Impact assessment of agricultural innovations: a review

Evaluación del impacto de las innovaciones agrarias: una revisión

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ABSTRACT

The current conditions of the markets and favorable policies, as well as the progress of science and communications, are promoting further development and diffusion of agricultural innovations, which have effects on different areas of agrarian development. The objective of this paper is to present a review of characteristics of agricultural innovations and their diffusion, adoption and impacts, as well as an update of the types and methods of assessment. Agricultural innovations are not only new or improved products, they are also models and systems, and should have a positive social effect. Innovation areas in developing countries are more concentrated on production and distribution, whereas developed countries concentrate on offering inputs. Investments from the private sector in agricultural innovations are growing faster than those from the public sector. The adoption of innovations is medium-term, and usually less than 100%. The impact of innovations includes intermediate areas, such as institutional, political, scientific and productive areas. The economic efficiency of the investment in innovations is the most often mentioned purpose of impact assessments in the literature. The efficiency analysis (*ex-post*) and its surplus approach is still the most used method for assessing impact of agricultural innovations. Nevertheless, other goals are becoming more important, such as food security, environmental protection and poverty reduction. Livelihood, comprehensive and multidimensional approaches go beyond the economic approach. Moreover, specific models with advantages of prognosis and improved precision are replacing or complementing the classic socio-economic approach.

Key words: diffusion, adoption, benefit-cost analysis, economic surplus approach, models.

RESUMEN

Las condiciones actuales de los mercados y políticas favorables, así como los avancesde la ciencia y la comunicación están promoviendo el desarrollo y la difusión de las innovaciones agrarias. Estos tienen efectos en las diferentes áreas del desarrollo agrario. El objetivo de este trabajo es presentar una revisión de las características de lasinnovaciones agrarias y su difusión, adopción e impacto, así como una actualización de los tipos y métodos de evaluación. Las innovaciones agrarias no son sólo los productos nuevos o mejorados, sino también los modelos y sistemas, que deben tener un efecto social positivo. Las innovaciones en los países desarrollados están más concentrados en la producción y la distribución, mientras que en los países en desarrollo se concentran más en la oferta de factores de producción. Las inversiones del sector privado en las innovaciones agrarias están creciendo más rápido que las del sector público. La adopción de las innovaciones es a medio plazo, y por lo general menoral 100%. El impacto de las innovaciones incluye áreas intermedias como el institucional, político, científico y productivo. El rendimiento económico de la inversión en innovación es el objetivo de la evaluación de impactomás mencionado en la literatura. El análisis de eficiencia (*ex-post*) y su enfoque del excedente económico sigue siendo el método más utilizado para evaluar el impacto de las innovaciones agrarias. Sin embargo, otros objetivos son cada vez más importantes, como la seguridad alimentaria, la protección del medio ambiente y la reducción de la pobreza. Lo que son medios de subsistencia, enfoques integrales y multidimensionales van más allá del enfoque económico. Por otra parte, modelos específicos con ventajas en pronóstico y mayor precisión están sustituyendo o complementando el clásico enfoque socioeconómico.

Palabras clave: difusión, adopción, análisis de costo-beneficio, enfoque de excedentes económicos, modelos.

Introduction

Innovation is a concept often used at the present, especially in the realms of business, technology and academia. It solves problems, satisfies needs and provides greater benefits for producers and other enterprises, as well as for consumers, organizations and society. In the agricultural sector, the development and offer of innovations have increased because of the favorable conditions of markets, national policies and access to scientific knowledge. The public and private sectors promote the generation, diffusion and adoption of agricultural innovations through investments in private firms, universities, semi-state and state research institutions. When one needs to know if

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the innovation investments have had the expected results, one looks at the information of impact assessments. The estimation of effects or impacts of innovations, before or after their adoption, provides valuable information for decision-makers of businesses, organizations, sectors and geographical units. In the present document, reviews of some characteristics of diffusion and adoption of agricultural innovations, as well as their impacts, are presented. Moreover, possible reasons for and the timing of impact assessments are discussed, as well as the types and methods that currently exist.

