UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH

DOCTORAL THESIS

Title	Assessment of the societal impact of research and innovation in the agri-food sector
University	Universitat Politècnica de Catalunya BarcelonaTech
Department	Agri-food Engineering and Biotechnology
Doctoral Program	Sustainability
Presented by	Nour Chams
Director:	Professor José M. Gil Roig
Co-director:	Dr. Bouali Guesmi

Universitat Politècnica de Catalunya BarcelonaTech

Assessment of the societal impact of research and innovation in the agri-food sector

Thesis presented by: Nour Chams
Director of thesis: Professor José M. Gil Roig
Co-director of thesis: Dr. Bouali Guesmi

Thesis presented to obtain the title of Doctorate degree by the Universitat Politècnica de Catalunya BarcelonaTech
PhD Program: Sustainability

Barcelona, September 2021

Acknowledgement

During my doctoral studies at the University Polytechnic of Catalonia, I received support, guidance, and mentoring from special professors, colleagues, friends, and family. Due to them, this journey is shaped with success, learning, and fruitful outcomes. I am extremely grateful to each and every advice and effort that they provided during this academic path.

Firstly, thanks to Professor José Maria Gil Roig and to Dr. Bouali Guesmi for being director and co-supervisor of my doctoral dissertation. With their unceasing supervision and insightful comments throughout the four years, they were constantly ready and keen to support me with valuable feedback, knowledgeable inputs, and inspiring discussions. I highly appreciate their constant guidance to disseminate research techniques, to articulate scientific expertise, and to enhance my academic skills and research capacity.

Second, I want to thank and express my sincere appreciation to the whole UPC community, to CREDA, and to IRTA for accommodating a constructive learning environment; to all my PhD fellows, in particular Adria, Antonio, Asma, Berta, Julia, Lucie, and Zack for continuously offering motivation, inspiration, emotional and academic support.

Last but not least, I owe a deep sense of gratitude to my mother Susana, to my father Adnan, to my sister Aya, and to my brother-in-law Khaled for their patience, encouragement, and understanding. They are the secret behind my educational achievement during all these years.

Nour Chams
Barcelona, September 2021

Assessment of the societal impact of research and innovation in the agri-food sector

Summary

Research value, research relevance, research quality, and research impact have been widely tackled by various disciplines, such as health, engineering, management, and sustainability. How research and innovation are being produced, evaluated, communicated, and disseminated is an interchangeable question among scholars, practitioners, and policy makers. Focusing on the agri-food sector, this doctoral thesis attempts to examine the societal impact of research and innovation, providing a methodological framework and a set of indicators to measure sustainability performance and knowledge transfer. It compromises mixed method techniques both qualitative and quantitative research designs to identify sustainability impact and to discuss its implication to various stakeholders. This thesis fulfills two main research gaps in the literature: first, to shift from "evaluating academic impact" to "evaluating sustainability impact" generated by research and innovation programs; and second, to propose quantifiable proxies of the societal impact of research, while taking into account stakeholders´ perspectives.

The structure of this doctoral thesis consists of the following chapters: Chapters 1 and 5 constitute the Introduction and Conclusion of the dissertation; Chapters 2, 3, and 4 represent the three research studies conducted during the doctoral program. Chapter 2 combines two methodological approaches, ASIRPA framework and Impact Oriented Monitoring (IOM) model. The outcome of Chapter 2 is an evaluative tool of research and innovation analyzing its impacts to the society and to the ecosystem. Based on multi-criteria decision making (MCDM) system, Chapter 3 relies on an empirical design, following outranking methodology (ELECTRE III). It provides comprehensive ranking matrices of four research cases studies. The main contribution of this chapter is to

triangulate stakeholders´ evaluation in the Spanish agri-food sector based on six standardized pillars of sustainability: economic, socio-territorial, health, environmental, political impacts and capacity building. Last but not least, Chapter 4 investigates the association between knowledge and innovation transfer and examines its effect on sustainability impacts. Following knowledge-based theory, the outcome of this chapter articulates how science can have a dual output as both scientific and societal.

Finally, to elaborate on the overall implication of this doctoral thesis, it provides insights for decision making and monitoring research uptake and policy design in the agri-food sector. Its practical inference indicates that research and innovation can reveal a significant influence on sustainability performance.

Keywords: research and innovation; impact assessment; stakeholders; societal impact; sustainability performance; knowledge and innovation transfer.

Evaluación del impacto de la investigación y la innovación en el sector agroalimentario

Resumen

El valor, la relevancia, la calidad y el impacto de la investigación han sido objeto de investigación en diversas disciplinas como por ejemplo la salud, la ingeniería, la gestión y la sostenibilidad. Cómo se genera, evalúa, comunica y difunde la investigación y la innovación es una cuestión que ha sido objetos de numerosos intercambios entre académicos, profesionales y decisores políticos. Centrándose en el sector agroalimentario, esta tesis doctoral intenta examinar el impacto social que genera la investigación y la innovación, proporcionando un marco metodológico, así como un conjunto de indicadores que permiten traducir los resultados de la investigación en impacto en términos de sostenibilidad y transferencia de conocimiento. El enfoque propuesto adopta un enfoque mixto combinando herramientas tanto cualitativas como cuantitativas, para identificar el impacto de la investigación, Desarrollo e innovación (I+D+i) en la sociedad; en definitiva, hasta qué punto contribuye a una sociedad más sostenible. Esta tesis cubre dos vacíos en la literatura existente hasta la fecha en esta temática: en primer lugar, ofrece un marco que permite convertir los resultados de la I+D+i en impacto; en segundo lugar, proporciona un sistema de indicadores cuantitativos que permite monitorizar este impacto dese el punto de vista de los agentes de la cadena implicados.

La estructura de esta tesis doctoral consta de los siguientes capítulos. La Tesis se inicia con una introducción que justifica la importancia del tema y la enmarca en la literatura existente. Se mencionan los vacíos encontrados en la literatura y se fijan los objetivos, cada uno de los cuales ha dado lugar a un trabajo independiente. Los capítulos 2, 3 y 4 representan el núcleo central de la misma y responden a cada uno de los tres objetivos mencionados. El Capítulo 2 propone una metodología de evaluación del

impacto que combina dos enfoques metodológicos, el marco ASIRPA y el modelo de Monitoreo Orientado al Impacto (IOM). El resultado del Capítulo 2 es una herramienta de evaluación de los impactos de la investigación y la innovación en la sociedad y el ecosistema a partir de una serie de indicadores de sostenibilidad. Basado en un sistema de toma de decisiones multicriterio (MCDM), el Capítulo 3 es un estudio empírico en el que a partir de cuatro casos de estudio y siguiendo una metodología de optimización multicriterio (ELECTRE III), se calculan unas matrices de clasificación integrales en relación con las prácticas de sostenibilidad. La principal contribución de este capítulo es triangular la evaluación de los actores del sector agroalimentario, generando seis pilares estandarizados: económico, socio-territorial, sanitario, medioambiental, impactos políticos y desarrollo de capacidades. Por último, pero no menos importante, el Capítulo 4 investiga la asociación entre transferencia de conocimiento e innovación y su efecto sobre los impactos de la sostenibilidad. Siguiendo la teoría basada en el conocimiento, el resultado de este capítulo articula cómo la ciencia puede generar un resultado dual desde combinando aspectos académicos y de impacto práctico en la cadena de valor. La Tesis finaliza con una apartado de consideraciones finales en el que se recogen las limitaciones de la misma y se sugieren líneas de actuación futura.

En definitiva, esta tesis trata de contribuir al conocimiento existente para analizar cómo se puede medir el impacto de la I+D+i en la sociedad, lo que puede facilitar la toma de decisiones por parte de los responsables de centros de investigación, así como de los responsables de las políticas públicas de investigación. Asimismo, esta Tesis ha demostrado la importancia de la investigación y la innovación en el desarrollo sostenible.

Palabras clave: investigación e innovación; evaluación del impacto; enfoque multi-actor; impacto social; sostenibilidad; transferencia de conocimiento.

Avaluació de l'impacte de la recerca i la innovació en el sector agroalimentari

Resum

El valor, la rellevància, la qualitat i l'impacte de la investigació han estat objecte d'investigació en diverses disciplines com ara la salut, l'enginyeria, la gestió i la sostenibilitat. Com es genera, avalua, comunica i difon la recerca i la innovació és una qüestió que ha estat objectes de nombrosos intercanvis entre acadèmics, professionals i decisors polítics. Centrant-se en el sector agroalimentari, aquesta tesi doctoral intenta examinar l'impacte social que genera la recerca i la innovació, proporcionant un marc metodològic així com un conjunt d'indicadors que permeten traduir els resultats de la recerca en impacte en termes de sostenibilitat i transferència de coneixement . L'enfocament proposat adopta un enfocament mixt combinant eines tant qualitatives com quantitatives, per identificar l'impacte de la investigació, Desenvolupament i innovació (R + D + I) en la societat; en definitiva, fins a quin punt contribueix a una societat més sostenible. Aquesta tesi cobreix dues buits en la literatura existent fins a la data en aquesta temàtica: en primer lloc, ofereix un marc que permet convertir els resultats de la R + D + I en impacte; en segon lloc, proporciona un sistema d'indicadors quantitatius que permet monitoritzar aquest impacte des del punt de vista dels agents de la cadena implicats.

L'estructura d'aquesta tesi doctoral consta dels següents capítols. La Tesi s'inicia amb una introducció que justifica la importància del tema i l'emmarca en la literatura existent. S'esmenten els buits trobats en la literatura i es fixen els objectius, cada un dels quals ha donat lloc a un treball independent. Els capítols 2, 3 i 4 representen el nucli central de la mateixa i responen a cada un dels tres objectius esmentats. El Capítol 2 proposa una metodologia d'avaluació de l'impacte que combina dos enfocaments metodològics, el marc ASIRPA i el model de Monitorització Orientat a l'Impacte (IOM). El resultat de el Capítol 2 és una eina d'avaluació dels impactes de la recerca i la innovació

en la societat i l'ecosistema a partir d'una sèrie d'indicadors de sostenibilitat. Basat en un sistema de presa de decisions multicriteri (MCDM), el Capítol 3 és un estudi empíric en el qual a partir de quatre casos d'estudi i seguint una metodologia d'optimització multicriteri (ELECTRE III), es calculen unes matrius de classificació integrals en relació amb les pràctiques de sostenibilitat. La principal contribució d'aquest capítol és triangular l'avaluació dels actors de el sector agroalimentari, generant sis pilars estandarditzats: econòmic, socioterritorial, sanitari, mediambiental, impactes polítics i desenvolupament de capacitats. Finalment, però no menys important, el Capítol 4 investiga l'associació entre transferència de coneixement i innovació i el seu efecte sobre els impactes de la sostenibilitat. Seguint la teoria basada en el coneixement, el resultat d'aquest capítol s'articula com la ciència pot generar un resultat dual des combinant aspectes acadèmics i d'impacte pràctic en la cadena de valor. La Tesi finalitza amb un apartat de consideracions finals en què es recullen les limitacions de la mateixa i es suggereixen línies d'actuació futura.

En definitiva, aquesta tesi tracta de contribuir a el coneixement existent per analitzar com es pot mesurar l'impacte de la R + D + I en la societat, el que pot facilitar la presa de decisions per part dels responsables de centres de recerca així com de els responsables de les polítiques públiques de recerca. Així mateix, aquesta Tesi ha demostrat la importància de la recerca i la innovació en el desenvolupament sostenible.

Paraules clau: recerca i innovació; avaluació de l'impacte; enfóc multi-actor; impacte social; sostenibilitat; transferència de coneixement.

Table of Contents

List of Tables and Figures

Chapter 1. Introduction

During the last decade with the emergence of the green revolution, the assessment of research has been extended to accommodate not only the evaluation of economic impact, but also a wider spectrum of impacts including social, cultural, and environmental returns (Donovan, 2011). While global Research and Development (RD) spending has kept rising up to 22% between 2002 and 2008 (Pardey et al., 2016), its growth rate has been decreasing (Cai et al., 2017). Research funding has been facing some challenges as allocation of resources, limitations in budgeting, and cost-benefit evaluation (Heisey et al., 2010).

According to the Europe 2020 strategy, Research, Development and Innovation (RDi) are fundamental factors contributing both to the "strategy's smart growth" and to sustainability goals. Between 2007 and 2014, the European Union (EU) noticed a continuous increase in RD expenditures, from 1.77% of the gross domestic product (GDP) in 2007 to 2.04% in 2014. In 2016, the total amount of RD spending of the EU member states reaches €300 billion and the RD intensity remains stable at 2.03% of GDP. The latest statistical figures of 2019 indicate that RD expenditures reached the €306 billion at 2.19% of GDP. The major sectors contributing to RD investments are distributed as follow: business enterprise (65%), higher education (23%), government (12%) and private non-profit (1%) (Eurostat, 2017; 2020).

As for Catalonia, the total RD spending for 2017 reaches €3.107 million (1.52% of GDP) and €3.597 million in 2019, with an increase of 2.14% (idescat, 2020). The distribution of RD investment is as follow: 57.5% from business enterprise sector, 19.5% from government, and 23.0% from higher education sector (Eurostat, 2017). The research and scientific sector contributes widely to the labor force and employment opportunities in EU.

In 2015, the RD personnel occupies 1.3% of the total labor force in EU with 44.2% female workers (EC, 2017). Between 2008 and 2018, the number of researchers increased by 22.6% reaching €1.79 million (EC, 2020).

Part of agricultural productivity improvement can be attributed to RDi investments and to the efficiency of public funded projects and research institutes (Cai et al., 2017). However, some factors, such as time lag in productivity response, uncertainty, and risk impact, influence the translation of research returns (Alston et al., 2010; Cai et al., 2017). In order to enhance RD expenditures, to achieve the Sustainable Development Goals (SDGs) and to attain EU2020 objectives, further attention is needed to improve RDi outcomes and identify the "broader impacts" of research. This doctoral thesis addresses the following research questions: 1) to provide a methodological framework to evaluate and monitor RDi and to identify sustainability indicators in the agri-food sector (Chapter 2); 2) to conduct a comparative analysis between RDi and sustainability impact in two different agri-food industries (Chapter 3); and 3) to identify RDi knowledge transfer indicators and to examine how they impact sustainability performance (Chapter 4).

