004), estimated that Brazil received $16 of benefit from every dollar invested by Embrapa in improving upland rice, edible beans, and soybean varieties. The total research benefits over the period 1981–2003 amounted to $14.8 billion in present value (1999 prices) terms—or 6.1 percent of the corresponding value of crop output—of which $3.1 billion were attributed to the efforts of Embrapa. These benefits to Brazil came from either maintaining yields in the face of pressures that would otherwise cause them to fall, or improving the yield performance over time relative to base-year yields. They represent the gains from varietal improvement research alone, abstracting from other factors that can affect yields. The internal rates of return (IRR) for the R&D investments in these crops estimated by the authors were the following: 10-15% for beans, 22-23% for upland rice and 52-53% for soybeans, according the two hypothesis (4 or 10% discount rate and lag length for the stream of benefits - to 1998 or to 2003).

Another example of econometric studies of impact are those developed using the Total Factor Productivity TPF index and analyzing its sources of growth, including agricultural research. During the last decades, several impact studies has been developed in Brazil to analyze the evolution of the agricultural productivity using TFP measures, mostly, using the Tornqvist index.

Avila and Evenson (1995) estimated Tornqvist-Theil TFP indexes for the Brazilian agricultural sector and by sub-sector – crops and livestock, for the 1970-85 period using agricultural census data. This study showed highest TFP growth in the Southeast and Center-west regions (3.1 and 3.8%, respectively). The annual rate of growth of the Brazilian agricultural sector was 2.45%. Productivity growth was higher in crops (3.63%) than livestock (2.12%).

The authors demonstrated a leading contribution to this growth by sector and aggregate of the Embrapa research programs where from 6 to 12 % of growth (9 percent in the aggregate) can be attributes to these programs and the industrial R&D sector where a similar contribution is estimated. State research institutions, while modest are important and probably contributed 5 percent to the 1985/1970 growth. If we consider our crops sector estimates, extension and human capital have probably contributed another 3 percent.

It is important to highlight that the results obtained at Embrapa in other TFP studies (Avila et al., 2010a; Avila and Evenson, 2010b and, Avila et al.,2013) or by other Brazilian authors (Araujo et al., 2002; Gasques et al., 2004, 2010), have consistently showed the decisive roles played by investment in agricultural research, in particular, those of Embrapa.

A study of the long-term association between a series of food basket prices in Brazil and a series of investments in agricultural research found that, in the long term, 10% increase of the budget of Embrapa implies 2.23% drop in the price of the food basket (Souza et al., 2013). As the poor spend the bulk of their income purchasing food, lowering food prices relieves the monthly budget of the neediest. From February 1976 to July 2012, the accumulated reduction was of 79.82%. The authors concluded, “continuous incentives to agriculture, taking advantage of its immense technological basis to expand exports and accumulate funds, is the appropriate mechanism to stabilize domestic prices and significantly mitigate poverty in the country”.

Souza et al. (2013), also developed a joint analysis of data from the 1995/1996 and 2006 agricultural censuses shows that, based on 1995/1996 agriculture, an increase in research intensity in any given Embrapa unit implicated an average increase in rural producers’ gross income of 8.8% over the period. For this analysis a sample of 86,626 rural establishments with positive net income and receiving technical assistance was used.

5. IMPACT SYSTEM GOVERNANCE AND CHALLENGES

5.1 GOVERNANCE

The system is coordinated and methodologically supported by an impact assessment team located at headquarters, under the guidance of the Secretariat of Management and Institutional development. This secretariat is also responsible for the analysis and consolidation of the annual results in a special format for the Social Balance Report.

The Social report follows a model suggested by the Brazilian Institute for Social and Economic Analysis (Ibase), but adapted to Embrapa. The basic difference from the original document is due to the adaptation of some of its criteria, created especially to for a non-profit organization focused on agricultural R&Ds. In the case of Embrapa, although it was founded as a company in 1973 to overcome the Brazilian public sector bureaucracy, it was not created to generate profits. Its contribution lies in the development of Brazilian agriculture and its biggest challenge is therefore to demonstrate the role of agricultural research as a strategic effort with significant impact for the country.

Its main objective is to disseminate to the Brazilian society the results of the main positive impacts of technologies developed by the institution and transferred to society and the social benefits generated from knowledge.

From its inception the Social Balance this Report has undergone several modifications, not only in terms of graphics, but also its content. Its current form offers a document of about 40 pages that should not be confused with an Activity Report. The Social Balance Report primarily covers the **impacts** of major technologies, products and services developed by the Company and appropriated by society. It also presents relevant information about the social performance of the institution and has been improved over the years, according to the evolution of the methodology used in its production and research results.

The website of the Social Balance (http://bs.sede.embrapa.br/) was also improved over the years with the addition of more dynamic search tools, as well as more detailed information and databases with descriptions of social actions. In addition to providing for public consultation the detailed reports of the information presented on the technologies developed by Embrapa, these items, in the printed version, are only highlighted. Below is a view of the title page of the last three issues of the Embrapa social report (Figure 11).

