General lines to build a model of innovation impact assessment processes addressed to agricultural research organisations

Linhas gerais para construção de um modelo de avaliação de impacto da inovação aplicável a organizações de pesquisa agropecuária

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ABSTRACT
This article is focused on a conceptual model of the innovation impact assessment process, especially directed to agricultural research organisations. This research proposes an existing methodology based on a literature review. The innovative contributions of this article are I. theoretical lines for constructing a model of impact assessment as a base for a future data-based management system; II. a conceptual base of innovation impact assessment process that considers a cross-cut view of sustainability, integrating the environmental, social, policy, and economic dimensions. This article intends to present a theoretical model addressed to research and innovation organisations that will contribute to fulfilling the United Nations' sustainable development goals towards more productive and sustainable agriculture and accomplishing stakeholder challenges and demands.

Keywords: Agricultural Research. Impact Assessment. Innovation. Sustainability.

RESUMO
Este artigo está focado em um modelo conceitual de avaliação de impacto, especialmente direcionado a organizações de pesquisa agropecuária. Baseado em revisão de literatura, suas contribuições inovadoras são: I. linhas teóricas para a construção de um modelo de avaliação de impacto como base para um futuro sistema de gestão; II. uma base conceitual para avaliação de impacto de inovação que leva em conta uma perspectiva transversal de sustentabilidade, integrando as dimensões ambiental, social, política e econômica. O artigo apresenta um modelo teórico aplicável a organizações de pesquisa e inovação em sintonia com os Objetivos de Desenvolvimento Sustentável das Nações Unidas, bem

como buscando uma lógica sistêmica que atenda aos desafios e demandas das partes interessadas da instituição de pesquisa.

Palavras-chave: *Pesquisa Agropecuária. Avaliação de Impacto. Inovação. Sustentabilidade.*

1 INTRODUCTION

Innovation impact assessment is important in adjusting institutional policies and setting research priorities for project leaders, top managers, and their stakeholders.

In this context, agricultural research institutions are imbued to generate innovation for the sector. Initially, verification of how the organisation reaches and impacts its target audiences, how it affects farmer's profits and supply chains, and the degree of benefits it may generate will be necessary. As such, it is important to evaluate the impact severity level and how it affects the environment in farms, the supply chain, and society's quality of life. Positive and negative effects must be evaluated by considering the organisation's health, society, and environment (ASIF *et al.*, 2011, p. 353-367).

After some literature reviews on corporate impact assessment, it was clear that innovation impact assessment methodologies could be increased (ASIF *et al.*, 2011, p. 353-367; BARROS DE MENDONÇA; LAQUES, 2017). We have observed that systemic cross-cut perception sustainability and setting different scales about sustainability components could be introduced. In this respect, according to the Cato (2009, p. 36-37) approach, we understand that the environmental dimension is more important than the social dimension and that this one is more important than the economic dimension. Under a reverse view, if we destroy or mismanage the ecological environment, we are going to weaken the social quality of life that, consequentially, will affect the health of the economy.

As a management tool, it is expected that this proposed new impact assessment model will facilitate technological innovation processes to fit into the sustainability concepts and inserted by a unique managerial system. This innovation conception is expected to help agricultural research organisations better serve the productive sector in producing healthy food for local and global demands. Generating safe food attends the objectives of food security, by enlarging sustainable production processes, according to the parameters established by the World Health Organization (WHO, 2006) and the United Nation's sustainable development goals.

This article is structured in four parts: introduction, materials and methods, results, and discussion.

2 MATERIAL AND METHOD

2.1 MATERIAL

Material is based on a literature review according to the following steps.

2.1.1 THE ROLE OF RESEARCH & INNOVATION TOWARDS SUSTAINABILITY PRODUCTION

Nowadays, organisations must replace their old practices with low sustainability rates with principles, objectives, and guidelines capable of leading to sustainable development. This replacement depends on sustainable innovation. Moreover, this new attitude goes through all types of organisations, an essential condition for it to remain alive in an increasingly dynamic and demanding market environment for social and environmental responsibility (BARBIERI *et al.*, 2010, p. 146-154).

When evaluating research related to agricultural production, it is not enough to assess production processes and outputs; instead, innovation impact assessment is the key point for identifying farmer's, industry's, and consumer satisfaction and improving producer's quality of life, profitability and the effects on the environment, that is, innovation impact assessment goes beyond outcomes. Hence, a major goal of agricultural research organisations has been developing impact evaluation processes (ALSTON; NORTON; PARDY, 1995).

The evaluation must consider *ex-ante* and *ex-post* analysis, focusing on sustainability impacts and considering their continuous improvement - reducing negative and increasing positive effects (CRAIG, 2002, p. 282-311).

Sustainability reports and Social Responsibility reports represent a track to demonstrate how an organisation has been more or less sustainable by appraising the impact of its performance and results on society, the economy, and the environment (BARROS DE MENDONÇA; LAQUES, 2017).

2.1.2 INNOVATION: BASIC CONCEPTS

The Oslo Manual (INSEE, 2016) indicates some innovation categories: product innovation, process innovation, organisational innovation, and marketing innovation. For Planing (2017), an invention must arrive at the market, but that is not enough. Innovation comes from interactions within a collective of actors that allows the mobilisation of different types of knowledge - scientific and non-scientific (BARRET *et al.*, 2018). Social innovations represent new solutions for products, processes, services, technologies, and models, simultaneously meeting a social need (PISANO; LANGE; BERGER, 2015).

"Innovation is the process of making changes to something established by introducing something new. As such, it can be radical or incremental, and it can be applied to products, processes or services and in any organisation" (O'SULLIVAN, 2008, p. 3).

In the present day, integrating sustainability (through its social, ecological, and economic dimensions) in innovation projects becomes an essential condition for attuning to markets and the demands of society (BROOK; PAGNANELLI, 2014, p. 46-62).

2.1.3 IMPACT ASSESSMENT DEFINITIONS

The impact is conceptualised as "positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended" (OECD, 2002).