Agricultural innovations

From the concept of innovation to the concept of agricultural innovations

Joseph Schumpeter, who formally addressed this issue and developed a theory about innovation in 1939, defined it as a new combination of production inputs, which result in a new product, a new production method, a new market, new raw material sources, or a new position in the market (Schumpeter, 1939; Weber, 2000). Many authors have extended the original concept, such as in scope (before and after production) as well as categorization (radical to imitative), identification (new or improved) and purpose (European Commission, 1995; Garcia and Calantone, 2002; OECD and EUROSTAT, 2005; World Bank, 2007; Greenhalgh and Rogers, 2010). The current concept applied to agriculture allows for defining agricultural innovations as a new or improved product (either a good or a service), process, system or model, created for consumers, enterprises, value chains, markets or organizations to achieve the goals of the agricultural sector. This concept implicitly contains the idea that innovations should be environmentally-friendly and should offer economic as well as social benefits. According to Wright and Shih (2010), agricultural innovations are created for more yield, quality and quantity of production, as well as for the diversification of products and lowering of prices for consumers.

The most important areas of agricultural innovations

The areas of agricultural innovations with the highest relevance are somewhat different in each country. They depend on the priorities set by governments and markets. After a review of the panorama of innovations in Colombia (Uribe *et al.*, 2011), Germany (Bokelmann *et al.*, 2011), India (Srinivasan and Jha, 2002), and Mexico (Herrera, 2006), one can say that in general, developing countries are focused on providing agricultural products of higher quality and diversity as well as on making the production and distribution processes more efficient, improving the working conditions of employees and reducing the environmental impact. While developed countries are more interested in offering innovations in production inputs to cover domestic needs and the demand of international markets, as well as in areas related to the generation of alternative energies based on agricultural production.

The private sector is increasing its investments in agricultural innovations

The national system of innovation is economically and politically supported by governments (Carlsson, 2006; Chung, 2002; OCDE and EUROSTAT, 2005). In 2002, in India, 85% of investments for research came from the state, the other 15% from the private sector. Nevertheless, between the mid-1990s and 2009 the seed and plant biotech industry grew more than tenfold, but growth was also very rapid in agricultural machinery, animal health, sugar and biofuel (Srinivasan and Jha, 2002). According to Morris *et al.* (2003), of 1,000 maize breeders worldwide, 60% worked in the public sector and 40% in the private sector, 60% of them were in multinational companies. Causes for this phenomenon are: increasing demand for agricultural products and inputs, introduction of liberalization policies for private investment in agriculture, progress in the basic sciences and engineering for private technology development, strengthening of intellectual property rights, and state investment in agricultural research and higher education (Pray and Nagarajan, 2012). The participation of the private sector in generating agricultural innovations seems to be higher in those countries where the economic, scientific and political conditions are favorable, such as in developed countries. The private sector focuses principally on the market. From there on, it develops agricultural innovations more rapidly and diversely and usually more cheaply than the public sector. However, it should be taken into account that the private sector develops agricultural innovations based on its economic interests first. Furthermore, access to the knowledge and information that have been generated while developing innovations is limited for the public.

Impact of agricultural innovations

Desirable, direct, anticipated and medium-term impacts are the most known

The impacts or consequences of adoption of innovations are classified through different criteria. According to Rogers (1995), Kelley *et al.* (2008) and Airaghi *et al.* (1999), the impacts based on their effects can be:

- desirable (positive) or undesirable (negative),
- direct or indirect,
- primary or secondary,
- anticipated or unanticipated, and
- short-term, medium-term or long-term.

The types that are more often assessed are: desirable, direct, primary, anticipated and medium-term impacts. However, in the last two decades, negative and indirect impacts, as well as unanticipated and long-term ones, have received special attention for assessment because of their importance in social, economic an environment areas (Espinoza, 2007; Maxwell *et al*., 2012; Mutuc *et al*., 2012).

The areas of impact are more than just social and economic

Focusing on assessment areas, the impact of adopted innovations is approached by areas and lines (Tab. 1). The final impact types are social and economic. Sometimes the environmental impact is also considered as a final impact type, but in the end, it leads to the social and economic impacts too.

The most widely-known impact types were the social and economic ones, but in the beginning of 1990s, the environmental type also started to gain importance, which, together with the scientific, political and institutional types, is considered an intermediate impact, because in the end they have social and economic consequences, and these define the welfare of a society.