1.1 Conceptualization of societal impact

Different concepts have been interchangeably used among scholars to describe the societal impact (also known as sustainability impact), such as: "third stream activities, societal benefits, societal quality, usefulness, public values, knowledge transfer, and societal relevance" (Bornmann, 2013). The aforementioned terminologies are used in the assessment of research at multi-dimensional aspects. To understand the meaning of impact, it is essential to distinguish the conceptual differences between "quality", "importance" and "impact".

According to Martin (1996), quality of research is defined as the degree of originality of the findings, error-free results and satisfaction to attain cognitive and social goals; whereas importance of research represents "the potential influence on surrounding research activities and on the advancement of scientific knowledge". In contrast, impact means the "actual influence of research at a given time" (Martin, 1996). Furthermore, the Australian and the British research councils explicitly differentiate between research quality and impact. They define quality as an indicator of scientific excellence and academic evaluation. In contrast, impact is described as research outcome influencing the whole society and perceived as a social contract between science and community (Nightingale and Scott, 2007).

Throughout the three chapters (2, 3, and 4) of this dissertation, Martin´s definition (1996) of research impact is followed, reflecting the broader influence of a specific research project to the society and the environment. Whereas, the sustainability impact is defined as economic, social, and environmental performances generated from a specific research project. In the three studies, six pillars are applied as proxies of sustainability impact: economic, socio-territorial, political, environmental, health, and capacity building. The aforementioned pillars form the synthetic index of sustainability performance, generated from the analysis of 32 case studies selected from the "Institut National de la Recherche Agronomique" (INRA) and four case studies selected from "the Institute of Agri-food Research and Technology" (IRTA).

1.2 Methodologies for impact assessment of RDi

To estimate the return of RD investments, econometric models are widely used at macro-level of analysis due to their accountability (Salter and Martin, 2001). They can be classified either into direct estimates of agricultural productivity, as measurement of agricultural input and output; or indirect estimate of firm behavior as return and cost function (Heisey et al., 2010). However, econometric methods are not recommended for decision-making process when evaluating the performance of a specific project (Bornmann, 2013). Moreover, this technique is appropriate neither for small-scale analysis nor for intangible impact assessment. According to Salter and Martin (2001), econometric studies rely on "simplistic and often unrealistic assumptions about the nature of innovation. Using only econometric models is very hard to trace the benefits of research component of new technologies".

This thesis relies on mixed method techniques, focusing on case study analysis. Generally speaking, case studies are commonly used to assess micro-dimensions of research impact. They are considered as adequate tool to investigate the effect of technology and innovation (Freeman, 1984) and mostly, they are used to examine the output of an individual project or program (Bornmann, 2013). Due to the complexity of the innovation process and involvement of various actors in RDi, case study relies rigorously on anecdote, storytelling, and datasets (Chapter 2). This methodology is time-consuming, expensive to manage, selective analysis, and provides information limited to certain context (Salter and Martin, 2001). In addition to case study design, this dissertation compromises stakeholder survey analysis (Chapters 3 and 4), which is frequently used to extrapolate the results at a wider scale (Bornmann, 2013). This methodological design is perceived as a comparative tool of various research projects (Salter and Martin, 2001). The stakeholder survey is used to collect quantitative data reflecting the evaluation of various actors involved in the case studies.

To further elaborate on the datasets and methodologies applied in this thesis, the three empirical chapters combine both qualitative and quantitative research designs with an aim to triangulate the results, provide rigorous insights, and evaluate whether the outcome is consistent among the different methods applied. Chapter 2 relies on one case study "best practices in rice cultivation" implementing two methodological models: Socio-Economic Analysis of the Impacts of Public Agricultural Research (ASIRPA) (Joly et al., 2015) and Impact Oriented Monitoring (IOM) model (Guinea et al., 2015). In contrast, in chapter 3, four case studies are included in the analysis. Multiple cases are examined to provide a holistic comparative approach on how RDi projects in different agri-food industries (rice cultivation, crossbreeding methods for almond varieties, recirculation system in aquaculture, and meat production) may reveal different sustainability impacts. To do so, the empirical analysis relies on a multicriteria decision making (MCDM) method. Whereas, chapter 4 consists of an explanatory analysis of two cases studies (rice cultivation and crossbreeding methods for almond varieties). The rationale behind the selection of these two case studies is to be able to reflect the differences in RDi knowledge transfer mechanisms and sustainability impact. Case 1 (rice cultivation) represents the "knowledge production" type of RDi; whereas Case 2 (crossbreeding methods for almond varieties) characterizes the innovation aspect of RDi. As for the data sources, chapters 2, 3, and 4 rely on the same datasets generated from the stakeholder survey and interviews collected between January 2018 and September 2018. Moreover, an additional database (2013-2020) consisting of secondary data collected by IRTA is used to measure knowledge and innovation transfer of RDi in chapter 4.

1.3 Research Gaps

Despite the fact that RDi assessment has been widely tackled during the last decade, there is still lack of standardized parameters and common consensus among scholars to evaluate its societal impacts. The methodological challenge is to quantify the multi-dimensional outcomes of RDi at economic, social, health, political, and environmental aspects. Godin and Doré (2005) affirm that there is almost a full absence in the literature of systematic tools and indicators to assess the cultural, social, political, and organizational impact of research. There is a growing need to propose adequate methods to measure impact and to quantify its economic and non-economic outputs. As quoted by Williams (2020), the measurement of impact "has been highly contested", however the field is still under-theorized. Consequently, several research evaluations still lack the capacity to capture the complexity and the multifaceted benefits of research (Reed, 2018). According to Niederkrotenthaler et al. (2011), many studies have been postulating more than demonstrating the societal impact of research. On the other hand, Bell et al. (2011) point out that there is a lack of clearly documented empirical environmental-impact evaluations. There is no agreement among scholars on a standardized index or a suitable database, methods, and frameworks that can be adopted by research institutes, universities and federal centers to measure and monitor the societal impact of science and research (Bensing et al., 2003). Therefore, the challenge remains in selecting the appropriate methodological design that is coherent to a given impact and context (Reed et al., 2021).

In the agri-food sector, there are significant studies adopting research impact tools to evaluate agri-food research. The economic evaluation of RDi has been extensively examined in the literature. However, the assessment of the societal impacts remains underdeveloped (Weißhuhn et al., 2017). Prior studies tend to be focused on research discipline rather than on typology of impact. Scholars call for further consideration to engage both stakeholders and end-users assessment, incorporating larger scope and long-run evaluation of RDi outcomes (Guinea et al., 2015). Moreover, taking into account the external perspective of various stakeholders is perceived as a constructive tool to recognize the opinion of third parties and to clarify whether or not the actual impact has been adequately transmitted.

Therefore, the motivation behind this doctoral thesis is to fulfill the aforementioned research gaps, to contribute to the debate on RDi in the agri-food literature, and to highlight the implications of RDi to UN SDGs and to policy-makers in the field. The main objectives pursued in this dissertation intend first, to investigate the RDi impact at multilevel of analysis; second, to generate a standardized and exhaustive list of sustainability indicators measuring research benefits; third, to engage stakeholders´ perspectives in the evaluation process of case studies in the agri-food sector, in Spain; and last but not least, to examine the association between knowledge and innovation transfer and sustainability performance. This thesis contributes to previous literature on the research impact assessment, both from a methodological and an empirical point of views.

Beside the Introduction and Conclusion sections, the present dissertation is organized into three chapters containing three research articles. The first article (chapter 2), entitled " Beyond the scientific contribution: Assessment of the societal impact of research and innovation to build a sustainable agri-food sector" has been published in the ***Journal of Environmental Management***, and presented at the ***8th European Association of***

Agricultural Economists (EAAE) PhD Workshop, Uppsala-Sweden (10-12th June, 2019). The second paper (chapter 3), entitled "How does it matter? The nexus between research impact and sustainability assessment: From stakeholders' perspective", is under review in ***Research Evaluation*** journal and presented at the ***18th European Association of Agricultural Economists (EAAE) Congress, Prague-Czech Republic (20th–23rd July, 2021)***. The last article (chapter 4), entitled "Between "research producers" and "research adopters": The role of knowledge and innovation transfer on sustainability impact has been presented at the ***31st International Conference of Agricultural Economists (ICAE) Conference, New Delhi- India (17th-31st August, 2021) and will be submitted to Journal of Technology Transfer in October 2021***.

Chapter 2. Beyond the scientific contribution: Assessment of the societal impact of research and innovation to build a sustainable agri-food sector

Abstract

Due to the crisis of climate change and the increased attention toward environmental management issues, the agri-food sector has been extensively relying on research, development, and innovation (RDi) to transform the conventional agricultural production into a sustainable and eco-friendly industry. While the academic contribution of research has been relatively easily identified in the literature, the assessment of its societal impact remains underdeveloped. Accordingly, this study employs mixed-method evaluation approaches, mainly the ASIRPA framework and the Impact Oriented Monitoring (IOM) model to better understand and measure the multi-dimensional impacts of RDi in the agri-food sector in Spain. The objective of this analysis is to identify the generated impact and assess its contribution to the society and the ecosystem. An in-depth case study analysis is developed to examine the "best practices" program to promote sustainable techniques in the rice cultivation. The empirical findings suggest a standardized index to measure economic, socio-territorial, health, political, environmental impacts, and capacity building, involving the stakeholder-network evaluation. Thus, the study provides important implications for firm management decisions, monitoring research uptake and policy design in the agri-food sector.

Keywords: research outcome; sustainability performance; societal impact; innovative agri-food sector.

2.1 Introduction

The agri-food sector is considered as one of the most influential industries in a country, contributing to its national welfare, poverty reduction, and food security, and participating in its economic growth, such as employment, development and technologies, income, domestic consumption and foreign trading (Birkhaeuser et al., 1991). The aftermath of the Second World War was the emergence of a new era of technological booming and scientific revolution in the agriculture field (Winsberg, 1980). A drastic metamorphosis has been challenging the agricultural systems to adopt innovative approaches and to integrate efficient transfer of knowledge at macro and micro levels. Improving both economic and environmental performances of firms are key drivers of this change (Prändl-Zika, 2008). In this regard, research institutions and centers play a crucial role in the advancement of the agri-food sector. Research, development, and innovation (RDi) facilitate the transitional transformation by identifying appropriate strategies to incorporate sustainable and innovative practices in the agrarian mechanisms. For instance, growing social and political concerns regarding the impact of climate change have led to an extensive RDi investments to fulfill the future targets of the Sustainable Development Goals (SDGs) (UN, 2015) i.e., well-being, minimizing hunger and mal-nutrition, maximizing agricultural productivity, and promoting sustainability performances (Garnett et al., 2013; Thornton et al., 2013; Sanchez-Escobar et al., 2018).

Both public and private research funding organizations play a key role in achieving SDGs (Zhu, 2017). As suggested by previous findings (Fuglie and Heisey, 2007), public investment in agricultural RDi generates a significant economic benefit. Salter and Martin (2001) categorize these benefits and describe the contribution of research to the economy and the society as a leading factor for the expansion and availability of knowledge among firms. The latter is perceived as capacity building within and among research organizations to enhance both corporate and technological activities. Despite the relevant growth of RDi expenditure across the European member states, there is an emergent challenge facing the academic and research communities to evaluate the RDi outcomes and identify its “broader” impacts on the society.

Improvement of agricultural production can be attributed to RDi investments and to the efficiency of public funded projects and research institutes (Cai et al., 2017). However, the evaluation process of RDi impact faces multiple challenges (e.g., time lag in productivity response, uncertainty, and risk impact) that can affect the translation of research return and its non-academic impact on the society (Alston et al., 2009). Accordingly, the methodological challenge is to quantify the multi-dimensional outcomes of RDi at the economic, socio-territorial, health, political, and environmental aspects. During the last decades with the ushering of “green revolution”, the assessment of research has been extended to accommodate not only the economic impact, but also a wider spectrum of impacts (Huang and Odum, 1991; Donovan, 2011). Bornmann (2013) decomposes the social impact of research scopes into three components: societal products (outputs), societal use (references), and societal benefits (changes in society). The author advocates that the society can benefit from science and research only if the outcomes are translated into useful products.

In the agriculture sector, there are remarkable studies adopting research impact assessment (RIA) to evaluate agri-food programs. The economic evaluation of RDi has been widely investigated in the literature. However, the assessment of the social, environmental or sustainable impacts remains extremely limited in the literature (Dendena and Corsi, 2015;

Weißhuhn et al., 2017). Another important gap of RIA emphasizes on the lack of impact-oriented assessment tools (Penfield et al., 2013). Previous studies tend to be driven by research disciplines rather than being guided by typology of the impact; therefore, there is a need to conduct further investigation with an attempt to measure and monitor various types of impacts generated from RDi and to elaborate on how the scientific contribution is translated into a societal contribution to the public and the ecosystem.

For the sake of this study, the evaluation of the impact of RDi relies on the assessment of the scientific development of IRTA. Known as the leading system of public agricultural research activities in Catalonia-Spain, IRTA seeks to design and implement RIA measures to examine the outcomes of agri-food innovations. Over 30 years, this research institution has made a contribution to the agricultural research in Catalonia, as it has been strengthening the research capacity with other worldwide partnerships. The main research disciplines tackled by IRTA are focused on crop systems and soil management, dairy production, wheat and barley breeding, fertilization and plant protection, animal welfare, and integrated pest management for fruits and vegetables. In this context, this study aims to identify the societal impact of IRTA's RDi and to go beyond the conventional appraisal of its economic return and academic outcome. Therefore, a case study analysis of the 5-years "best practices" program is conducted to measure the impact of research development in the rice cultivation on the Spanish society.

