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USING THE ECONOMIC SURPLUS METHOD TO ASSESS ECONOMIC IMPACTS OF NEW TECHNOLOGIES: CASE STUDIES OF EMBRAPA

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Abstract

Assessment of economic impacts of new technologies delivers helpful information to justify investment efforts in research and development to generate new technologies. In Brazilian agricultural research and development, it's a convention to assess economic impacts of technologies generated and adapted by EMBRAPA. As soon as new technologies are adopted, ex-post assessment is conducted to evaluate net benefits of its adoption. In agricultural research, the economic surplus method represents one of the suitable frameworks to measure the aggregated social benefits of a research project. With this method it is possible to estimate the return of investments by calculating a variation of consumer and producer surplus through a technological change originated by research results. Therefore, in a first step the gain of adoption i.e., increases in productivity, quality improvements, cost reduction etc. is estimated. In a second step, costs involved in generation and adaptation of the technology are enumerated. The difference between the gains and the costs of generation and transfer represents the net benefit of the technology, explained by the net present value, the internal rate of return and the benefit-cost-ratio. The so far obtained results serve as additional information for each technology to improve its adoption by beneficiaries and to enable access to the new financing sources. Some examples of such technologies are (a) the finishing of lambs in confinement in the Brazilian semi-arid Northeast during the dry season, when feeding resources are scarce and the lamb meat prices are high; (b) strategic vermifugation of goats herds and sheep flocks in the Brazilian semi-arid areas; (c) standardized cuts for goat and sheep carcass and (d) enrichment of the native pastures in Brazilian Northeast with Cynodon dactylon for sheep production. The assessment of the economic impacts of these technologies estimated positive net present values for all four considered technologies, internal rates of return of 26.2% (a), 13.8% (b), 52.8% (c) and 31.0% (d) and the benefit-cost-ratios of 2.92 (a), 1.19 (b), 11.64 (c) and 3.37 (d).
Keywords: *Agricultural research, economic impact assessment, economic surplus method*

Introduction

Resources for agricultural research are scarce. Therefore, the efficient resource allocation and the necessity to justify their use to the society require the assessment of economic impacts of research. Without the economic analysis it would be hard to know the social value of scientific knowledge and technologies and to make judgments about the trade-offs in the allocation of scarce resources in research (Alston et al., 1998).

In Brazilian agricultural research and development, it's a convention to assess economic impacts of technologies generated and adapted by EMBRAPA. As soon as new technologies are adopted, ex-post assessment is conducted to evaluate net benefits of its adoption.

Methods of economic assessment

The more common methods of economic assessment belong to three main groups: the econometric methods, the programming methods and the consumer surplus methods (Masters et al., 1996).

The econometric methods aim to estimate a marginal productivity of research during a long time period (Masters et al., 1996). Thus, the econometric models use a production function, a cost function or an analysis of total productivity of factors to estimate a change in productivity due to investment in research (Maredia et al., 2000).

The programming methods try to identify one or more optimal technologies or research activities from a set of options. Thus, these methods try to maximize one objective, i.e. farmers' profit subjected to constraints like availability of land, labour and other inputs.

The economic surplus method's goal is to measure the aggregated social benefits of a research project. With this method it is possible to estimate the return of investments by calculating a variation of consumer and producer surplus through a technological change originated by research. Afterwards, the economic surplus is utilized together with the research costs to calculate the net present value (NPV), the internal rate of return (IRR), or the benefit-cost-ratio (BCR) (Maredia et al., 2000).

The main advantage of using the economic surplus method is that the model needs less information than the other models. Additionally, it can produce useful and effective outputs in showing the benefits generated by agricultural research.

The economic surplus method

This paper is based on the economic surplus method. Therefore, this method is further explained in order to provide information that facilitates discussions on the economic benefits of four analyzed technologies.

The economic surplus approach permits the estimation of the economic benefits generated by adoption of technological innovations, compared to the situation before (without) the adoption, where only traditional technology was available.