The high quantity of terminologies, approaches and analyses on impact evaluation creates a dispersion and disintegration in understanding this issue. They are biodiversity impact assessment; climate change impact assessment; economic evaluation; environmental impact assessment; environmental, social, and health impact evaluation; these represent just some of a long list of approaches to impact evaluation that indicates how large the scope of this issue has become (POPE; ANNANDALE; MORRISON-SAUNDERS, 2004).

However, the above list could be completed by adding a research impact assessment - RIA. According to the International School on Research Impact Assessment, the importance of research impact assessment is growing, and research organisations must meet the requirements of donors who invest in research and expect economic and social returns (ISRIA, 2017).

Many organisations have adopted several ways to evaluate their research impacts, including in the agricultural field, for instance, the Consultative Group for International Agricultural Research (CGIAR), the Brazilian Agricultural Research Corporation (EMBRAPA, 2015), the Economic Research Service (ERS) of the United States Department of Agriculture (USDA) and the Commonwealth Scientific and Industrial Research Organization for Australian Research - CSIRO (JOLY *et al.*, 2016).

It is possible to identify a template below (Figure 1) that represents a general model of innovation impact assessment, which will serve as the basis for the new and future model to be drawn in Part III of this article. The figure was adapted from Kuby's (1999) scheme and Dowthwaite's *et al.* approach (2003), and it demonstrates a complete systemic vision of impact assessment from the planning phase to the effect phase, which means the stages after an organisation produces its technologies and their absorption by producers and clients as well as its immediate consequences to the economic, social and ecological environment.

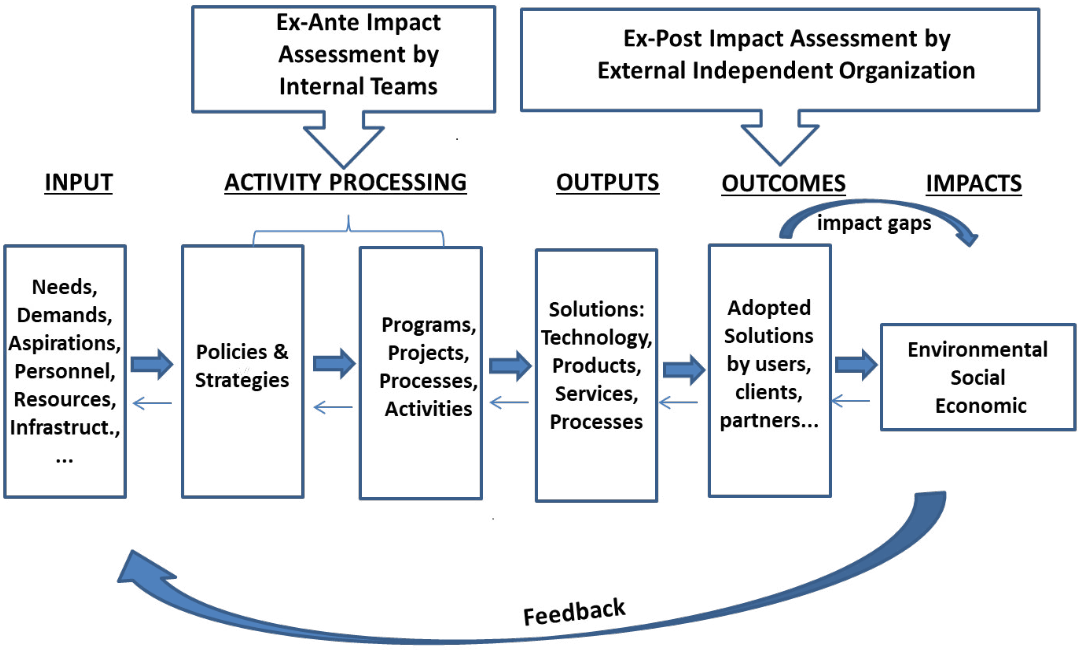

Figure 1 | General Model of Impacts Pathway (Adapted from GTZ Impact Model - KUBY, 1999)

In addition, the effect phase considers the long-term impacts on the economy, society, and environment, which could be named impact gaps and lagged impacts because it is difficult to determine when impacts will happen and whether they will generate simple or complex, direct or indirect effects.

2.1.4 THE IMPORTANCE OF A CONCEPTUAL MODEL FOR INNOVATION IMPACT ASSESSMENT

i) Some Approaches about System, Model, and Conceptual Model

The system can be defined as a set of components that interconnect and interrelate with each other so that their parts form a whole, and this interaction provides some logical purpose, generating final effects over a certain time, with some regularity, forming a network of causes and effects. These components can be objects, equipment, information, people, or even other systems, that is, subsystems. These components can be either fixed or transient. The system has boundaries, and both its internal and external part is called the system's environment (BUCKLEY, 1976, p. 9-68; LAW; KELTON, 1991).

A theoretical model is a hypothetical and theorised reference that analyses a concrete reality and uses it as a baseline for application in the practical world or for developing others (JAPIASSU; MARCONDES, 1989).

ii) Impact Assessment Integrative View: a cross-cut focus

According to Bantilan *et al.* (2014), assessment implies in the quantitative and qualitative analysis, making estimates or valuation and can be focused on four objectives: assessment of the processes; assessment of generated products/services (outputs); assessment of generated outcomes; assessment of generated innovation's impacts to the environment, economic, and society (farmers, industries, services - supply-chain, local, regional and national governments, stakeholders, shareholders, and consumers).

Impacts have three dimensions to be considered (BANTILAN *et al.*, 2014):

- the space scale (local, intra-regional, national, and international);
- the time scale (short, mid, and long-term of effect, as well as passing time or continuous effect), and
- the grade of impact or the intensity scale (low, mid, or high intensity).

All these approaches based on systemic and holistic views give references for a cross-cut focus in the proposed impact assessment model (JAPIASSU; MARCONDES, 1989).