This study contributes to the RIA literature both from a methodological and empirical point of views. There is a growing consensus among policy-makers and practitioners that there is no "single impact" to be measured and no "best approach" for doing so (Horton and Mackay, 2003; Weißhuhn et al., 2017). In contrast to previous studies, this work moves away from identifying a "unique method". Instead a mixed-method research design is applied to examine the generated impact and evaluate the multi-dimensional effect of agri-food RDi. Due to the increased attention of the European Commission (EC) and after the Lisbon Strategy (the Lisbon Strategy, 2010), the assessment framework of research is shifting to extend the scope of evaluation by integrating a wider scale of socio-economic and sustainability indicators. Moreover, it is important to differentiate each level of impact assessment and to identify the stakeholders´ evaluation of the outcome of RDi at each dimension. To the best of our knowledge, there is no prior study in Spain that analyzes the societal impact of agricultural RDi. Furthermore, ours constitutes the first study that applies the Impact Oriented Monitoring (IOM) model recently proposed by Guinea et al. (2015) to the agricultural research area. Finally, the implication of this study supports policy-making and regulatory formulation in the paddy and rice industry. This study addresses the question on how research projects in the area of agri-food sector are generating impacts and how they are being beneficial to the society. The result of the case study can be useful as a standardized tool applicable to evaluate and monitor the impacts of various crops' cultivation, as well as it assists in the accomplishment of adequate research policy planning and project management strategies.

2.2 Case-study background and experimental area

Rice cultivation has a significant socio-cultural influence and ecological implication in the Mediterranean region of Europe (EU). The two leading rice producers in EU are Italy (51%) and Spain (29%), fulfilling 80% of the European demand. The remaining 12% are provided from Greece and Portugal. At a global level, Spain occupies the seventeenth place as the world largest producer and exporter of rice (FAS-USDA, 2012). The Spanish rice cultivation are mainly located in three different areas: Ebro Delta, Albufera de Valencia, and Marismas del Guadalquivir. In Catalonia, the total rice yield has reached the 135,000 tons in 2016 and distributed as follow: Girona (6,016 tons), Lleida (223 tons), and Tarragona (129,292 tons) (Idescat, 2017). This case-study is focused on one region of the Catalan rice cultivation, which is the peninsula of Ebro Delta. The latter is known as the primary rice-producing field, located in the province of Tarragona-Catalonia and contributing to 98.5% and 20% of the total rice production in Catalonia and Spain, respectively. On average, the annual rice yield of Ebro Delta reaches approximately 90,000 tons over 22,000 hectares (ha). Due to the mild climate and the constant supervision of the Protected Geographical Indicator classification from the Government of Catalonia, this land is known to provide good quality of rice grains with optimum ripeness.

The rice cultivation consists of an important agricultural system with field management, ecological role, and conservation of biodiversity and the ecosystem (Reig-Martínez et al., 2008). The major factors affecting agronomic characteristics of the rice seeds and inducing undesirable impacts on the ecosystem are identified as: water type and level, fertilizers and pesticides application, and the biogeography (Sabiha et al., 2016). Overall, during the last decades, the rice farming has been facing critical challenges and complications in this regard. Between 1980 and 2006, rice producing countries in EU suffered from a dramatic decrease in the number of farms (Ferrero and Tinarelli, 2008). For instance, in Italy, it was reduced to one-half; whereas in Spain, it declined to the one-fifth of the total number. However, during the same period, the average surface area per farm improved due to high mechanization and technological development (Van Nguyen and Ferrero, 2006). Spain has been marked by a marginal decline (5% on average) in agriculture. Most of the farmers have switched from rice to corn cultivation, since the latter requires less amount of water for irrigation. Consequently, the Spanish rice-growing lands have decreased by 6% affecting the total rice yield (FAS-USDA, 2012). As for Ebro Delta, the major issues threatening this peninsula are extensive conflict between economic and developmental activities and preservation of the ecosystem and natural resources. In general, the struggle of balancing between the dual performance of optimizing economic return while minimizing harmful environmental damages, is widely detected in the agri-food sector and particularly in the paddy rice cultivation. Thus, there is an emergent need to incorporate innovative and sustainable practices to facilitate the achievement of this equilibrium between economic profitability and ecological conservation.

In the same vein, other critical conditions of the Ebro Delta fields have been identified. Water salinity, strong northwest winds, and disease from stem borer insect "*Chilo supressalis*" are unfavorable factors that influence negatively the rice fields (CIHEAM, 1997). To overcome these obstacles, farmers have been shifting from traditional to sustainable cultivation. New innovative techniques have been implemented to enhance productivity through efficient assets allocation, input usage, and cost-cutting methods. However, there is still a need to transmit to farmers the importance of adopting these efficient and modern strategies. The role of research and innovation in this context is to increase awareness among rice growers towards quality production of rice and environmentally-friendly performances as land and water management, pesticides usage, and application of chemical fertilizers.

At the EU level, the main regulator of the rice cultivation is the common agricultural policy CAP. Since 1962, the EU's CAP is the core body mediating between the agriculture sector and the society, providing a rigorous support to farmers (Bartolini et al., 2007). Lately, based on recommendations of the Food and Agriculture Organization of the United Nations (FAO), the Mediterranean rice network has been intensively boosting researchers and encouraging collaboration at regional level between various research public institutions (e.g., Central Institute of Freshwater Aquaculture (CIFA), and Institute for Food Research and Technology (IRTA) (Spain); National Agricultural Research Foundation (NAGREF) (Greece); The Council for Research and Experimentation in Agriculture - Rice Research Unit (CRA-RIS) and "Ente Nazionale Risi" (ENR) (Italy); EAN (Portugal); and "Institut National de la Recherche Agronomique" (INRA) (France). These research organizations have been involved in scientific and technical advancement vis-à-vis rice growing, eco-friendly rice cultivation strategies, seed quality improvement, and know-how transfer and dissemination to rice-farmers.

2.3 Methodology

Different methodological frameworks such as econometric modeling (Salter and Martin, 2001), surveys, and case studies (Bornmann, 2013) have been used to assess the value and outcomes of RDi. These methodologies aim to quantify the impact of scientific development on the agri-food sector translated as: agriculture productivity, farmers' skills to adopt innovative techniques, evaluation of cost reduction strategies, and improvement of resources consumption (Fuglie and Heisey, 2007). In contrast to econometric modeling, case studies approach is conducted to assess the micro-dimension of the research impact and to include the impact-evaluation of different stakeholders involved in the development of the research program addressed. It is an appropriate tool to investigate the effect of technology and innovation (Freeman, 1984) and often used to examine the output of an individual project or program (Bornmann, 2013).

Due to the complexity of the innovation process and the involvement of various actors in the RDi, this analysis consists of a case-study, relying rigorously on both qualitative information as narratives, and datasets and quantitative evaluation as stakeholder survey analysis. The importance of this methodological design is the triangulation of impact assessment. To mitigate biasness of self-evaluation and to obtain objective evaluation, this study includes analysis of the stakeholder-network involved in the RDi. The methodological framework comprises a mixed design of the path blazed by Joly et al. (2015) and Guinea et al. (2015). Moreover, the IOM approach has been adapted to accommodate the diversity of impact dimensions in the agriculture domain, by integrating the Socio-Economic Analysis of the Impacts of Public Agricultural Research (ASIRPA) (Joly et al., 2015). The following section elaborates on the two models applied to conduct the assessment of the societal impact of RDi of IRTA.

2.3.1 Theoretical framework

The ASIRPA methodology, recently proposed by INRA researchers, overcomes the most relevant limitations associated to mainstream RIA models. ASIRPA is an ex-post RIA and a comprehensive tool applied to identify the economic, societal, and environmental outcomes of research. While previous approaches consist of classic and traditional case-studies based on storytelling, this framework allows accounting for broader impact of scientific activities, without foregoing the advantages of the aforementioned applications. ASIRPA approach mainly relies on standardized case-studies, combining qualitative and quantitative techniques, and has been applied across different INRA research departments (Joly et al., 2015). In this context, we intend to conduct the same analysis adopting the aforementioned model to analyze the societal impact generated by IRTA in the Spanish agri-food sector. One attractive advantage of this methodology is its ability to take into account the contribution of network of actors to the innovation process, as well as to scale-up the results from individual case-study to a global picture of the impact (Joly et al., 2015). Three main standardized tools underpin the ASIRPA framework namely, impact pathway, impact chronology, and vector of impact, which represent the results of this research (Matt et al., 2017). ASIRPA has revealed robust, accountable, and applicable method to measure wider aspects of impact: 1) social impact; 2) environmental impact; 3) organizational impact; 4) cultural impact and 5) political impact.

The IOM model is another innovative evaluation methodology for impact assessment. This recent RIA technique provides a straightforward and clear method to gather, organize, and discriminate between data on project results and impacts. It is mainly inspired by the Payback Model (Donovan and Hanney, 2011) and consists of two well-differentiated components, namely the theoretical framework component and the impact monitoring system. While the former is designed to identify and classify inputs, activities, outputs, and impacts generated by research according to time or categories (Figure 2.1), the latter deals with the data collection and assessment tool through the results framework and the coordinators' survey. The advantage of this methodology is that it can be implemented during and after the project timeline to examine immediate and short-term impacts, as well as to identify some potential long-term impacts.

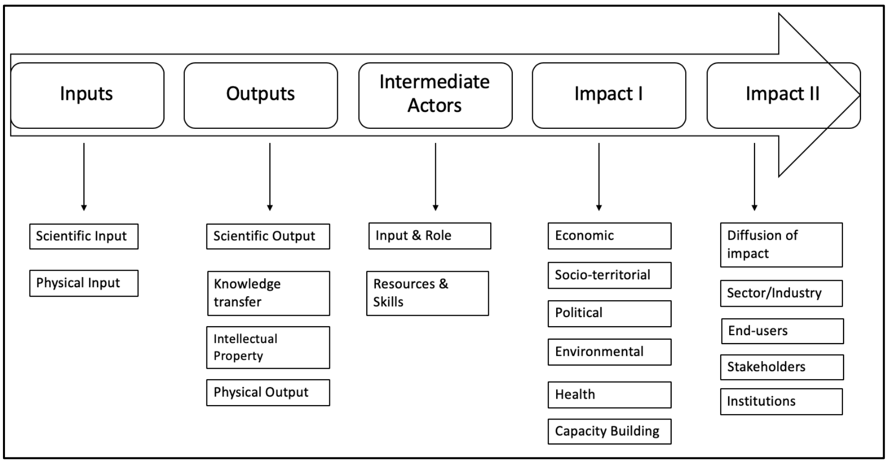

Figure 2.1 Impact monitoring framework

2.3.2 Methodological design and data collection

Following previous research (Spaapen and Van Drooge, 2011; Bornmann, 2013; Joly et al., 2015), the empirical application is based only on successful cases proposed by the head of IRTA research discipline. The reason behind the selection of successful cases is to be able to identify and to measure the generated impact. IRTA's communication department has been contacted to collect data using "highlights: fact sheets" of research results during the last five years from 2013 to 2018 (Gaunand et al., 2015). The innovation project (annual activity reports) of the "best practices" in rice cultivation constitutes the database of our analysis providing detailed information on department, title, subject type, abstract describing the innovation, topic, content, strengths, partners, products/outputs, patents, and prospects or long-term impacts. As proposed by Matt et al. (2017), the selection focuses on significant research results from IRTA laboratories that had or are likely to have an impact on the society. Furthermore, the innovation program is anticipated to reveal not only an academic contribution, but also non-academic impacts. According to recent science standards (Research Evaluation Framework, 2011), the case selection is expected to reveal diversified impacts influencing positively farmers and regulatory agents in the rice industry.

Besides the impact categories defined in the IOM methodology (i.e., knowledge production; research targeting and capacity building; informing policy and product development; dissemination and knowledge transfer), additional components are included to reflect the characteristics of the agri-food sector. Similar to ASIRPA, six dimensions have been defined to measure the impact of agricultural science on the society: economic, environmental, political, socio-territorial, health, and capacity building. The quantification and qualification of impacts mainly rely on descriptors, gathered based on exhaustive literature review (De Jong et al., 2014). Accordingly, the first step of this study consists of a content analysis of case studies of RDi from INRA and IRTA. The aim is to identify a list of standardized parameters applicable to different agri-food domains and to build a homogenous index to measure the multi-dimensional impacts.

Three analytical tools have been integrated including: 1) a project results framework; 2) a coordinators' survey; and 3) an assessment tool (scoring matrix). Structured interviews and open-ended questions were addressed to different actors involved in the research process (IRTA staff, researchers, project managers and directors, stakeholders, policy-makers and experts, etc.). Comprehensive data was collected in order to achieve an overview of research evaluation (figure 2.2). Information obtained from the interviews are gathered and summarized in systematic measurable indicators. The stakeholder survey was mainly distributed among 28 participants. The sample of the stakeholder survey consists of: project coordinators, co-partners, end-users (i.e., farmers), support technicians, and intermediary actors. Based on a ten-point rating scale, participants were asked to grade the importance of each sub-dimension of impact. The score for impact represents the average of its sub-dimension scores. Figure 2.2 summarizes the steps followed for the methodological model applied to conduct the case-study analysis.

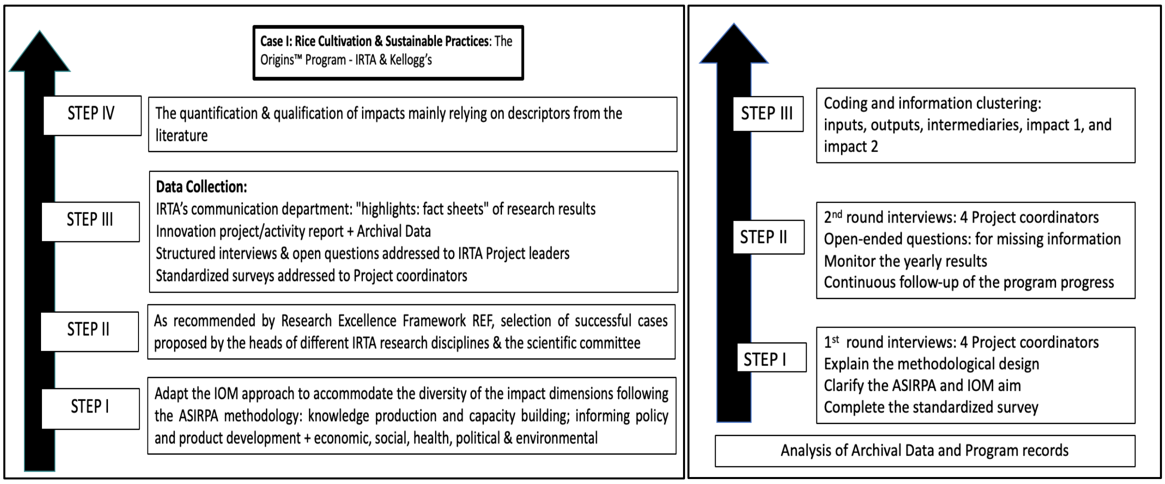

Figure 2.2 Methodological design of the study

2.4 Results and Discussion

In 2013, IRTA launched "Origins™ Project" with an aim to transform Ebro Delta fields into a sustainable peninsula of rice cultivation. The objective of this research development is to provide a voluntary opportunity to rice farmers to improve cost effectiveness, optimize resources usage, increase productivity and yield, and maximize the economic return of the rice industry. Moreover, the motivation behind this collaboration is to offer the consumer a healthy balanced cereal product, manufactured from sustainable cultivated rice grains and responsible plantation taking into account the environmental conservation. The purpose of the program is to promote efficient management and allocation of resources and to minimize harmful impact on the ecosystem by adopting environmental-friendly strategies.