Figure 1 shows the impact of research on economic surplus. If a supply curve moves to the right due to positive impacts of research on productivity increasing and cost reduction, the consumer achieve a gain of B + C (that means the consumer is benefiting with research because of price decreasing). The producer loses the area B due to price reduction but gains an area A through demand increasing. The impacts on producer depend of the elasticity of demand and supply curves. Therefore, the benefit of research for the society will be the sum of the areas A and C.

Thus the economic surplus method requires information on productivity increase generated by research, equilibrium price of assessed product, adoption rate and costs, timeframe between research and adoption, and price elasticity of supply and demand[1]. With this information available it is possible to calculate the magnitude of change of the supply curve as a result of the adoption of technological innovations (Maredia et al., 2000).

[1] If the objective of assessment is to calculate the returns of the institution, instead of the general impacts of research it is necessary to include the institutions' participation in development and transfer of assessed technologies.

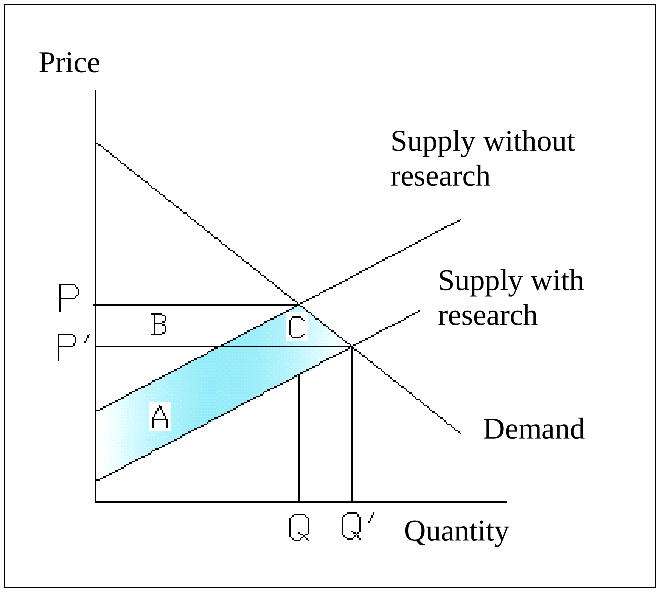

Figure 1. Demand and supply curves and impact of research on the supply curve

However, as shown by Masters et al. (1996), sensitivity analysis assure that the elasticities of supply and demand have little influence in determination of economic surplus when compared to other variables, i.e. price, productivity, quantity etc.

Following this approach, the economic impact assessment of EMBRAPA, including the technologies assessed in this paper, uses a methodology that considers two variants of the economic surplus method. The first variant covers the cases where the technological innovation leads to cost reduction. The gains generated by cost reduction are represented in Figure 2. With the reduction of costs, inputs can be saved and thus the supply curve (S0) moves downwards (S1). For these cases, the supply curve is perfectly elastic and the demand curve is perfectly inelastic. The area P_0xyP_1 corresponds to the economic surplus (Figure 2).

The second variant is used for impacts that increase production (profits of incomes or expansion of area). In this case, the demand curve is considered as perfectly elastic and the supply curve as perfectly inelastic. According to Figure 3, the generated surplus is represented by the area $QxyQ_1$.