During the impact assessment process, stakeholder participation is essential to guarantee the success of the process and its results (LUYET *et al.*, 2012). This approach has already been demonstrated by the interaction between stakeholder groups, such as civil society, farmers, scientists, and technicians, in rural governance processes (WILSON, 2004).

Despite the search for existing models and, considering the citations of concepts and approaches exposed so far on models of impact assessment of technological innovations, we observed gaps regarding models that consider and deepen the impacts on the following aspects: watersheds; soils; improvement of the quality of life for producer's and their families; farmers profitability; effects on national GDP. We also identified fragile approaches on the impact pathways along the supply chains and, mainly, the absence of indicators that allow a sustainability index from the technological innovations adopted. These and other aspects must be considered in the conceptual model proposed here.

2.2 METHOD

This work adopts a general methodological strategy called "method of development strategy" (CONTANDRIOPOULOS *et al*., 1994, p. 41), which aims to improve some specific technology, which in this article means: the model of innovation impact assessment.

The modelling process started with developing a proto-model based on the literature review, my assumptions, theoretical choices committed to sustainability principles, and achieving an integrated view.

This methodological strategy is presented as a research strategy that aims to use existing knowledge systematically, elaborate a new intervention, considerably improve an existing intervention, or elaborate or improve an instrument, a device, or a method of measurement, including improvements within a qualitative perspective. It means that this proto-model is a pre-conceived framework to support and guide the analysis of the experiences and helps select what should be inspected in each case-study institution during the following steps (CONTANDRIOPOULOS *et al*., 1994, p. 41).

As such, this article is based on a literature review and a critical analysis to reach the final conceptual model of an innovation impact assessment process.

Literature review represents the essential theoretical base as input for enriching knowledge on the recent discussions (from books and papers) towards new information and concepts on impact assessment and associated knowledge, allowing a broader and deeper discussion on the theme. Therefore, a literature review was carried out on impact assessment (economic, social, policy, and environmental), processes of innovation, and sustainability.

3 RESULTS

The concepts described here are already reflections of the summary of a previous selection of several other concepts, which means that the proposed innovation impact assessment model includes the positive aspects of those concepts.

3.1 THE PROTO-MODEL: A CONCEPTUAL BASE FOR AN INNOVATION IMPACT ASSESSMENT PROCESS

The proto-model was developed based on the literature review and, from now on, aims to serve as a parameter for the innovation impact assessment model to be constructed. After analysing four research organisations' innovation impact assessment experiences, the next step is to improve the proto-model, passing by the benchmarking approach to arrive at a model as ideal as possible to be applied by research institutions. The following citations summarise the significant structural aspects for fitting the proto-model framework.

The United Nations Sustainable Development Goals (SDG) show that within the 17 Goals, 7 have a direct or indirect relationship with agricultural activity. Particularly, research and innovation organisations have a key role in reaching SDG 2 (Zero Hunger) and 12 (Responsible Consumption and Production), while food production must be increased by a sustainable way of production (UN, 2015).

To avoid bias in research teams, the impact assessment system must be impartial, driven by independent and external teams, and focus on the impacts pathway (MERGAERT; MINTO, 2015; UNDG, 2011).

The Proto-Model, as shown in Figure 2 below, was developed from the literature review, and it represents the conceptual framework on which the model of the innovation impact assessment management system is supported. The Proto-Model demonstrates that the impact assessment system is an open system, with a high degree of interaction between the internal organisational environment (of the research institution) and the environment, social, policy, and economic dimensions, including stakeholders, clients, and users of innovation's solutions as well as the external environment.

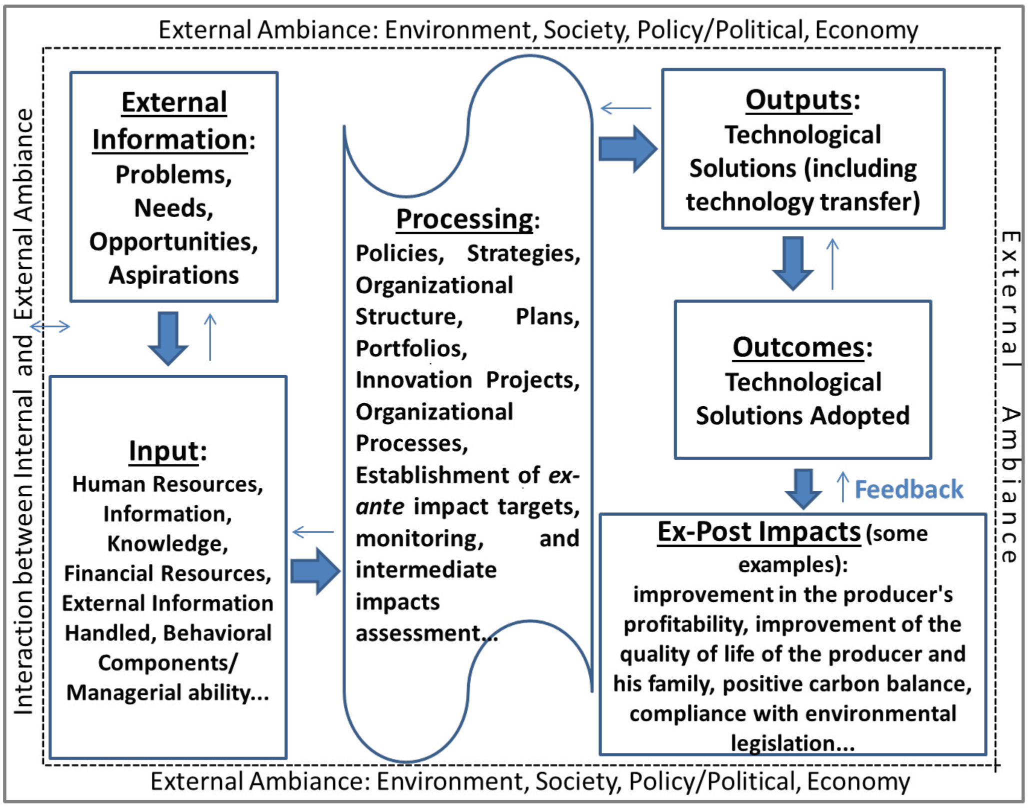

Figure 2 | Proto-Model of Innovation's Impact Assessment Management System (Adapted from Goldstein & Renault, 2004 and Jonkers et al., 2018)