The major driver of IRTA is to improve competitiveness of the rice sector, ensuring a sustainable and quality production in the Spanish market. The RDi consist of exploring and developing various scientific and practical techniques in the rice cultivation, such as: plant material evaluation trials (i.e., grain yield, seed quality, and evaluation of plant disease);

fertilization trials (i.e., design trials and monitoring treatments); and transfer services (i.e., survey application to farm sector, results transfer, and technology adoption).

The results of the case study are classified into different categories monitoring the impact generated during and post project timeline. The empirical findings reveal the inputs, outputs, knowledge flow and dissemination, and the impacts generated from Origins™ program. Figure 2.3 represents the impact chronology, identifying the major events related to the rice industry and reflecting both the European and the project contexts.

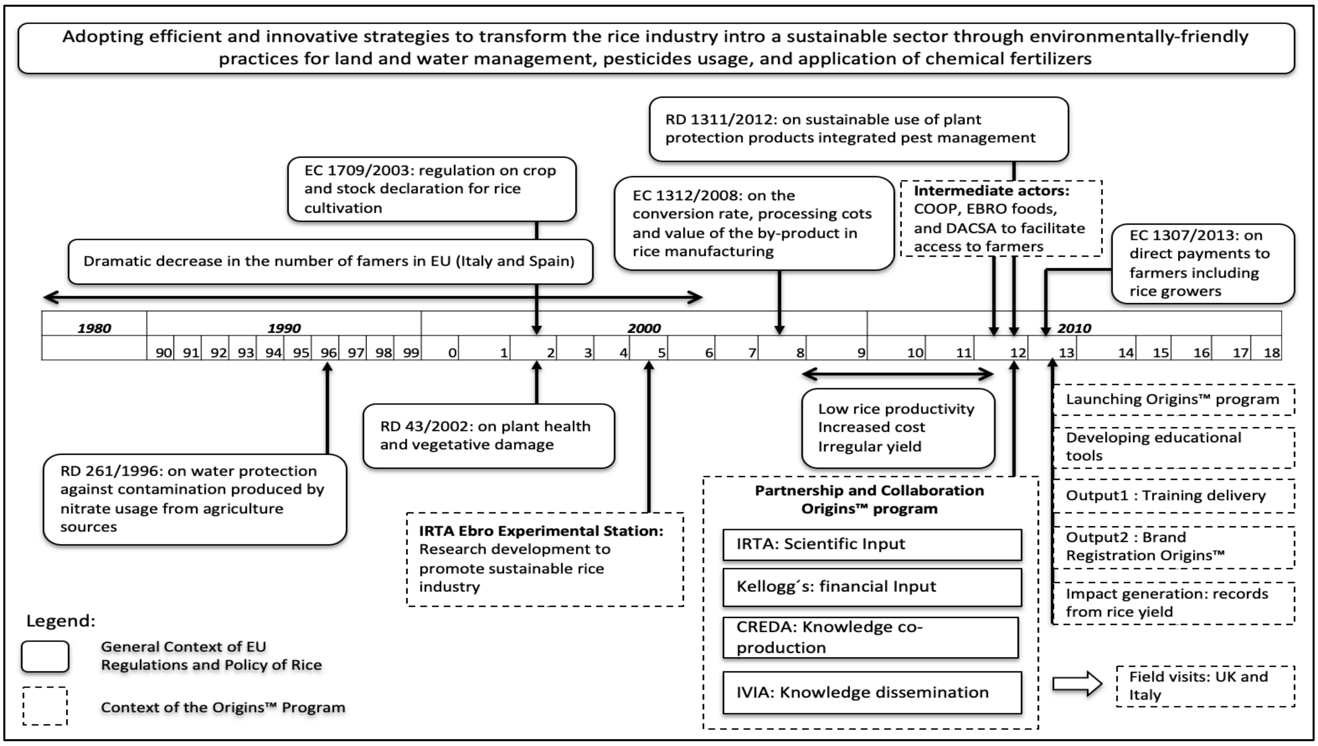

Figure 2.3 Impact Chronology

2.4.1 Input

Both researchers and practitioners have been emphasizing on the transitional era facing the agri-food sector to achieve sustainable performances (OECD, 2011; Markard et al., 2012; Loorbach et al., 2017). To incorporate green practices in the rice cultivation, RDi play a crucial role to implement eco-friendly strategies and to promote farmer´s awareness toward the importance of balancing between profitability and the ecosystem (Bilali, 2019). In this context, IRTA contributes to transform the rice sector from conventional to sustainable cultivation system. To provide consumers with cereals cultivated according to environmental-friendly standards, the research institute provides scientific inputs to initiate the adoption of sustainable practices in the rice plantation. Sustainable techniques consist of improving crops quality, irrigation systems, efficient use of water, fertilization and field preparation (Lu et al., 2010; Noya et al., 2018). This input is classified as: assemble and transfer of knowledge (Argote and Ingram, 2000; Hamdoun et al., 2018), technical development, and scientific leadership (Guinea et al., 2015). It consists of building a strong connection with the primary rice sector through communication capacity and human resources capital.

Whereas, Kellogg´s company was the financial capstone of Origins™ program. Kellogg´s cereal products extensively rely on rice produced from Ebro Delta Natural Park (Ebro foods, 2018). For this reason, the motivation is to sponsor Origins™ program in Spain, with aim of implementing new innovative and sustainable performances in the rice sector. The major objective is to promote practices based on three pillars: social, economic, and ecological.

This research collaboration targets and solves a problem of public interest in the agri-food industry and generates a set of new normative implications for rice farmers. Each actor provided various resources and assets to achieve the objective of the program and to accomplish the desired outcomes. As indicated by the network of actors of Origins™ project, the stages of know-how consist of three steps: initiation of know-how by delivering the training and conducting the workshops; practical implication on field by growing a plot adopting sustainable practices; evaluation, communication, and dissemination of science by sharing the knowledge produced within and across farmers.

2.4.2 Output

The preliminary result and output of the project, which is delivering the first training session to farmers, was dated on May 2013. After various years of investigation, IRTA´s researchers have addressed the main obstacles identified in rice cultivation and generated solutions and improvement of the agri-food production. The scientific output consists of program workshop and development of educational materials to promote sustainable practices in rice plantation. The training content comprises in-class lectures and practical coursework in labs or field (applied topics, technical sheets, videos, and round table discussion); field days as showcases (critical time, feedback, and farmer's support for adaptation); trips and visits to various rice fields (Andalucía, Aragon, and Navarra). Over five years, from 2013 to 2018, the annual output was expanding and targeting higher number of farmers and larger surface of rice cultivation. For instance, in 2013, the workshop was delivered to 16 farmers consisting of 8 ha and 4 showcases; in 2014, the number of farmers increased to 35 in total, 15 showcases and 74 ha. While in 2015, the surface area of rice growing increased by more than 33 times since the starting date of the program reaching 1200 ha, 54 farmers and 15 showcases. The latest results indicate an increase in the number of farmers (71) voluntary implementing the "best practices" in the agricultural systems.

Elaborating on this RDi, the outcome is classified as "capacity building" and "knowledge transfer" through learning tools from the academic and scientific advancement (Figure 2.4). Origins™ project has generated two main outputs: a scientific output as published articles in press, e-magazines, reports, educational manual, and training materials that has been presented in national and international conferences; and an intellectual property rights as brand registration of the Origins™. Adoption of the "best practices" fostered by the rice farmers, post-evaluation, and follow-ups through "customized assistance" are strategies incorporated to extend the knowledge produced to different regions and several rice producers. The "best practices" are described as implementing sustainable methods and tools for better social, economic, and environmental performances (i.e., land preparation, water management, fertilization, weeds management, pest management, and disease management) (Altieri and Nicholls 2004; Gurr et al. 2004; Holland 2004).

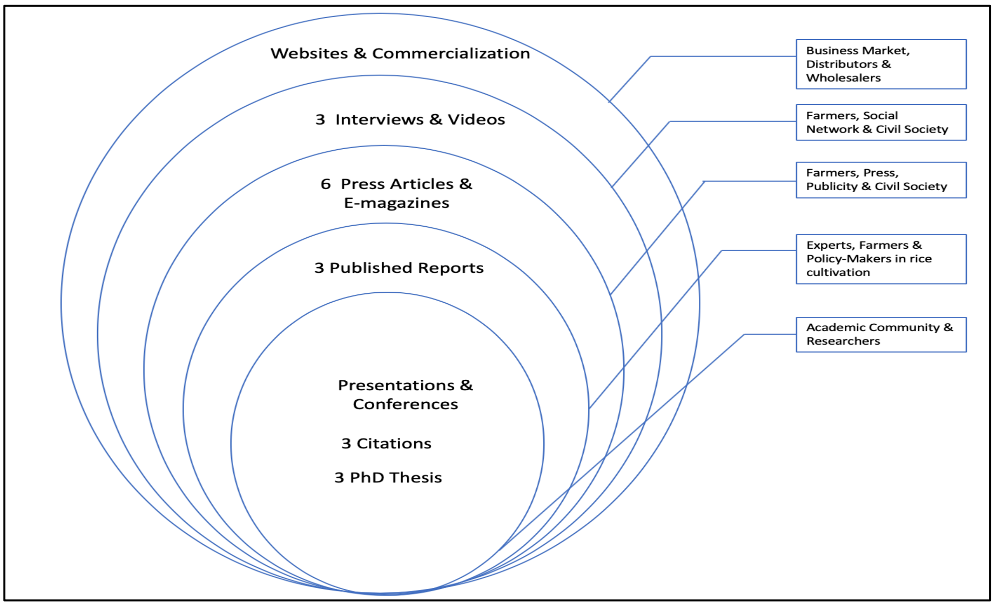

Figure 2.4 IRTA's Scientific Output

2.4.3 Knowledge flow and dissemination

Key factor to guarantee an efficient and consistent knowledge flow and dissemination of the output is the communication channels and coordination between the stakeholder-network such as farmers, institutions, firms, researchers, and technicians (Lwoga et al., 2011; Cvitanovic et al., 2016). The two phases for transmitting the know-how and the scientific development consist of theoretical formation, and practical application. Following intensive workshops, farmers apply the knowledge acquired through showcase plots cultivating new rice fields and monitoring them throughout the season. An important challenge is to make the training accessible to higher number of farmers, easy content to acquire, and beneficial to all participants. Other tools for diffusion and valuation of the program consists of development of communication means and marketing strategies. The main intermediary actors facilitating the process of knowledge transfer and diffusion of Origins™ program are: Center for Agro-food Economics and Development (CREDA) for the co-production of knowledge and cost-benefit analysis of "best practices"; Valencian Institute of Agricultural Research (IVIA) to adopt the training program and integrate sustainable techniques into the Valencian rice lands; Cooperative organizations (Càmara Arrossera del Montsià and Arrosssaires Delta de l'Ebre) and leading companies in the Catalan rice industry (Ebro Foods and DACSA) as key access to rice producers and farmers.

At the regional level, Origins™ program has been applied as a "model" to other projects, transferring the knowledge produced by IRTA to other rice fields. The corresponding sustainable techniques have been implemented in a very modest way in Valencia and Seville, tackling water conservation methods and greenhouse gas (GHG) emission reduction. At the global level, Origins™ Program has been effective since 2013 in various European regions (such as United Kingdom (UK), Italy, Spain, etc.) through Global Supplier Code of Conduct. Experts and researchers train and provide access to theoretical and practical support to farmers in order to achieve high standard and quality of the grains produced and implement social and eco-friendly performances in the rice cultivation.

2.4.4 Impact Assessment

The impact generated through the RDi is perceived as both technical and practical improvement, by promoting awareness and well-being of the rice farmers. The main contribution is classified as amelioration of the value of supplying high quality of rice and increasing the environmental protection. Since 2013, the average yield produced has been incrementally increasing compared to the average yield of the area (Ebro-Delta), with an annual growth of 15%. As reported by the project coordinator, in 2018 more than 27% of the rice field of Ebro Delta applied "best practices" in the cultivation of rice as an outcome of Origins™ program. The following practices include: soil analysis, planting techniques, fertilization dosage and frequency, water and land management, identification and monitoring weeds, pests and diseases. The rice produced in Ebro delta is considered as the main raw material to manufacture Kellogg's breakfast products that are exported to more than 20 countries all over the world (Ebro, 2018).

The broader impacts of this case study are classified as follow: high-medium level for capacity building, environmental, and health impacts; medium-low level for economic, socio-territorial, and political impacts (figures 2.5 and 2.6). Figure 2.5 displays the impact pathway of Origins™ program identifying major inputs, outputs, intermediaries, and scaling up and scaling-out the multi-dimensional impacts (1 and 2).