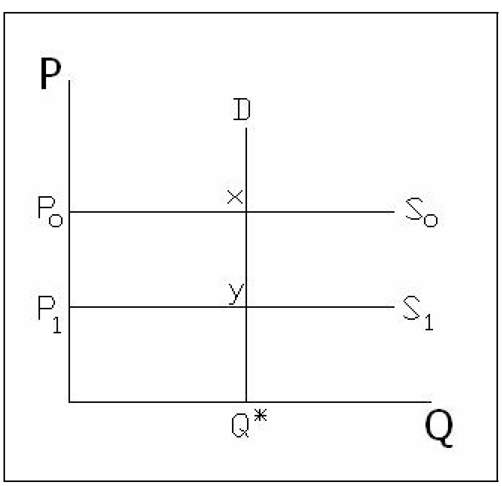

Figure 2. Economic surplus with a perfectly elastic supply curve and a perfectly inelastic demand curve

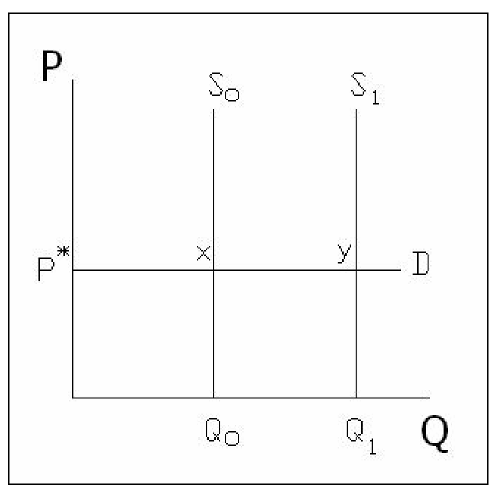

Figure 3. Economic surplus with a perfectly elastic demand curve and a perfectly inelastic supply curve

Using these two variants, the benefits of the four technologies presented in this paper had been estimated.
As mentioned, to analyze the research's viability is necessary to estimate the research costs. These costs involve the generation of research and technologies, i.e. the salaries of involved researchers according to their time dedicated to the research, costs to use vehicles, infrastructure, administrative costs, etc. Additional extension programs may be required in order to speed up the adoption. These programs need to be taken into consideration in the analysis.

The costs of research

Another stage, as important as assessing the benefits generated by research, is the estimation of the costs of the technology generation process. The benefits need to be put in relation to the costs to analyze the economic viability of research.
The costs involve all the expenses necessary for carrying out research, except the expenses that would have been made of any form (Masters et al., 1996). Thus, the costs must include all the expenses referring to the research, development and technology transfer that the institution has carried out.
In relation to the costs with staff, an often used form to carry out the estimates is to consider the wages of the involved team together with the ratio of time that each one dedicated every year to the research (Pardey et al., 2002). Thus, the costs with staff involve the wages of the employees proportionally to the time of dedication to the activity of the evaluated research.
The operation costs generally are divided by diverse research projects. Thus, it must be taken into consideration the asset spent in the research being evaluated. Examples of assets used are fuel, energy, laboratory, field products and other inputs. The same comment serves for costs of capital, like land, buildings, machines and equipment.
There are other costs that must be considered, as, for example, administrative expenses, costs of complementary services as libraries and the costs of technology transfer. Frequently extension programs to speed up the adoption of the technology are necessary (Masters et al., 1996). Thus, the costs of extension carried out by the research institution to enable adoption must also be considered.

The benefit-cost analysis

Knowing the benefits and costs of the research throughout a period of time, it is possible to carry out profitability analyses to show economic viability of the research.
The most known three ways to carry out profitability analyses are the Net Present Value (NPV), the Internal Rate of Return (IRR) and the Benefit-Cost-Ratio (BCR).
NPV in the year t is equal to a flow of benefits generated by an investment minus a flow of costs of this investment discounted by an appropriate rate. If NPV is positive, then the investment is considered as profitable.

$$NPV_t = PV(B)_t - PV(C)_t = \sum_{j=0} \frac{(B_{t+j} - C_{t+j})}{(1+i)^j}$$

IRR is the rate that turns the NPV to zero or turns the present value of benefits equals to the present value of costs. The IRR should be higher than the rates available on the market for alternative capital use in order to consider the investment as profitable.

$$0 = \sum_{j=0} \frac{(B_{t+j} - C_{t+j})}{(1+IRR)^j}$$

BCR represents the relation between the present value of the benefits and the present value of the costs. The investment is considered profitable if the benefit/cost ratio is higher than 1.

$$BCR_t = \frac{PV(B)_t}{PV(C)_t}$$

The profitability analysis allows to verify the viability of the projects and helps in the selection of the most efficient projects, having influence in the resources allocation. However, it is important that qualitative analyses of the projects are carried out to enable understanding of those elements that are not possible to be assessed with a financial analysis only.