According to Figure 2 above, the proto-model adopts five variables as a structural base which will permeate all stages of the above system (AVILA; RODRIGUES; VEDOVOTO, 2008; BUCKLEY, 1976; CATO, 2009; DOUTHWAITE, 2003; GOLDSTEIN; RENAULT, 2004; JOLY *et al*., 2016; JONKERS *et al*., 2018; KUBY, 1999; LAW; KELTON, 1991; MARKUS; MAJCHRZAK; GASSER, 2002; METHERBE, 1986; RODRIGUES *et al*., 2010):

3.1.1 CONNECTION WITH INSTITUTIONAL POLICIES AND STRATEGIES

The information and signals from the external environment should guide the construction of policies and institutional strategies. In the scope of these, the impact assessment system must be included as an institutional priority.

3.1.2 THE EXISTENCE OF A FRAMEWORK TO EVALUATE THE INNOVATION'S IMPACT

It is essential for the research organisation to have a structure to manage the innovation impact assessment process, preferably driven by a permanent structure. A stable or permanent structure is a way to avoid discontinuities in actions.

3.1.3 CONNECTION WITH THE INNOVATION PROCESS OF THE ORGANISATION

By aiming to monitor the innovation process step-by-step, the impact assessment system must be coupled with the innovation system, allowing course adjustments throughout the innovation process.

3.1.4 ADOPTION OF SUSTAINABILITY CONCEPTS BY A CROSS-CUT VIEW

Integrating the economic, social, policy, and environmental dimensions is necessary. It is important to make an integrative analysis among all socio-economic and environmental dimensions, understanding that there are different values among them (with their respective classification of importance – CATO, 2009, p. 36-37).

3.1.5 PROCESS ANALYSIS FOCUSING ON THE IMPACT'S PATHWAYS AND EX-ANTE/EX-POST ANALYSES

To assess innovation impacts means monitoring every step of the innovation process, starting with the stages of identifying the demands and needs of clients and stakeholders. The extension of steps should contemplate from an ex-ante impact assessment to post-innovation impact generation over time (ex-post impacts), including impact delays, in society, the economy, and the environment.

3.2 INTRINSIC RELATIONSHIP BETWEEN THE OPEN INNOVATION AND THE PROTO-MODEL

Consistent with innovation characteristics and impact assessment in continuous interrelationship with stakeholders and all components, directly and indirectly, influential in generating solutions.

A research organisation can generate technological innovation, product innovation, process innovation, organisational innovation, service innovation, and marketing innovation (DIEZ, 2001; THOMPSON; LINDAHL, 2013, p. 277-288). Global quickness requires systemic reading, in a dynamic and complex environment, in non-linear processes of innovation (GREENACRE *et al.*, 2012). It is essential that an invention can arrive at the market, but this is not enough. A feedback loop and a close relationship with the needs and desires of society are also required and denote that innovation is important, while these factors will depend on the impact analysis, sustainability warranty, and longevity (PLANING, 2017).

The organisation that adopts the model of innovation's impact assessment management process designed in this article must implement an open innovation platform to support the *ex-ante* and *ex-post* impact analysis (CHESBROUGH *et al.*, 2006). This platform has to be operated by a whole, and integrative management system based on the proto-model here considered, which requires a dynamic interaction with its stakeholders throughout the entire innovation process.

4 DISCUSSION – PROPOSED CONCEPTUAL MODEL

4.1 GENERAL OVERVIEW OF THE MODEL

The Conceptual Model of Innovation's Impact Assessment Process – IAP designed here is especially directed to agricultural research organisations and is focused on the ex-post impacts.

This article does not pretend to undergo comparative analysis nor to identify and critically delve into the positive and negative points among the theory sets studied, but intends to focus on the new impact assessment model developed, as well as on its structure and operational components. This model is also the result of my academic training and professional experience.

Synthetically, what is the purpose of assessing impacts, and what is their main focus?

IAP can reach a large spectrum of purposes and audiences, but it is mainly directed to a synthesised group of objectives. It means considering the four impacts intentions (ISRIA, 2017):

1. Accountability (to be transparent, comply with demands to oversight bodies and supervision of public resources and society in general);

2. Allocation (to be an instrument of governance and management for an organisation's managers);

3. Analysis (to be an internal team instrument of continuous improvement of the impact assessment process and innovation process, by a cross-cut view of sustainability); and

4. Advocacy (to demonstrate the importance of innovation for stakeholders).

4.1.1 WHAT IS THE IAP MODEL?

IAP is a management tool in support of decision-making. By means of feedback on the impacts that innovations cause and listening to its stakeholders, it helps to adjust policies, strategic plans, priorities, research, and innovation projects.

IAP is a base for a system that visualises and coordinates *ex-post* assessments addressed to the social, policy, economic and environmental dimensions. The system is based on the impact pathway, which is coupled with the innovation process course. And it tracks the various space and time scales, considering the time-delayed impact.

IAP is composed of several parts by interrelating, interacting, and inter-influencing among them. This general theory of systems is the groundwork that will guide the general concept of an impact assessment system as well as a proposed open innovation model (BERTALANFFY, 1968; BUCKLEY, 1976; JAPIASSU; MARCONDES, 1989).

4.2 DEFINING INNOVATION BY THE IAP APPROACH

As mentioned previously, an innovation impact assessment model must be coupled to the innovation system because the evaluation will measure the impacts of what the research organisation produces for its stakeholders, market, and society. Thus, focusing on the ultimate goal of this article, it is essential to understand the concept of innovation, its types, its characteristics, and its architecture in the context of IAP.