Assessment of impact of agricultural innovations

Different purposes of impact assessments

The general purpose of an assessment of an agricultural innovation was to know if it has produced the desirable effects, where they were needed (Paz *et al*., 2006). This complex and frequently expensive process has focused mainly on demonstrating the positive results of the innovation, and the well-done work of its developers and diffusers. Most of the assessments were dedicated to the determination of the rate of adoption of the innovation and the economic benefits of its investment. In this way, one was able to show the credibility of the research institution and assure new findings (Horton *et al*., 1993; Peterson and Horton, 1993; Airaghi *et al*., 1999; Anandajayasekeram and Babu, 2007; Blazy *et al*., 2010). However, nowadays, there are more reasons to assess innovations, such as searching for unexpected effects of innovation, feedback for researchers and research institutions, identifying defects in the development and diffusion of innovation and learning from them, as well as deriving strategic and programmatic lessons that provide for future investment, providing information for management decisions, to determinate external effects of innovation, prioritize the best investments, and promote and manage new and ongoing research (Horton *et al*., 1993; Airaghi *et al*., 1999; Pingali, 2001; Baur *et al*., 2003; Blazy *et al*., 2010; Crespi *et al*., 2011).

TABLE 1. Types of impact and their lines.

Types of impact		Lines of impact
Intermediate (cause and effect)	Scientific	New techniques or methods. Diffusion of new knowledge through publication in high-quality journals and thesis. Feedback to researchers. Interchange of knowledge.
	Political	Enactment or change of laws. Imposition or change of requirements, levies, permits and regulations. Creation of new plans and programs.
	Institutional	Changes in organizational structure. Changes in the number of scientists. Changes in the composition of the research team. Changes in program funds. Changes in the participation of public and private sectors. Multidisciplinary approaches and improvements. Improving communication and knowledge transfer. Improving capacity for research and transfer.
Intermediate	Productive	Increasing yield and production. Improving quality of product. Increasing diversity of products. Efficiency of use of inputs. Increasing flexibility of production. Improving production systems.
Intermediate (sometimes final)	Environmental	Soil erosion, degradation and compaction. Soil, water and air contamination. Effects on biodiversity. Changes in hydrological cycles. Production of greenhouse gases. Effects of climate change. Genetic contamination. Loss of natural vegetation.
Final (welfare)	Economic	Generation of employment. Increasing incomes. Reduction of costs. Increasing benefits. Improving prices. Increasing participation in the market. Entering new markets. Increasing demand and offer. Rate of return Reducing risk. Distribution of benefits by gender, income group and allocation.
	Social	Improving food security. Improving nutrition. Reduction of poverty. Quality of work conditions. Women participation and status. Improving knowledge on an innovation. Health of workers. Increasing free time for the producers and their family. Rural migration. Creation and changes among organizations. Creation and changes in social networks.

Sources: Based on Pefile, 2010; OECD and Eurostat, 2005; Pingali, 2001; Ortiz and Pradel, 2009; Mutuc *et al.*, 2012; Maxwell *et al.*, 2012; Janssen *et al.*, 2009; Oehmke and Crawford, 1996; Peterson and Horton, 1993; Anandajayasekeram and Babu, 2007; Hemmelskamp, 1997; Utting, 2009; Ortiz and Pradel, 2009; Esterhuizen, 2007; Vedovoto *et al.*, 2010.

Adoption is a long-term process and sometimes only partial

According to Peterson and Horton (1993), an assessment is a long process that can last between 10 and 15 years. Reilly and Schimmelpfennig (1999) found that the adoption of a new variety of crop could take between 3 and 14 years, the adoption of dams and irrigation from 50 to 100 years, irrigation equipment from 20 to 25 years, fertilizer 10 years, and transportation systems from 3 to 5 years. Durable or capital goods and complex technology take more time to be adopted than transitory goods or simple technology. In Tab. 2, the time considered to achieve the desirable adoption lasts from 4 to 41 years. The same Table shows a range of the adoption rate from 10 to 100%, but most of them are lower than 100%. Romero (2009) found, in an assessment study, an adoption rate of from 6 to 94%, and Laxmi *et al.* (2007), in a study on Tillage in India, expected an adoption rate of less than 35%. That is because, in most cases, the innovations cover only a part of the market.