Figure 11 – The most recent issues of the Embrapa Social Report – 2012/14

5.2 FUTURE CHALLENGES

The Embrapa impact assessment team for the next decades must be concentrated not only in the improvement of the quality of the multidimensional impacts estimations of the technologies already included in the process, but also look and to analyze other impacts actually not cover by the set of methodologies in use.

One of the strong demand posed to the impact team is to measure the impact of public policies developed or improved with the Embrapa support. In 2014 the first survey of the main policies already in place in Brazil that has received a technical support of Embrapa was prepared. In this survey 60 public policies were identified and

our mission during the next years is to select some of them and to start with estimation of their impacts. This effort should also produce a methodology that allow the Embrapa centers involved in each one of them to monitor and evaluate them continuously.

At present, one the main challenges assigned to the impact team is to collaborate in the implementation of the strategic plan of Embrapa for 2015/34. This plan has a new strategic map where five impact axes were clearly established and they must to guide all the production system in a way to accomplish the institutional goals (Figure 12).

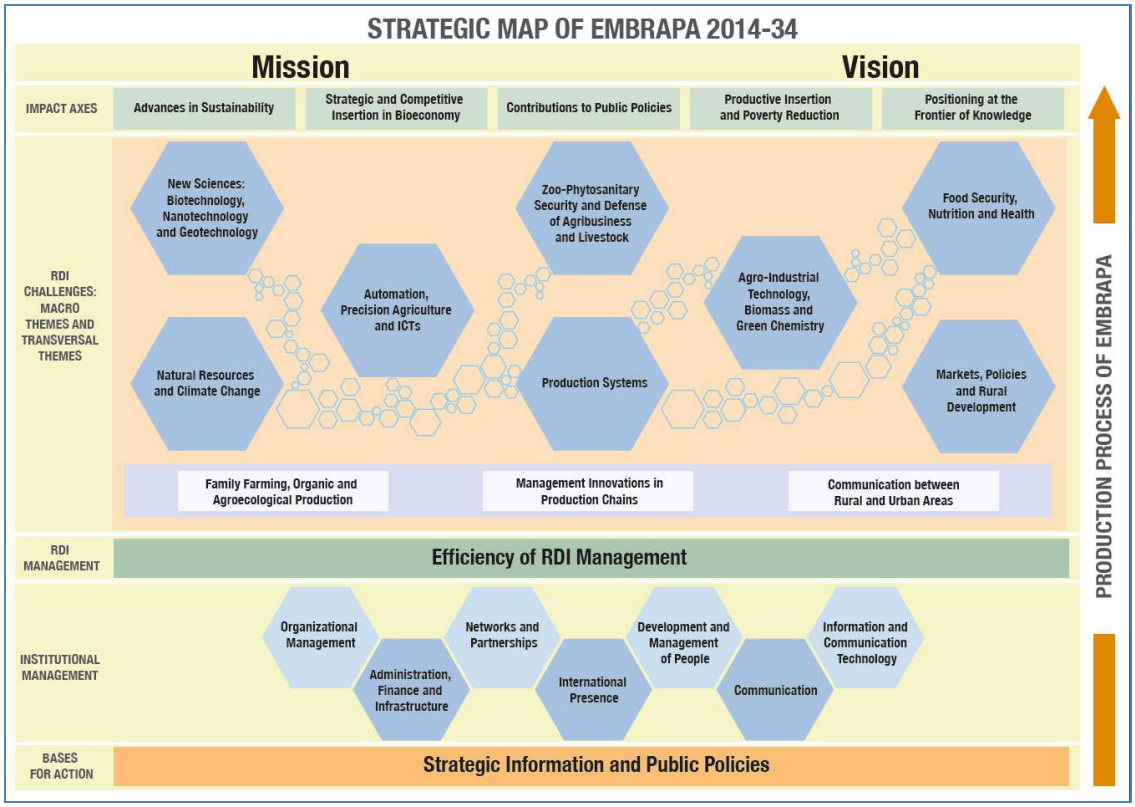

Figure 12 – Strategic map of Embrapa – 2014/34

In this process oriented to improve the management of the institutional strategy, one of the mission of the impact assessment is to support the R&D selection process of new projects with ex-ante impact evaluation. To develop ex-ante evaluation of R&D is new for Embrapa, but it is essential to the institution to accomplish its VI strategic plan. An Embrapa team is already working in this process and expects to put it in place in the beginning of the next year.

Another initiative to reorganize the institutional process to evaluate the ex-post impacts of the Embrapa technologies in a way to also aligned it to the five impact axes established at the new strategic plan. The impact is also one of the main criteria employed to evaluate the research centers at the new integrated performance management system (*Integro*), currently adopted by Embrapa.

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