By synthesising and within the IAP and open innovation context: innovation is the outcome effectively acquired, transferred, and absorbed by the users and clients resulting from the interaction, tuning, and continuous exchange between stakeholders and the research organisation (BROOK; PAGNANELLI, 2014; CHESBROUGH *et al.*, 2006; CHRISTENSEN *et al.*, 2015; INSEE, 2016; O'SULLIVAN, 2008; PISANO; LANGE; BERGER, 2015; PLANING, 2017).

4.3 IAP AS A TOOL FOR MANAGEMENT - ITS OPERATIONAL COMPONENTS

4.3.1 IAP AS A TOOL FOR MANAGEMENT

In this article, management represents the process of internal driving of the research organisation, with appropriate structure, processes, resources, and staff, by answering with efficiency, efficacy, and effectivity the governance and external environmental demands/aspirations and needs. Then, IAP is a managerial tool for helping managers construct and adjust priorities of research & innovation, leading innovation projects and processes of innovation support in an agricultural research organisation.

4.3.2 IAP COMPONENTS

IAP consists of the following components: Principles, Values of the Impact, Defining Impact Dimensions, Impact Indicators Parameters, Nature of the Impact or Impact Classification, Impact Characteristics, Impact Intensity, Impact Scales, Level of Impacts, Frequency of the Impact, and, Impact Relevance.

4.3.3 IAP GENERAL PRINCIPLES

i. IAP must be connected with the institutional policies and strategies, and will be aligned with United Nations Sustainable Development Goals, in particular, 2 and 12;

ii. IAP must be in connection and with synchronicity with the innovation process of the organisation;

iii. IAP will adopt the process analysis focused on the impact pathway;

iv. IAP must adopt sustainability concepts from a cross-cut view by integrating economic, policy, social, and environmental dimensions.

4.4 VALUES OF THE IMPACT

Impacts Have Tangible Values and Non-Tangible Values (Worth). There are measurable and non-measurable values. The mathematical vision cannot measure some impacts because they are beyond economic values or not based on quantitative environmental measurements. Economic values are measurable, while cultural and social values cannot be measured because they are intangible. They can be immersed in an extensive complexity, as in the case of biodiversity in general (within a diffuse, complex, and broad ecosystem context).

4.5 DEFINING IMPACT DIMENSIONS: ENVIRONMENTAL, SOCIAL, POLICY, AND ECONOMIC

Environmental impacts are all those that affect the internal and external environment of the property where a particular solution was adopted, which means several spatial scales are directly or indirectly affected by the use of such a technological solution. For example, the carbon balance resulting from the use of the solution, which can directly affect the global climate; the use of certain chemical products that can directly affect the physical quality of the soil of the farm, and indirectly the chemical and biological quality, as well as the groundwater table.

Social Impacts can be understood as all effects arising from a solution that affects the local, state, national and global social environment within productive arrangements or supply chains, quality of life, nutrition and health, and well-being (The author).

Policy Impacts as a structural approach refers to public policies, such as economic policy, tax policy, social policy, health policy, environmental policy, etc., and all its derivatives, that is, plans, programs, projects, and activities.

Economic Impacts can be understood as the production technology affecting the farmer's production and hence generating positive or negative impacts on his economy (for instance: improvement of his profitability, improvement in the purchasing capacity of inputs for his production). Another form of economic impact is the reflexes on the supply chain and its consequence on GDP (Gross Domestic Product).

4.6 IMPACT'S INDICATORS PARAMETERS

By measuring impact, it is necessary to establish indicators and parameters related to the previous situation and after a technological solution has been adopted. This comparative analysis will establish the difference between the two moments: before and after a technology has been adopted by the farmer or by the productive sector.

4.7 NATURE OF THE IMPACT OR IMPACT CLASSIFICATION

The impact manifests itself in several ways. IAP classifies the nature of impact in: i) quality; ii) types; or timing.

4.7.1 THE QUALITY OF IMPACT CAN BE DEFINED AS POSITIVE OR NEGATIVE.

4.7.2 THE TYPES OF IMPACT ASSESSMENT OR THE TIMING OF IMPACT ASSESSMENT

Are expressed by two moments: *ex-ante* and *ex-post*. *Ex-Ante* Impact represents the planning phase in which a scenario exercise is carried out along the impact pathway on what may occur during the execution of the innovation stages. For that matter, the model proposed here is only focused on the "*ex-post*" moment. The *ex-post* impact assessment happens after the research organisation generates the outcomes.

4.8 IMPACT CHARACTERISTICS

It can be intended or unintended; intermediate or final. Before arriving at the producer, a technological solution undergoes tests and validation. However, it is possible that it may generate unintentional or unexpected impacts when arriving in the field, and on a large-scale basis. Unintentional impacts can also be considered externalities, that is when a solution is adopted, and it generates undesirable or even desirable effects that were not foreseen on the third party (for example, on the economy, society, or the environment).

Intermediate impacts occur during the various stages of the innovation process before it reaches its final outcomes when it will be subject to the last appraisal stage. According to the outcomes, the final impact evaluation begins, that is: the ex-post stage of impact evaluation is initiated until reaching the stages of impact unfolded assessment, which can reach different supply chains over time.

4.9 IMPACT INTENSITY

The impact intensity represents the strength level or intensity of impact, whether low, medium, or high intensity.

With the use of a scale ranging from -3 to +3 it will be possible to merge two impact characteristics: the level of intensity and the quality of the impact. The scale will be -3 the most negative, -2 the average negative, -1 the least negative, the 0 level (without relevant negative or positive impact), +1 with a low positive impact, +2 the average positive impact, and +3 with a high positive impact.

4.10 IMPACT SCALES

The impact scale concerns the extent of the impact, which has two dimensions: time and space. From a timescale perspective, there are short, medium, long, long-term, and perennial impacts. In this component, it is necessary to consider lag impacts, which means the impact length along the time: many impact types can delay causing gradual effects on the economy, policies, society, or environment over time.