Materials and methods

In a first step it was estimated the gain of adoption, i.e. increases in productivity, quality improvements, cost reduction etc. In a second step, the costs involved in generation, adaptation and transfer of the technology were enumerated. The difference between the gains and the costs of generation and transfer represents the net benefit of the technology, explained by IRR, NPV and BCR (Gittinger, 1982). To enable calculation with present values, a discount rate of 12% is being used in this paper. The so far obtained results serve as additional information for each technology to improve its adoption by beneficiaries and to enable access to new financing sources.

From the above presented theoretical approach, the evaluation of economic impacts of four technologies developed with participation of the Brazilian National Goats Research Center (EMBRAPA-CNPC) were carried out. The four technologies assessed in this paper are examples of economic impacts generated by EMBRAPA-CNPC's research. These assessed technologies and their variant of economic surplus are listed in Table 1.

Table 1. Analyzed technologies and variant of economic surplus generated by them.

Assessed technology	Variant of generated economic surplus (type of impact)
a) Finishing of lambs in confinement in the Brazilian semi-arid Northeast during the dry season, when feeding resources are scarce and the lamb meat prices are higher	Reduction of production costs
b) Strategic vermifugation of goat herds and sheep flocks in the Brazilian semi-arid region	Increase of productivity
c) Standardized cuts for goat and sheep carcass	Added value
d) Enrichment of the native pastures in Brazilian Northeast with *Cynodon dactylon* for sheep production	Increase of productivity

This analysis considers only EMBRAPA's costs and respective net benefits.

Results and discussion

The next four tables show the flows of benefits, costs and net benefits of each analyzed technology as well as their net present values, internal rates of return and benefit-cost-ratios.

Finishing of lambs in confinement in the Brazilian semi-arid region during the dry season

Table 2 presents the flows of benefits, costs and net benefits, as well as NPV, IRR and BCR of confined lamb finishment. The NPV is R$ 733,168.21, the IRR is 26.2% and the BCR is 2.9. These indicators show that the resources spent on research to generate and adapt the "confined lamb finishment" technology represent an efficient option of resource allocation.

Table 2. Net present value, internal rate of return and benefit-cost-ratio of confined lamb finishment.

Year	Flow of Benefits (R$)	Flow of Costs	Flow of Net Benefits (R$)
1 (1995)	0.00	100,710.37	(100,710.37)
2 (1996)	0.00	92,110.04	(92,110.04)
3 (1997)	0.00	85,698.95	(85,698.95)
4 (1998)	0.00	113,957.92	(113,957.92)
5 (1999)	0.00	26,399.50	(26,399.50)
6 (2000)	0.00	24,041.82	(24,041.82)
7 (2001)	244,998.11	21,777.61	223,220.50
8 (2002)	213,192.40	17,227.67	195,964.73
9 (2003)	217,800.00	16,000.00	201,800.00
10 (2004)	239,580.00	16,000.00	223,580.00
11 (2005)	263,538.00	16,000.00	247,538.00
12 (2006)	289,892.00	16,000.00	273,892.00
13 (2007)	318,881.00	16,000.00	302,881.00
14 (2008)	350,769.00	16,000.00	334,769.00
15 (2009)	385,846.00	16,000.00	369,846.00
16 (2010)	424,431.00	16,000.00	408,431.00
17 (2011)	466,874.00	16,000.00	450,874.00
18 (2012)	513,561.00	16,000.00	497,561.00
19 (2013)	564,917.00	16,000.00	548,917.00
20 (2014)	621,409.00	16,000.00	605,409.00
21 (2015)	683,550.00	16,000.00	667,550.00
		Net Present Value (NPV) (R$)	733,168.21
		Internal Rate of Return (IRR)	26.20%
		Benefit-Cost-Ratio (BCR)	2.92

Past values adjusted through IGP-DI index, prices of December 2003; Discount rate of 12%.