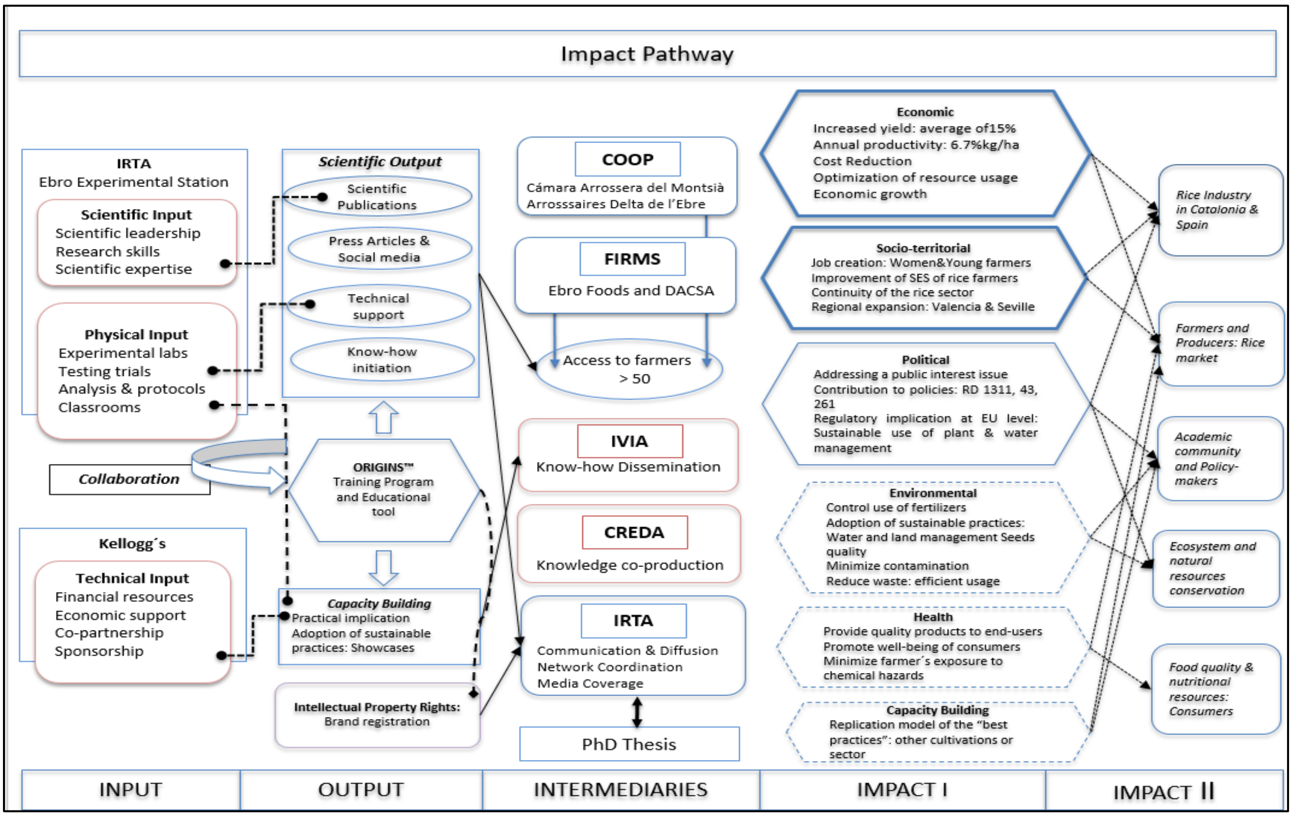

Figure 2.5 Impact Pathway

Economic Impact

The economic impact of the research project (table 2.3) is measured by a set of indicators as effect on productivity, expenses, and economic contribution to the growth of the Spanish rice industry (Witzke and Noleppa, 2016; Sanchez-Escobar et al., 2018; Acosta and Curt, 2019). Results show an economic improvement between 2013 and 2018. Applying the best techniques for land management and effective allocation of resources (sun exposure, saline or non-saline water, fertilizers and pesticides, phytosanitary and soil quality, etc.) has led to an increase in the rice yield, profitability, and minimization of costs. The training program and adoption of the best practices helped farmers to optimize their production through the implication of sustainable performances. Between 2013 and 2018, the total rice production (kg/ha) increased with an average growth of 15%.

Table 2.1 displays the annual production change of rice, providing a comparison of yields between Vitrines Delta (fields implementing IRTA's best practices) and the remaining cultivated lands of Ebro delta.

Table 2.1 Rice productivity of Ebro Delta between 2013 and 2018

Production (Kg/ha)					
Year	Number of Farmers	Hectares Cultivated	Ebro Delta	Vitrines Delta	% Change
2013	16	1637	6.840	7.661	**12.00**
2014	32	3142	6.532	7.319	**12.05**
2015	41	3661	6.566	7.832	**19.28**
2016	41	3661	7.020	7.387	**5.23**
2017	58	4454	6.600	7.030	**6.52**
2018	13	2870	6.840	9.114	**33.25**

Productivity improvement has an explicit impact on the socio-economic status of farmers and cultivators blossoming the rice industry and promoting better life conditions. Table 2.2 presents the economic impact of Origins™ program providing a cost-benefit analysis of three showcases. The two showcases on fertilizer´s impact (ammonium sulfate) and on the optimization of resources reveal a considerable positive effect on net farm income.

Table 2.2 Economic Impact of Origins™ Program: Cost-benefit analysis (euro €/per hectare)

Best Practices	***Showcase Water Impact: Irrigation with salty water and poor soil***					
	2013			**2014**		
	Revenue	Expenses	Profit	Revenue	Expense	Profit
Average	732.33	657.40	74.93	721.15	667.83	53.33
% Change Exp.	*1.59*					
% Change Profit	*-28.83*					
Best Practices	***Showcase Fertilizers' Impact: Ammonium Sulfate***					
	2015			**2016**		
	Revenue	Expenses	Profit	Revenue	Expenses	Profit
Average	771.30	664.60	106.70	831.03	642.57	188.40
% Change Exp.	***-3.32***					
% Change Profit	***76.57***					
Best Practices	***Showcase Optimization of resources Impact: Efficient Usage***					
	2016			**2017**		
	Revenue	Expense	Profit	Revenues	Expenses	Profit
Average	831,03	642,56	188,4	881,56	672,4	209,17
% Change Exp.	***4,64***					
% Change Profit	***11,02***					

Table 2.3 provides a summary of the scores assigned by each stakeholder to the economic impact generated. On average, technical support and co-partner assigned the highest values; whereas intermediaries assigned the lowest value. As for the importance weight of the economic impact, end-users and project coordinators provide the highest percentages. To evaluate the sub-indicators measuring the economic impact, there is a common agreement among the stakeholder group that the most important impact generated from the "best practice" case study is the introduction of innovative techniques.

Table 2.3 Stakeholder´s evaluation of the economic impact

ECONOMIC IMPACT EVALUATION	Sub-indicators	Coordinator	Co-partner	Intermediary	Technical support	End-users
Increase yield and productivity	8,14	7	8	7,64	9,48	8,00
Minimize losses: Reduce costs through optimization of resources usage	7,46	8	8	7,10	9,3	6,87
Maintain economic growth of the sector	7,22	6	7	6,87	9,02	6,82
Development of SMEs and Spin-offs	4,83	7	5	4,67	5,22	4,58
Improve the Catalan-Spanish market competitiveness : export and import balance	5,31	5	6	4,07	6,62	5,45
Build a sustainable value chain of the sector by new market entry	5,39	6	5	3,70	7,22	5,57
Introduce innovative techniques	7,37	8	9	7,27	7,96	7,03
Job creation and employment opportunities	5,26	5,10	8	4,53	5,34	5,43
Average of economic impact	**6,37**	**6,51**	**7,00**	**5,73**	**7,52**	**6,22**
Importance weight of economic impact (%)	**22.14**	**20**	**25**	**20**	**19**	**24,62**
Sample size (N)	**28**	**1**	**1**	**8**	**5**	**13**

Political Impact

The evaluation of political impact (table 2.4) relies on various indicators such as: contribution to public debate and policy negotiation, use for policy-making, and societal importance of the policy domain at stakes. Following Gaunand et al.'s (2017) measure, the global "political impact" level represents a weighted average score of three dimensions. A factor of one was assigned to the first two dimensions while a weighting factor of three is attributed to the importance of the policy domain at stake. In this context, the political impact is translated as the important role of RDi through addressing an issue of public interest within the crops and grains field and by providing new insights and scientific support to rice farmers. As a result, the program has an implication at regulatory level supporting the application of Spanish and

EU policies and laws: direct impact on 1) sustainable use of plant protection products and integrated pest management (RD 1311/2012), 2) plant health and vegetative damage (RD 43/2002), 3) protection of water against the contamination produced by nitrates from agricultural sources (RD 261/1996); and indirect impact on processing costs and value of by-products for various stages of rice processing (EC 1312/2008).

Table 2.4 provides a summary of the scores assigned by each stakeholder to the political impact generated. End-users and technical support assigned the highest values on average; whereas co-partner assigned the lowest value. As for the importance weight of the political impact, project coordinators and technical support provide the highest percentages. To evaluate the sub-indicators measuring the political impact, there is a common agreement among the stakeholder group that the most important impact generated from the "best practice" case study is the influence on public debate and policy negotiation.

Table 2.4 Stakeholder´s evaluation of the political impact

POLITICAL IMPACT EVALUATION	Sub-indicators	Coordinator	Co-partner	Intermediary	Technical support	End-users
Use in public debate & policy negotiation						
Quality and strength of research messages conveyed	6,73	9,80	1	5,87	8,86	6,50
Intensity and quality of media coverage	6,10	9,40	7	6,07	6,24	5,72
Intensity and quality of debate	4,92	4,90	1	3,65	4,94	5,88
Use for policy-making						
Stages of the policy cycle affected: agenda-setting, formulation, implementation and evaluation of policies	4,10	0,1	1	3,50	3,48	5,24
Territorial scales of policies affected	4,04	0,1	1	3,72	3,28	5,09
Relevance and novelty of the solution provided for the policy	4,16	0,1	1	3,92	4,04	4,94
Societal importance of the policy domain at stakes						
Magnitude of the affected population and policy	4,96	0,9	8	3,87	4,7	5,70
Societal concerns	5,40	7,6	8	5,28	6,00	4,82
Total average of political impact	**5.11**	**4,11**	**3,50**	**4,48**	**5,19**	**5,49**
Importance weight of political impact (%)	**1.89**	**5**	**0**	**1,6**	**2,31**	**1,25**
Sample size (N)	**28**	**1**	**1**	**8**	**5**	**13**

Socio-territorial Impact

This research program reveals some socio-territorial implications in the rural areas, influencing rice farmers' socio-economic status and providing new job opportunities for women and young farmers in the rice industry (table 2.5). Origins™ program accommodates a wide range of age groups. The average age of rice growers participating in Origins™ program varies between 18 and 70 years old. Accordingly, fundamental impacts are translated through explicit improvement of rice production through employment creation and women empowerment in the agri-food sector and enhancement of attractiveness of the rice industry to the young generation. Currently, among the Origins™ participants, ten farmers are women. This can be interpreted as an indication of the RDi contribution to the socio-financial conditions and territorial management of the rice industry. Through modernization and land usage, RDi enhance the prosperity of the rice sector supporting autonomous rice growers to maintain decent living standards and to sustain a continuity of their family business. Furthermore, the rice fields of Ebro Delta have been awarded the Protected Geographical Indication (PGI) (EC 1107/96). The PGI labeling reflects unique properties of the product, specific quality and goodwill.

Table 2.5 provides a summary of the scores assigned by each stakeholder to the socio-territorial impact generated. On average, technical support and co-partner assigned the highest values; whereas intermediaries assigned the lowest value. As for the importance weight of the socio-territorial impact, technical support and end-users provide the highest percentages. To evaluate the sub-indicators measuring the socio-territorial impact, there is a common agreement among the stakeholder group that the most important impact generated from the "best practice" case study is the promotion of sustainable rural development.

Table 2.5 Stakeholder´s evaluation of the socio-territorial impact

SOCIO-TERRITORIAL IMPACT EVALUATION	Sub-indicators	Coordinator	Co-partner	Intermediary	Technical support	End-users
Improvement of Farmers' conditions: Improve socio-economic status and decent life standards	7,16	6,10	9	5,80	6,70	8,01
Job creation for women and young farmers	6,52	6,10	9	4,74	6,96	7,15
Continuity of family business in the agri-food sector	7,01	7	9	6,30	8,54	6,65
Geographical Indication labelling	5,70	5	5	4,43	5,68	6,51
Sustain the Spanish cultivation-production: Market expansion local and global	6,39	5	7	6,11	6,78	6,45
Patents exploitation: National and International diffusion	4,47	5	3	2,90	3,48	5,78
Territorial management and landscape efficiency	6,34	7	9	6,70	5,56	6,20
Land-use planning operations	5,90	5	9	6,60	5,22	5,62
Platform for maintenance of the resource and the landscape	6,07	5	9	6,37	7,06	5,39
Promote sustainable rural development	7,43	8	10	7,70	9,18	6,36
Total average of socio-territorial impact	**6,30**	**5,92**	**7,90**	**5,77**	**6,52**	**6,41**
Importance weight of socio-territorial impact (%)	**15**	**10**	**15**	**14,38**	**17**	**15**
Sample size (N)	**28**	**1**	**1**	**8**	**5**	**13**

Environmental Impact

Previous studies indicate that rice cultivation produces drastic damages to the ecosystem as emission of GHC, water contamination, and food security (Hussain et al., 2014; Liao et al., 2018; Miller et al., 2019). Various strategies can mitigate the harmful impact induced by the rice plantation to the environment. Through RDi, two techniques were adopted by Ebro rice farmers to promote efficient sustainable cultivation. An important contribution of this case study to the environment lies on the fact that the program helps farmers to be more efficient through a more rational and less arbitrary use of fertilizers and pesticides in the rice cultivation towards the natural resources and the environment conservation (table 2.7). One of the main interventions is to control for time, frequency, and dosage of fertilizers application (nitrogen N, potassium K, and phosphorous P) (Zhao et al., 2010). The adequate fertilization usage reduces losses and contamination, while optimizing resources´ consumption (Sabiha and Rahman, 2018). Farmers were encouraged to avoid excess use of nitrogen, introduce sufficient amount of potassium, and minimize the use of seeds. Table 2.6 displays the outcomes of one showcase on resource optimization strategies.