A short-term impact occurs immediately within a year. The medium-term impact is more than one year, up to five years. The long-term impact is more than five years, up to twenty years. The extreme long-term impact is over 20 years and limited to 100 years. A perennial or persistent impact means an impact that may persist continuously for over a hundred years. During the impact assessment process, it is essential to consider the type of technological innovation generated. Some solutions will only generate effective impacts after 20 or 30 years, as in the case of forest technologies linked to noble species; while others reach the peak of their effects at the age of 5, such as those related to vegetables or grains. And these positive or even adverse effects can last for many years.

The impact from a spatial scale perspective means the geographic space where the effect of a product or service takes place (the reflexes of an adopted technological solution). It can be local space (inside the farm); municipality space; state or regional space; country space, and international space (or even global space). Usually, local impacts are impacts inside the farm which directly impact the environment, social aspects, and the economic components related to the production factors of the farmer (for example, profitability addition, an improvement in the quality of health & education).

4.11 LEVEL OF IMPACTS

They can be direct, indirect, and unfolded.

The direct impact is the direct effect on someone or something. Usually, direct impacts happen on the direct users of a certain technological solution. It is the direct effect on a farm and his/her owner, causing economic and social reflexes, including in the environment.

Indirect impacts are those arising after direct impacts. Normally, indirect impacts occur on indirect users.

The unfolded impacts are those with successive effects in supply chains, different from those initially related to the product generated with the use of a certain technology. That is, after a given technology generates direct and indirect impacts on specific supply chains, respectively. According to expectation, those indirect impacts can generate other different impacts on other supply chains, which were not previously expected. They can be called tertiary impacts, which may arise in the short, medium, or long term. It is important to emphasise that these tertiary impacts should be measured by the impact assessment model in the economic, policy, social, and environmental dimensions of different supply chains or businesses that can be generated according to the time elapsed.

4.12 FREQUENCY OF THE IMPACT

Impact frequency is an important measure for discerning risks and levels of harm to those potentially or affected by the impact. This measure should serve as a parameter for decision-making for corrective actions when negative impacts are identified or redefine priorities of policies and projects or reinforce positive impacts through renewed strategies. The frequency can be: Constant; Recurring (Intermittent); One-offs; Variable and Inconstant; or, Unpredictable.

4.13 IMPACT RELEVANCE (ON PEOPLE, SECTORS, OR ENVIRONMENT)

Frequently, an impact does not deserve so much concern because of its low relevance, or at least it requires less focused attention compared to others that are more impactful. Thus, a high-relevance impact (or even medium-relevance impact) should deserve attention and preventive measures, as well as corrective or minimising measures. The relevance classification is a benchmark for decision-making prioritisation for intervention or preventive action. The impact relevance depends on the vision or feeling of who is potentially affected, whether it is a public, a productive sector, part of society, or representatives of environmental interests (scientists and environmental activists, for instance).

Based on the literature studied and the author's experience, for this article, we set the following definitions: economic represents the productive sector in general or specific segments of producers, industry, commerce, and supply chains; policy means the policy-makers, government institutions, parliament, judiciary; social considers local, regional or national populations, specific social groups, families of producers, and traditional populations.

Relevance from the perspective of stakeholders and the economic, policy, and social sectors:

1. High-impact relevance for all stakeholders and sectors
2. High only for some stakeholders or sectors
3. Medium for all
4. Medium for some stakeholders or sectors
5. Low for all
6. Low for some stakeholders or sectors

To the environmental dimension, the impact relevance will be measured according to the following indicators (the environmental affected component must be specified): High; Medium; or Low.

4.14 THE MODEL OF RESEARCH & INNOVATION'S IMPACT ASSESSMENT PROCESS - IAP

Inspired by the General Model of Impacts Pathway, Figure 1 (Adapted from GTZ Impact Model - KUBY, 1999) and in the proto-model cited in Figure 2, the following Figure 3 demonstrates the core of the article by presenting the summarised model of the Impact Assessment Process, showing the general impacts and interrelationships among its elements, indicating the basic process flows.

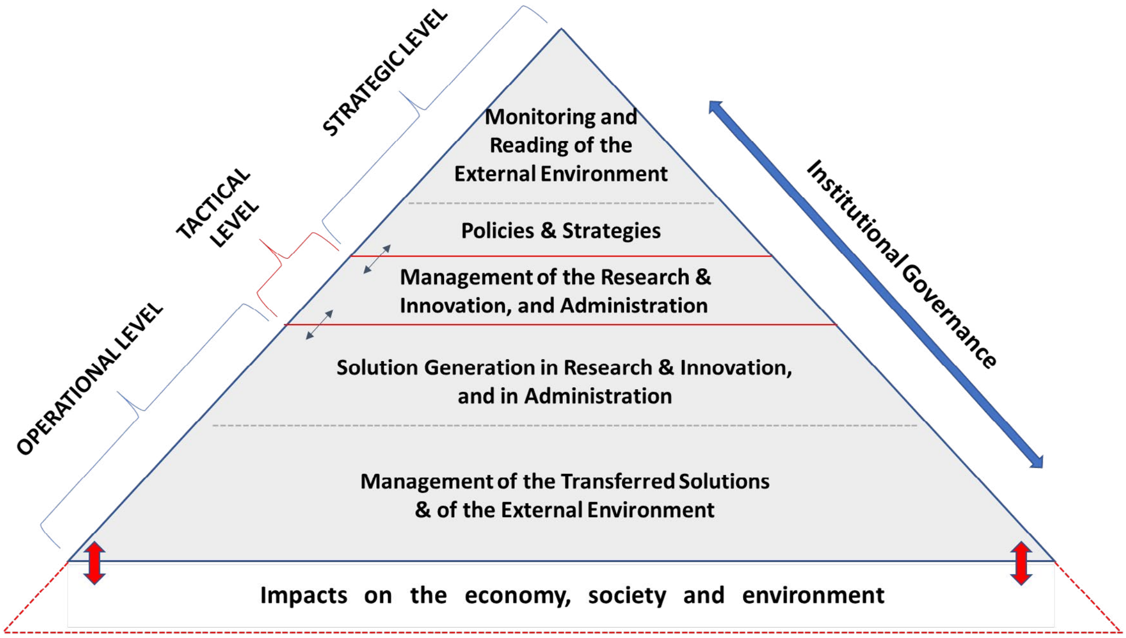

Figure 3 | Summarised model of the impact assessment process

Source: The author.