Despite all efforts to spread the innovations, there are cases in which the degree of adoption does not reach 100 %. That is common with innovations which are constituted by more than one component, such as the Integrated Pest Management (IPM) that has many methods for controlling plagues; some of them are not adopted by the producers for different reasons (Tab. 2). One of these reasons is the type of innovation adopters. Not all of them adopt the innovation at the same time (Fig. 1), and when there is not enough time, some of them do not adopt or adopt only partially (Rogers, 1995).

Most of the impact assessments are of a comprehensive type with a strong economic trend

Impact assessments can occur in two stages, before (*ex-ante*) or after (*ex-post*) the process (Fig. 2), which is comprised of the research, development, diffusion and adoption of innovations. Based on Anandajayasekeram and Babu (2007) and Tab. 1, there are six types of assessment: economic, social, environmental, productive, institutional and political. The first four could be carried out at the level of people. When the institutional and political types are included; one is speaking about comprehensive assessments. Tab. 2 allows one to see that the economic assessment was present in all cases; in 18%, there were the socio-economic and productive types, in 25%, the socio-economic and environmental assessments, and in 14% the socio-economic, productive and environmental types. In only a few cases, can one see the political and institutional assessments. On the other hand, almost all cases have two or more types of assessment, with a slight trend for another type of assessment: the comprehensive assessment.

Methods of impact assessment

For assessing the impact of agricultural innovations, Ortiz and Pradel (2009) proposed a sequence of steps:

I. Choice of the stage of the innovation.

II. Choice of the type of impact for the assessing.

III. Choice of the type of comparisons for the assessing.

IV. Definition of population and sample.

V. Definition of indicators for each type of impact.

VI. Collection of baseline information.

VII. Analyses of information.

The types of impact that will be assessed also define the assessment method.

Employed methods of impact assessment based on past and future frames

Almost 60% of the cases from Tab. 2 analyzed the effects of agricultural innovations after the process of research,

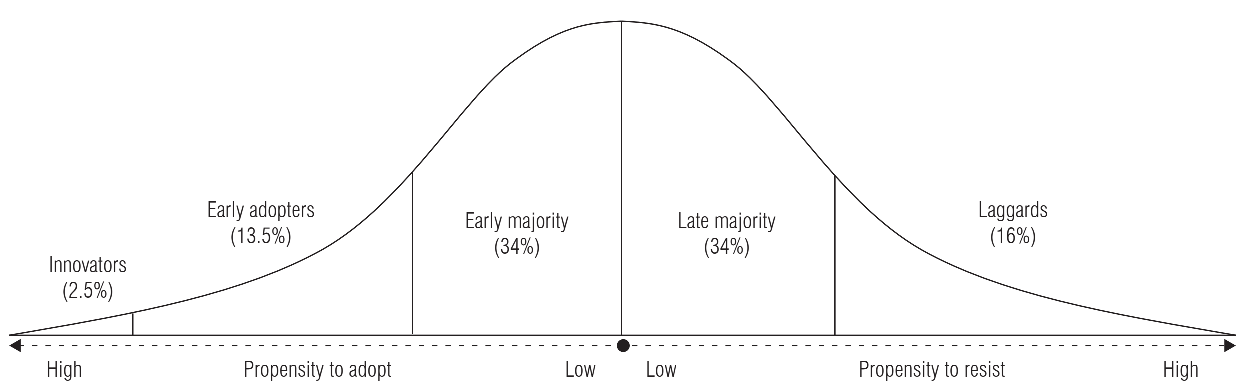

FIGURE 1. Types of adopters and their percentage distribution. Source: Robinson, 2009.