Strategic vermifugation of goat herds and sheep flocks in the Brazilian semi-arid areas

Table 3 presents the flows of benefits, costs and net benefits, as well as NPV, IRR and BCR of strategic vermifugation of goats herds and sheep flocks in the Brazilian semi-arid region. The NPV is R$ 579,154.38, the IRR is 13.8% and the BCR is 1.19. These indicators show that the resources spent on research to generate and adapt the technology of strategic vermifugation of goat herds and sheep flocks in the Brazilian semi-arid region represent an efficient option of resource allocation.

Table 3. Net present value, internal rate of return and benefit-cost-ratio of strategic vermifugation of goat herds and sheep flocks in the Brazilian semi-arid region.

Year	Flow of Benefits (R$)	Flow of Costs (R$)	Flow of Net Benefits (R$)
1 (1981)	0.00	782,250.00	(782,250.00)
2 (1982)	0.00	763,625.00	(763,625.00)
3 (1983)	0.00	745,000.00	(745,000.00)
4 (1984)	0.00	726,375.00	(726,375.00)
5 (1985)	0.00	190,000.00	(190,000.00)
6 (1986)	0.00	185,000.00	(185,000.00)
7 (1987)	133,056.00	180,000.00	(46,944.00)
8 (1988)	355,740.00	175,000.00	180,740.00
9 (1989)	565,488.00	170,000.00	395,488.00
10 (1990)	792,792.00	165,000.00	627,792.00
11 (1991)	960,960.00	160,000.00	800,960.00
12 (1992)	1,203,048.00	155,000.00	1,048,048.00
13 (1993)	1,330,560.00	150,000.00	1,180,560.00
14 (1994)	1,329,930.31	135,784.77	1,194,145.55
15 (1995)	1,388,234.26	118,300.63	1,269,933.63
16 (1996)	1,349,663.67	108,198.15	1,241,465.52
17 (1997)	1,395,248.62	100,667.29	1,294,581.33
18 (1998)	1,573,088.30	98,981.19	1,474,107.11
19 (1999)	1,486,456.69	82,498.43	1,403,958.27
20 (2000)	2,221,464.25	75,130.69	2,146,333.56
21 (2001)	2,112,228.57	68,055.03	2,044,173.54
22 (2002)	1,790,816.12	53,836.46	1,736,979.66
23 (2003)	1,894,200.00	50,000.00	1,844,200.00
Net Present Value (NPV) (R$)			579,154.38
Internal Rate of Return (IRR)			13.80%
Benefit-Cost-Ratio (BCR)			1.19

Past values adjusted through IGP-DI index, prices of December 2003; Discount rate of 12%.

Standardized cuts for goat and sheep carcass

Table 4 presents the flows of benefits, costs and net benefits, as well as NPV, IRR and BCR of standardized cuts for goat and sheep carcass. The NPV is R$ 3,743,065.52, the IRR is 52.8% and the BCR is 11.64. These indicators show that the resources spent on research to generate and adapt the technology of standardized cuts for goat and sheep carcass represent an efficient option of resource allocation.

Table 4. Net present value, internal rate of return and benefit-cost-ratio of standardized cuts for goat and sheep carcass.