The impact pathways happen within the research organisation (even if there is interaction with the external environment), generating intermediary impacts, and outside the organisation, generating direct, indirect, and unfolded impacts, where the pathways are more complex and, therefore, by requiring more comprehensive and complex approaches regarding monitoring and evaluation.

This monitoring and evaluation should include environmental analysis from the economic, policy, and social context and involve as many stakeholders as possible, which should be classified in order of importance versus direct or indirect influence on the organisation, as well as its outputs and outcomes. These measures will be reflected by the quality and degree of organisational sustainability.

We can observe in Figure 4 below the continuous flows among all stages of the innovation pathway, demonstrating the interdependence and interaction among their components. It is also clear that the impacts along the course of innovation and along the supply chains, which may affect to a greater or lesser degree the different members of the external environment (stakeholders, users, customers), as well as the environment itself, with repercussions on society and economy.

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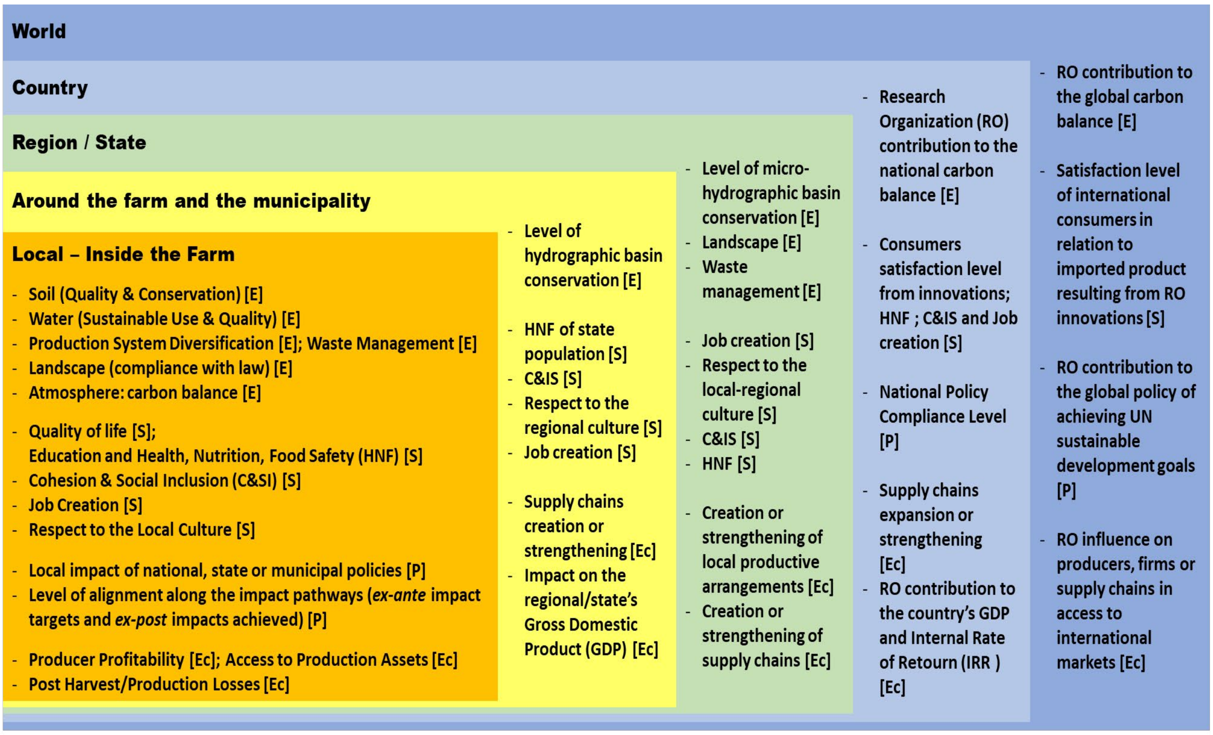

E=Environmental Dimension; S=Social; P=Policy/Political; Ec=Economic

Figure 4 | Impacts Through the Five Spatial Scale Perspective

Source: The author.

Each zone above demonstrates environments or spaces and their components along the supply chain, from the local level (within the property) and its surroundings, going from the national scope to the international environment. Thus, the proposal is to assess the impacts along these zones.

The impact assessment process is divided into zones (from 1 to 5), these are separated by different coloured blocks that demonstrate different spatial scales, which means that the flow towards *ex-post* impacts is a consequence of the farm's internal management processes to the stages in which external parties, along the supply chain, are affected by a given technological solution (following the impact pathway). These blocks contain a series of smaller processes, sub-processes, and activities, which will not be detailed here, a measure applicable in the case of an IAP operational manual. Still under the basic concepts of the general systems theory, the IAP Model is subdivided into three major levels: strategic, tactical, and operational, respectively.

Figure 4 above also presents the categories of impact indicators at each level of the spatial scale, with the first degree of direct impact on the property or at the local level (within the farm or industry that adopted the technological solution generated by the research body) and from this local space the flow proceeds to larger spatial scales. From this centre of impact, the displacement occurs towards the borders, that is, the scale is expanding, passing through the neighbourhood of the local property and covering the entire area of the municipality where it is located. Then, the impacts reach the state unit of the federation, next, they reach the geopolitical region and finally reach the national level. As the product generated by the property enters the supply chains that reach markets in other countries, the impact is moving internationally and globally.