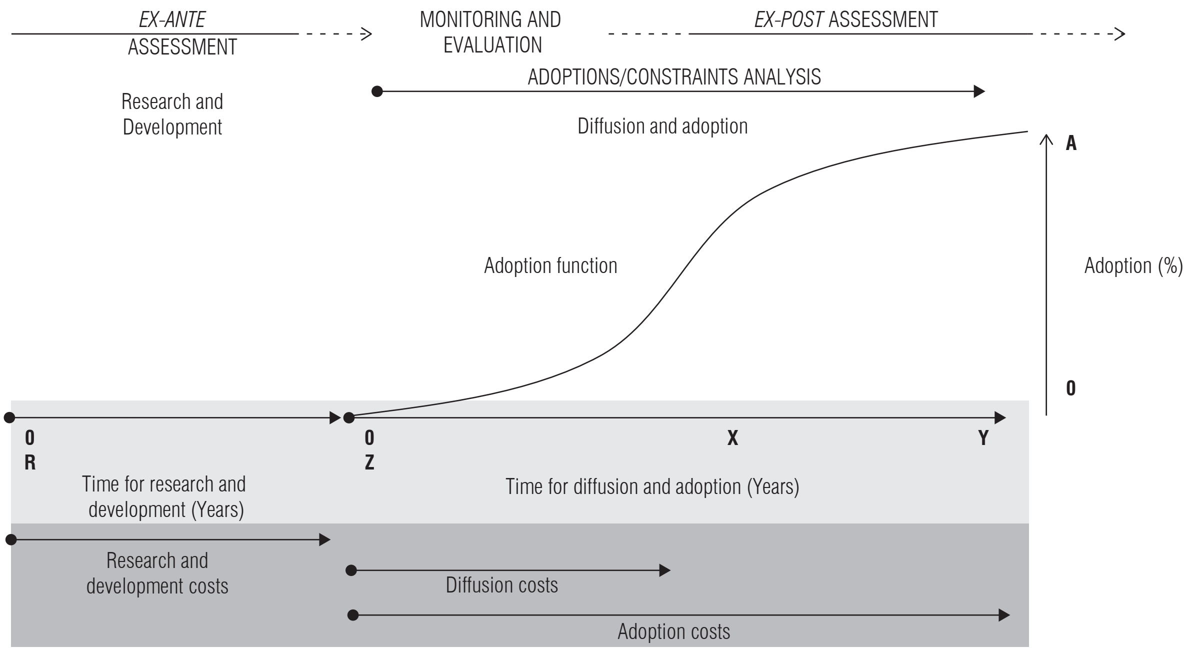

FIGURE 2. The impact assessment in relation to the research, development, diffusion and adoption of an innovation. Source: Adapted from Kelley *et al.*, 2008; Thorne *et al.*, 2002.

TABLE 2. Results of 28 cases of impact assessments.

Nr.	Author	Country of the study	Innovation	Time range of the analysis	Adoption		Assessment methods	Analyzed areas*	Economic results		
					Rate (%)	Grade (%)			ROR (%)	IRR (%)	CBA (%)
1	Fonseca *et al.* (1996)	Peru	New variety of potato (Chanchan).	1979-2020	11		Cost-benefit analysis approach.	Ec/Pr		26	
2	Unda *et al.* (1998)	Ecuador	IPM in potato cultivation.	1992-2012	97	61	Cost-benefit analysis approach.	Ec/So/Pr/En		34	
3	Campos and Beratto (2001)	Chile	New varieties of barley.	1978-1999	15-85		Cost-benefit analysis approach.	Ec/Pr	52		
4	Barea and Bejarano (2002)	Bolivia	IPM in potato cultivation.	1996-2020	10	77	Cost-benefit analysis approach.	Ec/So/Pr		48-70	
5	Calderón *et al.* (2002)	Bolivia	New method to produce potato seed.	1991-2012	49	20-70	Cost-benefit analysis approach.	Ec/So/Pr		54	
6	Esprella *et al.* (2002)	Bolivia	IPM in potato cultivation.	1989-2012	46	50 - 60	Cost-benefit analysis approach.	Ec/So/Pr		18	1.5
7	Fonseca *et al.* (2002)	Peru	New varieties of sweet potato	1991-2019	90		Cost-benefit analysis approach + sensibility analysis.	Ec/Pr		44-45	
8	Gabriel *et al.* (2003)	Bolivia	IPM in potato cultivation.	1992-2020	11	40	Cost-benefit analysis approach.	Ec/So/Pr/En		47	
9	Bejarano *et al.* (2004)	Bolivia	IPM in potato cultivation.		15	84	Cost-benefit analysis approach.	Ec/So/Pr			
10	Anandajayas-ekeram *et al.* (2007a)	Zimbabwe	New variety of sorghum	1988-1999	25		Economic surplus ap-proach + sensitivity analysis.	Ec/Pr	25		
11	Anandajayas-ekeram *et al.* (2007b)	Namibia	New variety of pearl millet	1986.-1995	65		Economic surplus ap-proach + sensitivity analysis.	Ec/So/Pr	4-13		
12	Bua *et al.* (2007)	Uganda	New varieties of cassava	1990-1999			Cost-benefit analysis approach.	Ec/Pr		167	18.2