Table 2.6 Best practices for optimization of resource allocation

<table>
<tr><td colspan="4">Optimization of Resources' Usage</td><td></td></tr>
<tr><td>Farmers</td><td>Productivity (Kg/ha)</td><td>Net Profit (€/ha)</td><td>Expenses</td><td></td></tr>
<tr><td rowspan="3">Farmer A</td><td rowspan="3">8.721</td><td rowspan="3">907</td><td>Adob: 174-50-36: 260 €/ha</td><td rowspan="3">Higher Profit Less Pesticides</td></tr>
<tr><td>2 Herbicides: Ronstar/BasagranM: 86 €/ha</td></tr>
<tr><td>2 Fungicides: Bumper/Bim: 46 €/ha</td></tr>
<tr><td rowspan="3">Farmer B</td><td rowspan="3">8.721</td><td rowspan="3">728</td><td>Adob: 195-36-44:271€/ha</td><td rowspan="3">Less Profit Higher Pesticides</td></tr>
<tr><td>3 Herbicides: Ronstar/Viper/BasagranM: 178 €/ha</td></tr>
<tr><td>3 Fungicides: Folicur/Propiconazol+Bim/Procloraz: 64 €/ha</td></tr>
<tr><td colspan="4">SAME YIELD, HIGHER PROFIT, REDUCED COST, MINIMIZE PESTICIDES & FERTILIZERS</td><td></td></tr>
</table>

One of the main practices applied during a specific campaign emphasizes on the reduction of herbicides and fungicides replacing potassium, sulfate, bionomic phosphate, and urea by ammonium sulfate. While maintaining good rice-yield and reducing costs, this substitution plays a major role on the environment conservation, through minimizing the methane emission. According to Bufogle et al. (1998), as source of nitrogen, ammonium sulfate has lower level of methane emission compared to urea.

Another interesting impact of using waste management techniques is the preservation of the ecosystem and protection of natural resources (Barth and Melin, 2018). The introduction of adequate and appropriate dose of fertilizers and pesticides ensures better environmental performances of farms by minimizing waste and reducing water pollution (Zhao et al., 2010). As indicated by IRTA researchers, the program adopted standards and guidelines of the Plant Health Service vis-à-vis phytosanitary warnings taking into account the meteorological conditions and level of inoculum (Normes OEPP, 2018). The best practices of Origins™ have also revealed a positive impact on water management and quality. Farmers attempt to avoid water circulation in the cultivated lands during the usage of herbicides in order to minimize the likelihood of water contamination.

Table 2.7 provides a summary of the scores assigned by each stakeholder to the environmental impact generated. Co-partner and technical support assigned high average values; whereas the intermediaries assigned the lowest value. As for the importance weight of the environmental impact, intermediaries and co-partner provide the highest percentages. To evaluate the sub-indicators measuring the environmental impact, there is a common agreement among the stakeholder group that the most important impact generated from the "best practice" case study is the reduction of GHG and CO2 emissions.

Table 2.7 Stakeholder´s evaluation of the environmental impact

ENVIRONMENTAL IMPACT EVALUATION	Sub-indicators	Coordinator	Co-partner	Intermediary	Technical support	End-users
Reduced consumption of water and energy	7,20	7	10	7,36	8,68	6,28
Waste and Resources Management	7,63	7	10	6,36	8,90	7,71
Reduced contamination and disease	7,86	7	10	7,04	8,28	8,05
Preservation of a breed/species	4,32	5,10	5	3,90	3,62	4,73
Controlled pesticides/fertilizers/fungicides dosage	8,54	8,10	10	8,56	9,08	8,23
Decrease in GHG emissions/CO2 emission	7,94	8,00	10	7,27	8,36	7,98
Protection of water quality	7,65	8,10	10	6,69	8,02	7,83
Number of hectares certified	6,44	6,40	5	5,39	5,94	7,39
Conservation of biodiversity	7,75	8	10	6,77	8,28	7,89
Sustain organic farming	4,42	5,00	2	3,99	4,26	4,88
Total average of environmental impact	**6,98**	**6,97**	**8,20**	**6,33**	**7,34**	**7,10**
Importance weight of environmental impact (%)	**21.25**	**20**	**25**	**25,63**	**22**	**18,08**
Sample size (N)	**28**	**1**	**1**	**8**	**5**	**13**

Health Impact

Improvements of crops´ quality and nutritional status of the soil has a direct impact on the health and well-being of consumers, farmers, and end-users (Rayee et al., 2018; Sabiha and Rahman, 2018). Sustainable rice farming practices would meet consumer needs for food security, food safety, and quality of rice and rice products (table 2.8). Moreover, another health impact is identified as reducing the exposure of rice growers to chemical hazards (Rahman, 2003). The application of reduced doses of fertilizers and pesticides minimizes the risk and the sanitary damages that might affect the farmers and the environment (Sabiha et al., 2016). Chemicals' calibration sessions help farmers to apply appropriate methods for effective dosage application, which in return reduces the drift of hazardous products to other fields.

Table 2.8 provides a summary of the scores assigned by each stakeholder to the health impact generated. For the average score of the health impact, co-partner and end-users assigned the highest values; whereas the coordinators assigned the lowest value. As for the importance weight, similarly co-partner and end-users provide the highest percentages. To evaluate the sub-indicators measuring the health impact, there is a common agreement among the stakeholder group that the most important impact generated from the "best practice" case study is to minimize the exposure of farmers to chemical hazards.

Table 2.8 Stakeholder´s evaluation of the health impact

HEALTH IMPACT EVALUATION	Sub-indicators	Coordinator	Co-partner	Intermediary	Technical support	End-users
Promote good nutritional status and well-being of the population	7,05	5,50	2	7,23	8,04	7,10
Reduce contamination level fulfilling the EU regulation	7,72	6,10	10	7,28	8,4	7,61
Provide rich source of food with healthy chemical composition: protein, fibers, vitamins, minerals	6,82	5,00	7	6,32	4,7	8,09
Lower risk of having health problem: obesity etc.	5,87	5,00	5	4,55	4,1	7,42
Improvement of the quality of the product	8,26	7,50	8	8,02	8,44	8,38
Minimize farm workers' exposure to chemical hazards	8,34	5,60	9	7,37	8,56	8,90
Control of pathogens and microbial levels: assuring food safety and high quality products	7,26	5,50	9	6,85	5,14	8,36
Promote animal welfare: feeding, growing condition etc.	4,96	0,10	1	3,17	2,76	7,50
Total average of health impact	**7,04**	**5,04**	**6,38**	**6,35**	**6,27**	**7,92**
Importance weight of health impact (%)	**9,36**	**5**	**15**	**6.9**	**4.4**	**12,70**
Sample size (N)	**28**	**1**	**1**	**8**	**5**	**13**

Capacity Building

The capacity building of Origins™ project consists of various stages, such as: interactive communication with rice farmers, identification of their demands, knowledge initiation and training delivery, scientific advice and technical guidance. It is measured as developing: educational training, theoretical and practical knowledge production, and scientific publication (table 2.9). In addition, this RDi program provides new insights of sustainable cultivation techniques and may act as an effective tool to motivate farmers to adopt the "best practices" in other crops cultivation.

Table 2.9 provides a summary of the scores assigned by each stakeholder to the capacity building. For the average score, co-partner and coordinators assigned the highest values; whereas end-users assigned the lowest value. As for the importance weight, coordinators and technical support provide the highest percentages. To evaluate the sub-indicators measuring capacity building, there is a common agreement among the stakeholder group that the most important impact generated from the "best practice" case study is the theoretical and practical knowledge production.

Table 2.9 Stakeholder´s evaluation of the capacity building

CAPACITY BUILDING EVALUATION	Sub-indicators	Coordinator	Co-partner	Intermediary	Technical support	End-users
New scientific collaborations or partnerships between the projects participants	7,62	8,10	10	7,88	8,18	7,03
Exchange of personal within project partners/career advancement/formal qualification	7,92	8,80	10	8,62	7,82	7,38
Adoption of the innovation in other industry/sector	6,17	7,40	10	5,73	5,42	6,28
Provide insights and future research direction in the agri-food field	7,52	9,00	10	7,38	7,42	7,29
Training and Course formation: scientific guidance and advice	8,46	8,00	10	7,95	9,78	8,08
Theoretical and practical knowledge production	8,62	9,40	10	8,07	9,82	8,22
Continuous improvement and development of new ideas	8,23	8,30	9	7,83	9,04	8,03

Innovative investigation techniques and methods: as model for replication in different domains	7,28	7,00	8	7,72	7,16	7,08
Engagement of various actors involved	7,78	9,70	10	8,55	9,08	6,51
Post-implementation evaluation and follow-up	7,38	8,90	10	7,98	8,66	6,19
Total average of capacity building	**7,70**	**8,46**	**9,70**	**7,77**	**8,24**	**7,21**
Importance weight of capacity building (%)	**30,36**	**40**	**20**	**31,88**	**36**	**27,31**
Sample size (N)	**28**	**1**	**1**	**8**	**5**	**13**

Figure 2.6 displays the radar chart of the societal impact of RDi addressed in this study. It represents a summary of the multi-dimensional impacts generated through the RDi project revealing the importance score of the stakeholder network for each impact category. As indicated, the stakeholder-network considers that this RDi reveals the highest importance scores for capacity building, environmental and health impacts.

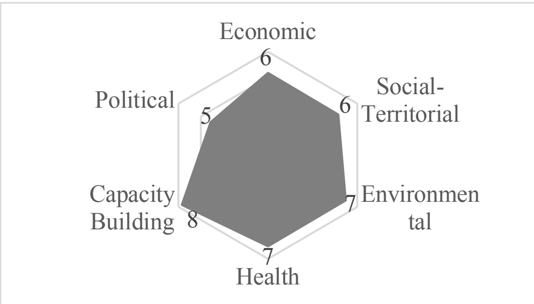

Figure 2.6 Radar chart of the societal impact

2.5 Conclusion

Nowadays, research impact assessment (RIA) is a key tool to improve the effectiveness of science and research for learning purposes and management of impact within a public research organization (PRO). Belcher et al. (2017) clearly state that "researchers are working deliberately not only to produce knowledge, but also to promote and facilitate the use of that knowledge to enable change, solve problems, and support innovation". In this context, the objective of research has been extended to be also valuable and applicable to the society as a whole. Consistently, to address the emergent concerns in regard to the benefits and investments in RDi, RIA allows to evaluate the four components of Morgan and Grant model (2013): 1) advocacy: to demonstrate value of research to government, stakeholders, and the public; 2) allocation: to fund and prioritize research based on its potential value in various realms of society; 3) accountability: to monitor and measure the contribution of research to the society; 4) analysis: to understand contributions of science to changes in practice and policy-making.

The case-study of "best practices" in rice cultivation shows that research and innovation development in the agri-food sector have a dual benefit: not only generating a scientific impact targeting the academic community and scholars in the agriculture literature, but also a societal impact influencing the civil community and the ecosystem. Furthermore, results show a multiple societal impact of changes in practices of many farmers indicating that RDi project affects more than one dimension of impact, however the degree of importance is unevenly distributed along the six selected dimensions.

The impact pathway analysis supports the relevance of long-term investments in research, and socio-economic partnerships for knowledge production to achieve broader impacts of science. Collaboration and interaction between public and private actors' network, and inter-exchange of skills and resources help overcome obstacles along the different steps of the impact pathway to improve competitiveness of the rice sector and well-being of the society. To scale up the results, the major beneficiaries of this scientific and research development are classified into four levels: individual, institutional, industry and territorial.

The individual level consists of rice farmers and producers; the institutional level represents the professional associations, agriculture organizations, cooperative firms, and technical centers; the rice industry, particularly in Catalonia and generally in Spain; and the territorial level as expansion of the impact to various areas such as in Ebro Delta, Valencia, and Seville. RIA process could become an evaluative practice within the public research organizations (PRO) to inform research policies and management about the societal impact of RDi outputs. In addition, the impact analysis involves institutional learning capacity and external communication purposes allowing different users to better understand the impact of their own research, and to foster exchanges with researchers and partners around these issues.

The case study analysis supports that the introduction of sustainability performance and green strategies shows promising lines to improve the growth of the rice market and productivity of this sector. At EU level, this research development can be considered as substantial initiative towards the application of some EU regulations related to agri-food policies. The "global" impact of the case study can be an implicit inference towards the adoption of Sustainable Development Goals (SDGs) Agenda 2030. Based on the findings of this study, the identified impacts can be perceived as an indirect implication of the following SDGs: reduce poverty (SDG1); zero hunger SDG2); clean water and sanitation (SDG6); industry, innovation and infrastructure (SDG9); reduce inequality (SDG10); responsible consumption and production (SDG12); life on land (SDG15).

Some shortcomings affecting our analysis as well as proposals for future research can be pointed out. One limitation of this analysis is the sample size of stakeholders. Collecting additional data would increase the reliability and the number of participants represented by our results. Further, a complementary approach based on ex-post and ex-ante evaluation methods constitutes another area that merits further attention to improve RIA ability to use a rich dataset, qualitative and quantitative measures to understand and report on the mechanisms that generate impacts.

References

Acosta, P., Curt, M. D., 2019. Understanding the expansion of oil palm cultivation: A case-study in Papua. J. Clean. Prod. 219, 199-216. https://doi.org/10.1016/j.jclepro.2019.02.029

Alston, J. M., Pardey, P. G., James, J. S., Andersen, M. A., 2010. The economics of agricultural R&D. Annu. Rev. Resour. Econ. 1, 537-565. https://doi.org/10.1146/annurev.resource.050708.144137

Altieri, M. A., Nicholls, C. I., 2004. Biodiversity and pest management in agroecosystems. Food Product Press, New York.