The spatial scale, therefore, has a direct relationship with the degree of data and information added, going from the most detailed to the most aggregated, respectively, from Zone 1 to 5, and this logic will be reflected in the reports that will consolidate this scale. Zone 1 of the spatial dimension represents the local space within the property. Zone 2 is the space within the municipality where the property is located. Zone 3 is the state of the federation where the municipality is located. Zone 4 is the country's space. Zone 5 is the international space or global area. The model establishes a cross-section of the indicators through the various spatial scales, going from the most detailed, within the property (local level), through the municipal level, where there is a little more aggregated information. Thus, in the sequence, the data and information are further aggregated at the state and national level, respectively, and finally, more summarised at the international or global level, seeking to reduce the information to a few essential indicators.

When analysing the sustainability dimension (economic, policy, social and environmental), as well as their respective components, attributes, and indicators, a larger set of items can be seen in the environmental and social dimensions of the local scale, and fewer items on the policy and economic issues. It is because environmental risks may generate irreversible local impacts or an unfolding sequential process of adverse effects on society and the economy, considering the principle of transversality.

On the other hand, it is necessary to emphasise the high degree of depth and impact expressed in policy and economic components descriptions. Furthermore, these indicators are levelled when analysing state, national and global scales. And yet, when calculating the sustainability balance of a technological solution, it is necessary to consistently apply the weighted average as a way of equalising these differences.

It is important to emphasise that it will be important to quantify the impact of sustainability through a sustainability index. The calculation to arrive at this index may result from adopting specific weights for each dimension (economic, environmental, social, and political). The result of the sustainability index measured for the adoption of a certain technology should be the subject of future research. A measurement summary of sustainability indicators can be seen below.

All indicators will adopt a measurement scale varying from -3, on the most negative impact, to +3, on the most positive impact, being “0” for cases of unchanging the case of neutral impacts. To target a more accessible approach for the comprehension of the indicators by society at large, it is possible to convert the values obtained into general concepts, such as: -3 = extremely negative; -2 = very negative; -1 = negative; 0 = neutral, unchanging or no significant change; + 1 = positive; + 2 = very positive; + 3 = extremely positive.

Figure 5, the conversion table below, demonstrates the correspondence of each impact indicator.

-3	-2	-1	0	+1	+2	+3
Extremely Negative	Very Negative	Negative	Unchanging (Neutral)	Positive	Very Positive	Extremely Positive

$$\frac{\text{[Economic] + [Political/Policy] + [Social] + [Environmental] Dimension}}{\text{Sustainability Function (SF)}} = \text{Sustainability Balance}$$

Figure 5 – Sustainability Scale for Measuring IAP Indicators

Source: The author

Figure 5, above, also displays the Sustainability Balance, which represents the sustainability indicator of an innovation’s solution generated by the research organisation. It is the weighted average of the respective indicators. SF is the sustainability function, represented by the sum of the weight of each dimension.

During the practical assessment process, some indicators will be according to data collected from each zone, as presented in Figure 4.

5 CONCLUSION

By studying the bibliographic references and adding my training and professional experience related to impact assessment, except for some failures to identify more complete approaches in the market, I realised the need for a more systemic, cross-cut, and integrated management approach to impact assessment. From this perspective, the proposal presented here emerged, which seeks to propose general lines for constructing an impact assessment process of innovation applied to agricultural research organisations, having as a central point Figure 4, which focuses on the aspects of data collection and measurable information to dimension the sustainability level of adopting a certain technology on a farm.

This article does not intend to exhaust the subject, and we are aware of the broad spectrum that the subject covers, requiring further investigation, especially to dimension the indicators that will measure the sustainability index of a particular farm and consequently of the tested technological innovation, considered in the 5 zones presented in the model, along the supply chain.

The main result expected from the effective operation of the model of innovation's impact assessment process is to support organisational governance and management by positively influencing towards continuous improvement of innovation policies and strategies, as well as to set priorities for research projects. It will be operated through the feedback of the system that should help the organisation achieve growing sustainability in its solution production so that agricultural systems and its supply chain can be increasingly sustainable, thus meeting the United Nations' sustainable development goals, with a special focus on meeting goals 2 and 12.

The world needs to reduce social inequalities, eliminate hunger and sustainably expand food production. Agricultural research organisations are key players in this scenario and need to be directly aligned with those needs, already validated by the United Nations.

Most agricultural research organisations worldwide are already seeking to internalise the UN's sustainable development goals. Thus, evaluating the impact in the economic, policy, social and environmental field of its research and, therefore, of its innovations. becomes fundamental in the pathway of the growing search for the sustainability of the countries and the planet.

From this perspective, proposing the improvement of the impact assessment processes was an important product of this article as a way of contributing to the efforts towards sustainable development, as well as supporting the decision-making processes of research organisations, especially from the agricultural sector. IAP intends to support the redefinition of priorities for research innovation in response to the expectations of its stakeholders.

Reports generated by IAP will be useful for strategic, tactical, and operational decision-making processes, providing subsidies to adjust policies, plans, programs, processes, projects, products, and services, aiming at a more sustainable production.

To apply IAP, it is essential to prepare an operational guide capable of translating each step to the real world, with methodological details, including specifying the executive management framework of the whole process.

Finally, by viewing sustainability for the agriculture sector as based on SDGs driven by the UN, the IAP presents a novel contribution as a differential in relation to what exists on impact assessment oriented to support agricultural research and innovation policies and strategies by the institution: the approaches considered in Figure 5 (with the sustainability balance formula) and Figure 4 with its various considerations, for example: a proposal to focus on the impacts along the entire supply chain that will adopt a certain technological solutions, as well as special attention on sustainability impacts within and around the property, paying attention to: the impacts on the soil; watersheds; productive landscape (level of diversification); carbon emissions (environmental focus); improvement of the farmer's and his family's quality of life (social focus); level of the farmer's profitability; and, effects on national GDP (economic focus).

The next step will be to test this conceptual model and validate it. Making this Model functional implies elaborating an operation guide, which should be the next step of this project to be developed.

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