* Ec = Economic, So = Social, Pr = Productive, En = Environmental, In = Institutional, Po = Political

Continúa

Nr.	Author	Country of the study	Innovation	Time range of the analysis	Adoption		Assessment methods	Analyzed areas*	Economic results		
					Rate (%)	Grade (%)			ROR (%)	IRR (%)	CBA (%)
13	Dias and Sain (2007)	Latin America	Several agricultural innovations	1999-2004			Economic surplus approach.	Ec/So/Pr/ En/In/Po		25	3.3
14	Esterhuizen (2007a)	South Africa	Proteaceae	1974-2005			Comprehensive approach.	Ec/So/En/ Po	8		
15	Esterhuizen (2007b)	South Africa	Biological control of *Prosopis species*	1986-2010			Effectiveness and efficiency analysis.	Ec/Pr/En	119		
16	Karanja (2007)	Kenya	Maize seed and production technology	1955-1988			Cost-benefit analysis (Productions function approach).	Ec/Pr/In/Po	39-68		
17	Laxmi *et al.* (2007)	India	Zero Tillage in rice-wheat systems.	1998-2014	50-90		Comprehensive analysis + economic surplus approach.	Ec/So/Pr/En		57	39
18	Marasas (2007)	South Africa	Russian wheat aphid integrated control	1980-2005	46		Economic surplus approach.	Ec/Pr/En	22-27		
19	Mazhangara *et al.* (2007)	Zimbabwe	Groundnut research	1966-2000	45-100		Cost-benefit analysis approach.	Ec/So/Pr/En	59		
20	Moshi *et al.*(2007)	Tanzania	New varieties and management of maize.	1976-1994	24-81		Economic surplus approach.	Ec/So/Pr/ En/Po	19-23		
21	Mudhara *et al.* (2007)	Zimbabwe	Cotton research	1970-1995			Cost-benefit analysis approach + sensitivity analysis.	Ec/So/Pr/ En/Po	47		
22	Murata *et al.* (2007)	Zimbabwe	Sunflower research	1976-2000	25-50	> 80	Comprehensive conceptual framework.	Ec/So/Pr/ En/Po	6-29		
23	Niederwieser (2007)	South Africa	Lachenalia research	1965-2010			Comprehensive impact assessment.	Ec/So/En/ Po	8-12		
24	Randela (2007)	South Africa	Control of Ticks and Tick-borne Diseases				Cost-benefit analysis approach + sensitivity analysis.	Ec/So/Pr			0.8-1.2
25	Townsend and Van Zyl (2007)	South Africa	Wine grape research	1980-1994			Economic surplus analysis (Production function approach).	Ec	40		
26	Zegeye *et al.* (2007)	Ethiopia	Maize technology	1986-2000			Economic surplus analysis.	Ec/So/Pr/ En/In	29		
27	La Rovere *et al.* (2008)	Mexico	New varieties of maize, new technology to storage	2001-2006	44	17-44	Livelihood approach.	Ec/So/Pr			
28	La Rovere *et al.* (2008)	Nepal	New varieties of maize	2002-2006	62		Livelihood approach.	Ec/So			

* Ec = Economic, So = Social, Pr = Productive, En = Environmental, In = Institutional, Po = Political

Sources: Based on the information of each case presented here.

development, diffusion and adoption. However, the data from the past is also used to assess the future impact as evidenced by 35% of the presented cases. There are methods to assess the impact in the past (*ex-post*), the past and future; the past, ongoing and future; and the future (*ex-ante*).

The most used method to assess impact in agriculture is the economic surplus approach

Each method is applied according to each case and availability of resources and time. There are many methods to assess the impact of agricultural innovations. But most of them are in the economic and environmental areas (Tab. 2). Almost all cases in Tab. 2 used the economic surplus approach (for consumers and producers) and respectively, cost-benefit analysis (for producers). Both are expressed mainly through their well-known economic indicator: the rate of return (ROR). However, the effects of innovations are not only on ROR, and most impact assessments use a multi-criteria analysis with a variety of methods (Tab. 3).