Argote, L., Ingram, P., 2000. Knowledge transfer: a basis for competitive advantage in firms. Organ. Behav. Hum. Decis. Process. 82, 150-169. https://doi.org/10.1006/obhd.2000.2893

Barth, H., Melin, M., 2018. A Green lean approach to global competition and climate change in the agricultural sector – A Swedish case study. J. Clean. Prod. 204, 183-192. https://doi.org/10.1016/j.jclepro.2018.09.021

Bartolini, F., Bazzani, G. M., Gallerani, V., Raggi, M., Viaggi, D., 2007. The impact of water and agriculture policy scenarios on irrigated farming systems in Italy: An analysis based on farm level multi-attribute linear programming models. Agric. Syst. 93, 90-114. https://doi.org/10.1016/j.agsy.2006.04.006

Belcher, B., Suryadarma, D., Halimanjaya, A., 2017. Evaluating policy-relevant research: lessons from a series of theory-based outcomes assessments. Palgrave Commun. 3, 17017. https://doi.org/10.1057/palcomms.2017.17

Bilali, H. E., 2019. Research on agro-food sustainability transitions: A systematic review of research themes and an analysis of research gaps. J. Clean. Prod. 221, 353-364. https://doi.org/10.1016/j.jclepro.2019.02.232

Birkhaeuser, D., Evenson, R. E., Feder, G., 1991. The economic impact of agricultural extension: A review. Econ. Dev. Cult. Ch. 39, 607-650. https://doi.org/10.1086/451893

Bornmann, L., 2013. What is societal impact of research and how can it be assessed? A literature survey. J. Am. Soc. Inf. Sci. Technol. 64, 217-233. https://doi.org/10.1002/asi.22803

Bufogle, A., Bollich, P. K., Kovar, J. L., Lindau, C. W., Macchiavellid, R. E., 1998. Comparison of ammonium sulfate and urea as nitrogen sources in rice production. J. Plant. Nutr. 21, 1601-1614. https://doi.org/10.1080/01904169809365507

Cai, Y., Golub, A. A., Hertel, T. W., 2017. Agricultural research spending must increase in light of future uncertainties. Food Policy. 70, 71-83. https://doi.org/10.1016/j.foodpol.2017.06.002

CIHEAM, 1997. Rice production and research in Spain. In: Chataigner J. (ed.). *Activités de recherche sur le riz en climat méditerranéen* . Montpellier (Cahiers Options Méditerranéennes) 24, 161-164.

Cvitanovic, C., Mcdonald, J., Hobday, A., 2016. From science to action: Principles for undertaking environmental research that enables knowledge exchange and evidence-based decision-making. J. Envir. Manag. 183, 864–874. https://doi.org/ 10.1016/j.jenvman.2016.09.038

De Jong, S., Barker, K., Cox, D., Sveinsdottir, T., Van den Besselaar, P., 2014. Understanding societal impact through productive interactions: ICT Research as a Case. Res. Eval. 23(2), 89-102. https://doi.org/10.1093/reseval/rvu001

Dendena, B., Corsi, S., 2015. The environmental and social impact assessment: A further step towards an integrated assessment process. Journal of Cleaner Production. 108, 965-977.

Donovan, C., 2011. State of the art of assessing research impact: Introduction to a special issue. Res. Eval. 20, 175-9. https://doi.org/10.3152/095820211X13118583635918

Donovan, C., Hanney, S., 2011. The 'Payback Framework' explained. Res. Eval. 20, 181-183. https://doi.org/10.3152/095820211X13118583635756

Douthwaite, B., Kuby, T., van de Fliert, E., Schulz, S., 2003. Impact pathway evaluation: an approach for achieving and attributing impact in complex systems. Agric. Syst. 78, 243-265. https://doi.org/10.1016/S0308-521X(03)00128-8

Ebro foods, 2018. Promoting biodiversity benefits sustainable rice production. www.ebrofoods.es/en/news/promoting-biodiversity-benefits-sustainable-rice-production-18-04/.

FAS-USDA, 2012. Spain Rice Market in the Iberian Peninsula Spanish Rice ... (2012). Retrieved from https://gain.fas.usda.gov/Recent GAIN Publications/Rice Market in the Iberian Peninsula – Spanish Rice Producers to swi_Madrid_Spain_8-20-2012.pdf

Ferrero, A., Tinarelli, A., 2008. Rice cultivation in the E.U. ecological conditions and agronomical practices. Pestic. Risk Asses. in Rice Paddies. 1-24. https://doi.org/10.1016/B978-044453087-5.50002-3

Freeman, C. (1984). The Economics of industrial innovation. Pinter, London.

Fuglie, K.O., Heisey, P.W., 2007. Economic Returns to Public Agricultural Research. Economic Brief 10, USDA/ERS.

Garnett, T., Appleby, M.C., Balmford, A., Bateman, I.J., Benton, T.G., Bloomer, P., Burlingame, B., Dawkins, M., Dolan, L., Fraser, D., Herrero, M., Hoffmann, I., Smith, P., Thornton, P.K., Toulmin, C., Vermeulen, S.J., Godfray, H.C.J., 2013. Sustainable intensification in agriculture: premises and policies. Sci. 341, 33-34. https://doi.org/10.1126/science.1234485

Gaunand, A., Hocdé, A., Lemarié, S., Matt, M., Turckheim, E., 2015. How does public agricultural research impact society? A characterization of various patterns. Res. Policy. 44, 849-861. https://doi.org/10.1016/j.respol.2015.01.009

Gaunand, A., Colinet, L., Joly, P.B., Matt, M., 2017. Counting what really counts? Assessing the political impact of science. J. Technol. Transf. 1-23. https://doi.org/10.1007/s10961-017-9605-9

Guinea, J., Sela, E., Gómez-Núñez, A. J., Mangwende, T., Ambali, A., Ngum, N., . . . Thepthien, B., 2015. Impact oriented monitoring: A new methodology for monitoring and evaluation of international public health research projects. Res. Eval. 24, 131-145. https://doi.org/10.1093/reseval/rvu034

Gurr, G. M., Wratten, S. D., Altieri, M.A., 2004. Ecological engineering for pest management. Advances in habitat manipulation for arthropods. *CSIRO*, Australia.

Hamdoun, M., Jabbour, C. J., Othman, H. B., 2018. Knowledge transfer and organizational innovation: Impacts of quality and environmental management. J. Clean. Prod. 193, 759-770. https://doi.org/10.1016/j.jclepro.2018.05.031

Harald Von, W., Noleppa, S., 2016. The high value to society of modern agriculture: global food security, climate protection, and preservation of the environment – evidence from the European Union. Front. Econ. Glob. Food Secur. in a Food Abund. World. 16, 55-65. https://doi.org/10.1108/S1574-871520150000016016

Holland, J. M., 2004. The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agric. Ecosyst. Environ. 103, 1–25. https://doi.org/10.1016/j.agee.2003.12.018

Horton, D., Mackay, R., 2003. Using evaluation to enhance institutional learning and change: Recent experiences with agricultural research and development. Agric. Syst. 78, 127-142. https://doi.org/10.1016/S0308-521X(03)00123-9

Hornton, P., Schuetz, T., Förch, W., Cramer, L., Abreu, D., Vermeulen, S., Campbell, B., 2017. Responding to global change: A theory of change approach to making agricultural research for development outcome-based. Agric. Syst. 152, 145-153. https://doi.org/10.1016/j.agsy.2017.01.005

Huang, S., Odum, H. T., 1991. Ecology and economy: Energy synthesis and public policy in Taiwan. J. Envir. Manag. 32, 313-333. https://doi.org/10.1016/s0301-4797(05)80069-6

Hussain, S., Peng, S., Fahad, S., Khaliq, A., Huang, J., Cui, K., Nie, L., 2014. Rice management interventions to mitigate greenhouse gas emissions: A review. Envir. Sci. Pollut. Res. 22, 3342-3360. https://doi.org/10.1007/s11356-014-3760-4

Idescat, Statistical institute of Catalonia (2017). Agricultural production. By products. Provinces. (n.d.). Retrieved from https://www.idescat.cat/pub/?id=aec&n=446&lang=en

Joly, P., Gaunand, A., Colinet, L., Larédo, P., Lemarié, S., Matt, M., 2015. ASIRPA: A comprehensive theory-based approach to assessing the societal impacts of a research organization. Res. Eval. 24, 440-453. https://doi.org/10.1093/reseval/rvv015

Liao, J., Hu, Y., Zhang, H., Liu, L., Liu, Z., Tan, Z., Wang, G., 2018. A rice mapping method based on time-series Landsat data for the extraction of growth period characteristics. Sustain. 10, 2570. https://doi.org/10.3390/su10072570

Loorbach, D., Frantzeskaki, N., Avelino, F., 2017. Sustainability transitions research: transforming science and practice for societal change. Annu. Rev. Envir. Resour. 42, 599-626. https://doi.org/10.1146/annurev-environ-102014-021340

Lu, H., Bai, Y., Ren, H., Campbell, D. E., 2010. Integrated emergy, energy and economic evaluation of rice and vegetable production systems in alluvial paddy fields: Implications for agricultural policy in China. J. Envir. Manag. 91, 2727-2735. https://doi.org/10.1016/j.jenvman.2010.07.025

Lwoga, E. T., Stilwell, C., Ngulube, P., 2011. Access and use of agricultural information and knowledge in Tanzania. Libr. Rev. 5, 383-395. https://doi.org/10.1108/00242531111135263

Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: an emerging field of research and its prospects. Res. Policy. 41, 955-967. https://doi.org/10.1016/j.respol.2012.02.013

Matt, M., Gaunand, A., Joly, P., Colinet, L., 2017. Opening the black box of impact – Ideal-type impact pathways in a public agricultural research organization. Res. Policy. 46, 207-218. https://doi.org/10.1016/j.respol.2016.09.016

Miller, S. A., Cunningham, P. R., Harvey, J. T., 2019. Rice-based ash in concrete: A review of past work and potential environmental sustainability. Resour. Conserv. Recycl. 146, 416–430. https://doi.org/10.1016/j.resconrec.2019.03.041

Molas-Gallart, J., Tang, P., 2011. Tracing ‘productive interactions’ to identify social impacts: An example from the social sciences. Res. Eval. 20, 219-226. https://doi.org/10.3152/095820211X12941371876706

Morgan, J. M., Grant, J., 2013. Making the grade: Methodologies for assessing and evidencing research impact. In: Dean, A., Wykes, M., and Stevens, H. (eds). *7 Essays on Impact*. University of Exeter.

Normes OEPP, 2018. European and Mediterranean Plant Protection Organization: Standards Phytosanitary treatments. EPPO Bulletin. 48, 533-535.

Noya, I., González-García, S., Bacenetti, J., Fiala, M., Moreira, M. T., 2018. Environmental impacts of the cultivation-phase associated with agricultural crops for feed production. J. Clean. Prod. 172, 3721-3733. https://doi.org/10.1016/j.jclepro.2017.07.132

OECD, 2011. Towards green growth - a summary for policy makers. Paris. https://doi.org/10.1787/9789264111318-en

Prändl-Zika, V., 2008. From subsistence farming towards a multifunctional agriculture: Sustainability in the Chinese rural reality. J. Envir. Manag. 87, 236-248. https://doi.org/10.1016/j.jenvman.2006.10.028

Penfield, T., Baker, M. J., Scoble, R., Wykes, M. C., 2013. Assessment, evaluations, and definitions of research impact: A review. Res. Eval. 23, 21-32. https://doi.org/10.1093/reseval/rvt021

Rahman, S., 2003. Environmental impacts of modern agricultural technology diffusion in Bangladesh: An analysis of farmers' perceptions and their determinants. J. Envir. Manag. 68, 183-191. https://doi.org/10.1016/S0301-4797(03)00066-5

Rayee, R., Tran, H., Xuan, T., Khanh, T., 2018. Imposed water deficit after anthesis for the improvement of macronutrients, quality, phytochemicals, and antioxidants in rice grain. Sustain. 10, 4843. https://doi.org/10.3390/su10124843

Reig, E., Picazo-Tadeo, A., Estruch, V., 2008. The policy analysis matrix with profit-efficient data: Evaluating profitability in rice cultivation. Span. J. Agric. Res. 6, 309-319. https://doi.org/10.5424/sjar/2008063-324

Sabiha, N., Rahman, S., 2018. Environment-Smart agriculture and mapping of interactions among environmental factors at the farm level: A directed graph approach. Sustain. 10, 1580. https://doi.org/10.3390/su10051580

Sabiha, N., Salim, R., Rahman, S., Rubzen, M.F., 2016. Measuring environmental sustainability in agriculture: A composite environmental impact index approach. J. Envir. Manag. 166, 84-93. https://doi.org/10.1016/j.jenvman.2015.10.003

Salter, A. J., Martin, B. R., 2001. The economic benefits of publicly funded basic research: a critical review. Res. Policy. 30, 509-532. https://doi.org/10.1016/s0048-7333(00)00091-3

Sanchez-Escobar, F., Coq-Huelva, D., Sanz-Cañada, J., 2018. Measurement of sustainable intensification by the integrated analysis of energy and economic flows: Case study of the olive-oil agricultural system of Estepa, Spain. J. Clean. Prod. 201, 463-470. https://doi.org/10.1016/j.jclepro.2018.07.294

Spaapen, J. M., Van Drooge, L., 2011. Introducing productive interactions in social assessment. Res. Eval. 20, 211-218. https://doi.org/10.3152/095820211X12941371876742

The Lisbon Strategy 2000 – 2010 An analysis and evaluation of the methods used and results achieved - Think Tank. (n.d.). Retrieved from http://www.europarl.europa.eu/thinktank/en/document.html?reference=IPOL-EMPL_ET(2010)440285

The United Nations 2030 Agenda for Sustainable Development (2015, October 04). Retrieved from https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Van Nguyen, N. Ferrero, A., 2006. Meeting the challenges of global rice production. Paddy Water Envir. 4, 1-9. https://doi.org/10.1007/s10333-005-0031-5

Walker, T., Maredia, M., Kelley, T., Rovere, R. L., Templeton, D., Thiele, G., Douthwaite, B., 2008. Strategic guidance for ex post impact assessment of agricultural research. Science Council Secretariat: Rome, Italy: Report prepared for the Standing Panel on Impact Assessment, CGIAR Science Council.

Weißhuhn, P., Helming, K., Ferretti, J., 2017. Research impact assessment in agriculture—A review of approaches and impact areas. Res. Eval. 27, 36-42. https://doi.org/10.1093/reseval/rvx034

Winsberg, M. D., 1980. Concentration and Specialization in United States Agriculture, 1939-1978. Econ. Geogr. 56, 183-189. https://doi.org/10.2307/142711

Witzke, H., Noleppa, S., 2016. The High Value to Society of Modern Agriculture: Global Food Security, Climate Protection, and Preservation of the Environment – Evidence from the European Union. Front. Econ. Glob. Food Secur. in a Food Abund. World. 16, 55-65. https://doi.org/10.1108/s1574-871520150000016016

Zhao, L., Wu, L., Dong, C., Li, Y., 2010. Rice yield, nitrogen utilization and ammonia volatilization as influenced by modified rice cultivation at varying nitrogen rates. Agric. Sci. 1, 10-16. https://doi.org/10.4236/as.2010.11002

Zhu, D., 2017. Research from global Sustainable Development Goals (SDGs) to sustainability science based on the object-subject-process framework. Chin. J. Popul. Resour. Envir. 15, 8-20. https://doi.org/10.1080/10042857.2017.1286147

Chapter 3. How does it matter? The nexus between research impact and sustainability assessment: From stakeholders' perspective

Abstract

A multi-criteria decision making (MCDM) system based on stakeholder evaluation is performed to investigate the nexus between research and sustainability performance in the agri-food sector in Spain. This study attempts to go a step further beyond the scientific assessment of research and tackles its societal contribution. The empirical application is built upon the outranking methodology (ELECTRE III) to assess sustainability performance of research case studies. The analysis proceeds to facilitate sustainability impact assessment that integrates stakeholder knowledge and provides ranking matrices of case studies selected from different disciplines. The research programs are evaluated based on six standardized pillars: economic, socio-territorial, health, environmental, political impacts and capacity building. This study reveals practical insights and implications for policy-makers and networks of actors to determine potential impacts of research and innovation on sustainability performances of the agri-food sector.