Year	Flow of Benefits (R$)	Flow of Costs (R$)	Flow of Net Benefits (R$)
1 (1995)	0.00	70,980.38	(70,980.38)
2 (1996)	0.00	64,918.89	(64,918.89)
3 (1997)	0.00	54,360.34	(54,360.34)
4 (1998)	0.00	59,388.72	(59,388.72)
5 (1999)	0.00	49,499.06	(49,499.06)
6 (2000)	144,250.93	45,078.41	99,172.51
7 (2001)	391,996.97	40,833.02	351,163.96
8 (2002)	497,448.92	32,301.88	465,147.05
9 (2003)	864,000.00	30,000.00	834,000.00
10 (2004)	950,400.00	30,000.00	920,400.00
11 (2005)	1,045,440.00	30,000.00	1,015,440.00
12 (2006)	1,149,984.00	30,000.00	1,119,984.00
13 (2007)	1,264,982.40	30,000.00	1,234,982.40
14 (2008)	1,391,480.64	30,000.00	1,361,480.64
15 (2009)	1,530,628.70	30,000.00	1,500,628.70
16 (2010)	1,683,691.57	30,000.00	1,653,691.57
17 (2011)	1,852,060.73	30,000.00	1,822,060.73
18 (2012)	2,037,266.81	30,000.00	2,007,266.81
19 (2013)	2,240,993.49	30,000.00	2,210,993.49
20 (2014)	2,465,092.83	30,000.00	2,435,092.83
21 (2015)	2,711,602.12	30,000.00	2,681,602.12
		Net Present Value (R$)	3,743,065.52
		Internal Rate of Return (IRR)	52.80%
		Benefit-Cost-Ratio (BCR)	11.64

Past values adjusted through IGP-DI index, prices of December 2003; Discount rate of 12%.

Enrichment of the native pastures in Brazilian Northeast with Cynodon dactylon for lamb production

Table 5 presents the flows of benefits, costs and net benefits, as well as NPV, IRR and BCR of native pastures enrichment with *Cynodon dactylon* for lamb production. The NPV is R$ 3,285,454.43, the IRR is 31.0% and the BCR is 3.37. These indicators show that the resources spent on research to generate and adapt the technology of enrichment of native pastures with *Cynodon dactylon* for lamb production represent an efficient option of resource allocation.

Table 5. Net present value, internal rate of return and benefit-cost-ratio of enrichment of native pastures with *Cynodon dactylon* for lamb production.

Year	Flow of Benefits (R$)	Flow of Costs (R$)	Flow of Net Benefits (R$)
2 (1991)	0.00	491,347.78	(491,347.78)
3 (1992)	0.00	438,229.10	(438,229.10)
4 (1993)	0.00	385,110.42	(385,110.42)
5 (1994)	0.00	387,584.57	(387,584.57)
6 (1995)	120,666.65	23,479.13	97,187.52
7 (1996)	530,170.91	21,474.09	508,696.83
8 (1997)	1,087,206.71	19,979.44	1,067,227.28
9 (1998)	1,496,595.64	19,644.80	1,476,950.84
10 (1999)	1,583,969.84	16,373.46	1,567,596.37
11 (2000)	1,699,456.21	14,911.19	1,684,545.03
12 (2001)	1,666,395.47	13,506.88	1,652,888.59
13 (2002)	1,113,230.39	10,684.92	1,102,545.47
14 (2003)	791,280.00	9,923.50	781,356.50
15 (2004)	813,260.00	9,923.50	803,336.50
16 (2005)	835,240.00	9,923.50	825,316.50
17 (2006)	835,240.00	9,923.50	825,316.50
18 (2007)	835,240.00	9,923.50	825,316.50
19 (2008)	835,240.00	9,923.50	825,316.50
20 (2009)	835,240.00	9,923.50	825,316.50
21 (2010)	835,240.00	9,923.50	825,316.50
22 (2011)	835,240.00	9,923.50	825,316.50
23 (2012)	813,260.00	9,923.50	803,336.50
24 (2013)	813,260.00	9,923.50	803,336.50
25 (2014)	791,280.00	9,923.50	781,356.50
26 (2015)	769,300.00	9,923.50	759,376.50
		Net Present Value (R$)	3,285,454.43
		Internal Rate of Return (IRR)	31.00%
		Benefit-Cost-Ratio (BCR)	3.37

Past values adjusted through IGP-DI index, prices of December 2003; Discount rate of 12%.