Other methods and specific models are replacing or complementing the classic socio-economic methods

The economic benefit is not everything. Some innovations do not contribute significantly to enhancing the economic benefits, but do for the social and environment benefits (Praneetvatakul and Waibel, 2006). In this sense, the livelihood approach was developed, which considers different

TABLE 3. Types, techniques and methods of impact assessment in agriculture.

Type	Technique	Method	
Institutional and political impact	• Simple comparison • Trend analysis	• Survey • Monitoring of selected variables	
Productive impact	• Simple comparison • Target versus actual	Effectiveness analysis	• Logical Framework Analysis
Environmental impact	Various (need biophysical information)	Environmental impact assessment	• On-site market impacts • On-site non-market impacts • Off-site market impacts • Off-site non-market impacts
		• Risk assessment (RA) • Environmental risk mapping • Life cycle analysis • Multi-agent system • Linear programming • Agro-environmental indicators • SimaPro: ReCiPe, BEES, Eco-indicator 99, Eco-indicator 95,CML 92, CML 2 (2000), EDIP/UMIP, EPS 2000, Ecopoints 97, Impact 2002+, TRAC, EPD method, Cumulative Energy Demand, IPCC Greenhouse gas emissions	
	Qualitative and quantitative	Qualitative assessment	
Economic impact	Various	Efficiency Analysis (ROR)	**Ex-ante:** • Financial Analysis (FA) • Cost-effectiveness analysis (CEA) • Break-even analysis (BEA) • Business case calculations (BCC) • Benefit-cost analysis (CBA) • Multi-criteria analysis (MCA) • Scoring models • Simulation models • Mathematical programming models **Ex-post:** • Econometric approach marginal rate of return (MRR) • Surplus approach or Index Number Approach **Average Rate of Return (ARR):** • Benefit-cost approach **Index number approach using elasticities:** • Linear functions with parallel shifts • Linear functions with non-parallel shifts • Non-linear functions with parallel shifts • Non-linear functions with non-parallel shifts • Unit cost saving approach • Others
Social impact	Comparison over the time	• Socio-economic survey • Adoption survey • Monitoring of selected variable • Propensity Score Matching (PSM)	

Source: Based on Anandajayasekeram and Babu, 2007; Abele *et al.,* 2005; Goedkoop *et al.*, 2008; Heijungs, 1995; Payraudeau and Van der Werf, 2005; Lapar *et al.,* 2011.

types of impacts (direct and indirect) in areas such as food security, lack of assets, risk, and vulnerability (La Rovere *et al*., 2008). Also, the comprehensive approach (Anandajayasekeram and Babu, 2007) and the multidimensional approach (Dias *et al*., 2007) are used, which simultaneously assess various impact types. On the other hand, specific models to assess impacts *ex-ante* have been developed. For example, the SIMBA model assesses and compares the effects of many innovations on banana plantation farms. It is adaptable to other crops (Blazy *et al*., 2009). The BANAD model simulates the consequences of biophysical processes and economic-technical decisions in economic, technology and environmental areas of banana plantation farms (Blazy *et al*., 2010). The SEAMLESS-Integrated Framework model "assess, *ex-ante*, agricultural and agri-environmental policies and technologies across a range of scales, from field–farm to regions and the European Union, as well as some global interactions"(Van Ittersum *et al*., 2008).

Conclusions

Agricultural innovations are new or improved products for consumers, as well as models and systems for enterprises, organizations or institutions. They should have preferably positive social effects. The innovation areas in developing countries are more concentrated on production and distribution, and in developed countries, on offering inputs. The private sector is increasing its investments in agricultural innovations more than the public one. Innovations are adopted in the medium-term, and usually only by a part of the market. The impacts of innovations are social, economic and environmental, but include intermediate areas such as institutional, political, scientific and productive ones. The most mentioned purpose of impact assessments is showing the economic efficiency of the investment in innovations, however, social, environmental, institutional and political goals are becoming more important. Over half of the impact assessment types are *ex-post*, but *ex-ante* analysis is gaining more relevance than before. For investors, assessing the socio-economic impacts is essential. In this sense, efficiency analysis (*ex-post*) and its surplus approach are still the most used type to assess innovations. But other approaches are gaining relevance because of their social and environmental goals, such as livelihood, comprehensive and multidimensional approaches. Moreover, specific mathematical models for crop, farm and sector analysis, with improved precision and advantages for prognosis, are replacing or complementing the classic socio-economic approach.

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