To summarize the results, table 6 presents NPV, IRR and BCR of the four assessed technologies. As can be verified in table 6, all analyzed technologies have positive attributes (NPV > 0; IRR > 12%; BCR > 1).

Table 6. Net present value, internal rate of return and benefit-cost-ratio of analyzed technologies.

Assessed technology	NPV (R$)	IRR (%)	BCR
a) Finishing of lambs in confinement in the Brazilian semi-arid Northeast during the dry season, when feeding resources are scarce and the lamb meat prices are higher	733,168.21	26.2%	2.92
b) Strategic vermifugation of goat herds and sheep flocks in the Brazilian semi-arid region	579,154.38	13.8%	1.19
c) Standardized cuts for goat and sheep carcass	3,743,065.52	52.8%	11.64
d) Enrichment of the native pastures in Brazilian Northeast with *Cynodon dactylon* for sheep production	3,285,454.43	31.0%	3.37

NPV: Net Present Value; IRR: Internal Rate of Return; BCR: Benefit-Cost-Ratio. Exchange rate: 1.00 US$ = 3.03 R$.

Technologies like ‘standardized cuts for goat and sheep carcass’ represent a very positive option for resource allocation due to the low resources needed and the high economic impacts achieved by using it (IRR: 52.8%; BCR: 11.64).

Conclusions and recommendations

Embrapa’s research and development activities represent economically efficient options of resource allocation.
Economic impacts of new technologies are measurable and give important information for decision making on resource allocation options.
Research institutions should concentrate their efforts on research activities that may lead to technologies which increase productivity, reduce costs and improve quality.
Funding institutions may include the assessment of economic impacts of research activities as a condition to analyze future applications for research funding in order to ensure a more efficiently use of scarce resources.

References

Alston, Julian M., Norton, George W., Pardey, Philip G. (1998). Science under Scarcity. Wallingfor, UK: Cab International. (First published in 1995 by Cornell University Press).

Ávila, Antônio Flávio Dias. (2001). Avaliação dos Impactos Econômicos, Sociais e Ambientais da Pesquisa da Embrapa: Metodologia de Referência. Embrapa, SEA.

Gittinger, James Price. (1982). Economic Analysis of Agricultural Projects. 2nd edition. Baltimore, London: The Johns Hopkins University Press. (EDI Series in Economic Development).

Maredia, Mywish, Byerlee, Derek, Anderson Jock. (2000). Ex Post Evaluation of Economic Impacts of Agricultural Research Programs: A Tour of Good Practice. Paper presented to the Workshop on "The Future of Impact Assessment in CGIAR: Needs, Constraints, and Options", Standing Panel on Impact Assessment (SPIA) of the Technical Advisory Committee, Rome, May 3-5, 2000.

Masters, William et al. (1996). The Economic Impact of Agricultural Research: A Practical Guide. Department of Agricultural Economics, Purdue University, West Lafayette, IN.

Pardey, Philip G., Vosti, Stephen A., Alston Julian M., Chan-Kang, Connie, Magalhães, Eduardo C. Calculando e Atribuindo os Benefícios da Pesquisa de Melhoramento de Variedades: O Caso da Embrapa. Brasília-DF, Brazil: Embrapa Informação Tecnológica, 2002. 248p.

Wander, Alcido E., Magalhães, Marília C., Vedovoto, Graciela L. Economic Impacts of New Technologies: A Case Study of EMBRAPA. In: 3RD INTERNATIONAL RECALL-SYMPOSIUM-CUM-WORKSHOP: GLOBALIZATION AND POVERTY - THE ROLE OF SCIENCE, 2003, Recife-PE, Brazil. (Proceedings in edition - publication forthcoming)