Keywords: sustainability assessment; research impact; multi-criteria decision making; agri-food sector

3.1 Introduction

Sustainability assessment is a complex paradigm, comprising a spectrum of analysis, factors, and uncertainties (Cinelli et al., 2014). It consists of multi-dimensional impacts, involving a network of stakeholders and a set of criteria (Ramanathan, 2001). During the last decades, an emergent concern is widely identified in the literature toward measurement and evaluation of sustainability implementation, adoption, and strategies in various disciplines (Bond et al., 2012). The scientific community has proposed both conceptual and methodological frameworks to describe and comprehend sustainability principles (Cinelli et al., 2014; Gibson 2006). The global aim is to develop a comprehensive set of pillars and parameters to operationalize and monitor sustainability practices (Pope et al., 2004; Sala et al., 2013a). In the same vein, sustainability assessment can be conducted from micro to macro levels at various evaluation scopes (Sala et al., 2013a; Zamagni et al., 2009).

Previous studies have commonly applied expert-system analysis or stakeholder evaluation in diverse ecological issues related to pollution, waste management, environmental damages, natural resources and water quality (Gamboa, 2006; Jamieson and Fedra, 1996; Marianne, 1996; Saarikoski et al., 2019; Zhou et al., 2004). While the bulk of literature examines one or two dimensions of sustainability, i.e., economic, ecological, or social (Sala et al., 2013a), a gap remains in addressing the global impact of agri-food research development and innovation (RDi) programs, i.e., different industries/disciplines. Moreover, to the best of our knowledge, no previous study has yet been undertaken to assess stakeholders´ perceptions of RDi impact in the Spanish agri-food sector. The main challenge facing researchers and policy-makers is to involve and encompass opinions and interests of stakeholders engaged in a specific research program (Braunschweig et al., 2001). Therefore, a standardized framework is proposed to compare four research programs in this corresponding sector. The purpose of this research is to provide policy makers and researchers with further insights about the contribution of science to both economic and societal targets.

According to institutional theory, Meyer and Rowan (1977) argue that institutions are considered as "rationalized" bodies with acquired roles and responsibilities to achieve a specific set of goals. According to the stakeholder framework, institutions are also perceived of as being authoritative entities responsible for addressing both the interests of shareholders as well as the needs of stakeholders (Freeman, 1984). Bridging these two theoretical paradigms, this study examines the role of research toward sustainability adoption. The empirical implementation relies on four case studies of RDi programs developed in four different industries and selected from the Spanish agri-food sector: *sustainable practices in rice cultivation* (Case 1); *innovative recirculation system for aquaculture* (Case 2); *genetic cross breeding methods in the almond industry* (Case 3); and *innovative technology in meat production* (Case 4). The case study analysis allows scaling up results from project level to general impact assessment of an agri-food research institute. The selection of a variety of research programs tackling sustainability and innovation in different agri-food disciplines contributes to making the analysis both more comprehensive and inclusive. In this study, the indicators used as proxy of the sustainability impact are generated from the analysis of case studies selected from INRA and IRTA (Chapter 2).

Following multi-criteria decision making (MCDM) techniques, the scope of this study is to compare and rank various sustainability impacts and sub-impacts generated by four research programs. The elimination and choice translating reality (ELECTRE) model is used for this purpose. This method empirically evaluates and highlights the outcomes of each program relative to the adoption of SDGs. The contribution of this work is first to connect the evaluation of stakeholder networks with sustainability impacts; and second, to broaden the spectrum, i.e., sub-indicators, of sustainability dimensions to not only emphasize the economic, social, and environmental pillars, but also to include political, health, and capacity building assessments. This tool allows policy makers and researchers to monitor and prioritize research funds, project planning and ranking, and evaluate the overall scientific outputs.

According to Qin et al. (2008: 2165), MCDM is considered an efficient evaluative tool "to identify priorities of sustainable goals and to rank the desirability of adaptation options." Using a standardized index, this methodology enables a comparative analysis of a set of research outcomes at multi-dimensional levels. It is perceived as a useful approach due to its flexibility and ability to include both qualitative and quantitative assessment (Chan et al., 2012) to investigate the analysis of experts and actors, and to facilitate decision making and policy planning (Ramanathan, 2001). Hajkowicz (2008) advocates that MCDM is a "process" rather than an "answer" and provides transparency, objectivity, and consistency among criteria choices. Due to the sensitivity of research impact, sustainability assessment entails an evaluation framework from a network of stakeholders with different expertise (Marttunen and Hämäläinen, 1995), ranking, and comparing multiple parameters and benchmarks. Taking into account various perspectives and triangulating the assessment from several experts' points of view might mitigate the effect of biasness and overcome subjective judgement (Ramanathan, 2001).

The remainder of the article is structured as follow. The second section elaborates on the methodological framework, justifying the implementation of MCDM techniques. A brief background of the four case studies and their impacts is presented in the third section. Section four reveals the results of ELECTRE III analysis and sensitivity checks. The final section consists of the conclusion and identifies implications of the study to the agri-food sector in general, and to sustainability assessment in particular.

3.2 Methodology

Since 1970, MCDM methods have been adopted in various project evaluations and integrated for policy formulation, case studies, and adaptation programs. This technique consists of an arcade of steps to compare, rank, and sort alternatives or criteria of sustainability pillars (Belton and Stewart, 2002; Epa, 2006; Munda, 2005). According to Cinelli et al. (2014), due to its flexibility, MCDM has been widely used in the literature of sustainability assessment, taking into account a broad spectrum of opinions among scholars, stakeholders, and regulators (Hajkowicz, 2008). It is perceived as an effective decision support tool, as it combines stakeholder engagement (Failing et al., 2007) and inter- and intra-assessment of various actors involved in specific decision making or research development (Gasparatos et al., 2008; Gasparatos and Scolobig, 2012; O'Neill et al., 1999). MCDM approaches mainly comprise three fundamental theories: utility function, outranking technique, and decision rule (Greco et al., 2004; Slowinski et al., 2012). Introduced by Keeney and Raiffa (1976), the utility theory is described as a “performance aggregation” tool to synthesize specific parameters for information. As for the outranking framework, also known as “preference aggregation” instrument, it is used to conduct comparative analysis between a range of alternatives (Roy, 1991). The last theoretical paradigm of MCDM is the decision rule, which originates a preference approach to decision classification and comparison (Greco et al., 2001b).

As part of the outranking theory, this study relies on the ELECTRE III framework. Assessment of sustainability performance encompasses a variety of information typologies and a range of uncertainty levels. Given that, the consensus in the literature converges toward the capacity of ELECTRE to acknowledge and mitigate these constraints (Garmendia et al., 2010b). According to Cinelli et al. (2014), ELECTRE is considered as a more appropriate tool in comparison to multiple attribute utility theory and analytical hierarchical process, in terms of application of sustainability approach and thresholds. Moreover, it accommodates the heterogeneity in parameters and variances vis-à-vis different preferences (Qin et al., 2008). One advantage of the ELECTRE method is that tradeoffs among multiple attributes are partially or non-compensatory (Garmendia et al., 2010b), and information contained in the decision matrix is fully utilized. The logic behind this technique is to evaluate whether criteria *a* outranks criteria *b* (Figueira et al., 2005; Roy, 1996). Known as credibility matrix, two indices are identified, concordance and discordance measures, which are used to generate a scale of outranking among the set of criteria addressed (Cinelli et al., 2014).

3.2.1 ELECTRE III: Ranking of research programs

The ELECTRE III approach is used to assess and rank sustainability impacts of four research programs. In this analysis, alternatives are the four case studies (Case1 = a1; Case2 = a2; Case3 = a3; Case4 = a4) and criteria are the six impacts as sustainability pillars (economic; socio-territorial; environmental; health; capacity building; political). Two decision models are generated: ranking based on the segregate dimensions and ranking based on the global impact (Appendix A). The outcome of ELECTRE III is the decision matrix, mapping the performance of each alternative, i.e., case study, based on the set of the identified criteria, i.e., sustainability impacts. The outputs can be classified in four contexts:

- Criteria a is *strictly preferred* to criteria b
- Criteria b is *strictly preferred* to criteria a
- Criteria a is *indifferent* to criteria b
- Criteria a is *incomparable* to criteria b

The main objectives of thresholds´ choice are, first to account for preference and indifference while comparing alternatives; and second to address the effect on the degree of compensation between the set of criteria (Buchholz et al., 2009; Mendoza and Martins, 2006).

- *i*: indicates the label of criteria.
- *gi(a)*: represents the individual importance evaluation of alternative *a* according to criteria *i.*
- *wi:* is the weight assigned by each evaluator to the criterion.
- *pi*: is the preference threshold representing strong preference i.e., evaluator strongly and strictly evaluates alternative *a* as more important than *b*, if $gi(a)>gi(b)+p(gi(b))$.
- *qi*: is the indifference threshold representing weak preference i.e., evaluator is indifferent between 2 alternatives. Alternative *a* is weakly preferred than *b,* if $gi(a)>gi(b)+q(gi(b))$.
- *vi:* is the veto threshold where the outranking relation is blocked i.e., alternative *b* cannot outrank *a*, if *a* exceeds that of *b* by a value greater than veto, if $gi(b) \geq gi(a) + vi(gi(a))$.

The output of ELECTRE III reveals concordance matrix (index for the strength to support that alternative *a* is at least as important as *b*); discordance matrix (index for the strength to support against the latter hypothesis); credibility matrix (index of the strength of the hypothesis); and dominance matrix. Several mathematical algorithms have been formulated to enhance multi-criteria performance (Ananda and Heralth, 2009; Figueira et al., 2005). Algorithms of each matrix are represented below:

- Ci(a,b) concordance index for each criterion and overall
  $Ci(a,b) = 0$, if $gi(b) \geq gi(a) + pi(gi(a))$
  $Ci(a,b) = 1$, if $gi(b) \leq gi(a) + qi(gi(a))$
  $Ci(a,b) = (gi(a) + pi(gi (a)) - gi (b))/(pi(gi(a))- qi(gi(a))$

Overall $C(a,b) = \sum wi\ Ci(a,b) / \sum wi$

- $Di(a,b)$ discordance index for each criterion
  $Di(a,b) = 0$, if $gi(b) \leq gi(a) + pi(gi(a))$
  $Di(a,b) = 1$, if $gi(b) \geq gi(a) + vi(gi(a))$
  $Di(a,b) = (gi(b) - gi\ (a) - pi(gi\ (a)))/(vi(gi(a))- pi(gi(a))$

- $S(a,b)$ credibility index
  $S(a,b) = C(a,b)$, if $di(a,b) \leq C(a,b)$ i $\forall$
  $S(a,b) = C(a,b) \quad \prod di(a,b) > C(a,b) \quad (1- di(a,b))/(1 - C(a,b))$

3.2.2 Data collection

A standardized index of indicators and sub-indicators is generated to evaluate each impact dimension: economic, socio-territorial, environmental, health, capacity building, and political. Each of the six impacts is measured by a set of sub-indicators, between eight and ten items. These items were standardized from the analysis conducted in Chapter 2 (from 32 INRA case studies and 4 IRTA cases studies selected from different industries in the agri-food sector). For instance, the economic indicator consists of eight items as assessment of productivity, cost reduction, economic growth, job creation, trade balance, small and medium enterprises (SMEs) and market entry, etc. As for the socio-territorial impact, ten measures are identified: socio-economic status (SES), business continuity, market expansion, patents exploitation, territorial management and land-use planning, and sustainable rural development, etc. For the political dimension, three major sub-indicators are derived: use in public debate (quality of research messages, intensity of media coverage, intensity of the debate); use for policy-making (policy cycle affected, territorial scale, relevance and novelty of the proposed solution); and societal importance of policy domain and magnitude of the affected population. Ten items are selected for the evaluation of environmental impact, as example: efficient consumption, waste and resources management, reduced contamination and disease, controlled pesticides/fertilizers dosage, decrease in greenhouse gas (GHG) and carbon dioxide (CO2) emission, and conservation of biodiversity. The health impact is measured by eight parameters: nutritional status and well-being, accessibility to rich nutrients, reduced health complication, minimize chemical exposure, control of pathogens and microbial levels, etc. To evaluate capacity building, ten criteria are suggested, such as scientific collaboration and partnership, adoption of innovation, insights and future research opportunities, training and formation, career advancement, knowledge production, and stakeholder engagement etc.

Through the stakeholder survey and the coordinators interviews, the data collection took place between January 2018 and September 2018. Two rounds of meetings were conducted in March 2018 and July 2018 with the project coordinators and researchers involved in the selected RDi projects. The project leaders facilitated the contact of the other stakeholders (end-users, policy-makers, and intermediaries). Between July 2018 and September 2018, the survey was addressed to all stakeholders engaged in the four case studies. The stakeholder group consists of: researchers, project coordinators, co-partners, experts, technicians, end-users, and policy-makers. The standardized index was distributed to the stakeholder network, which includes 120 participants. Due to some missing data, the final sample of this study consists of 53 evaluators, evenly distributed among the case studies and the stakeholders' group. The lowest response rate was among the end-users´ category. Each evaluator compares and rates each indicator and sub-indicator generated from the four case studies. The rating scale varies between 0 (not important) to 10 (very important). Beside evaluating individual sub-indicators, participants had to assign an importance weight (relative weight, *w*) for each general sustainability pillars (i.e., economic, socio-territorial, political, environmental, etc.). The following section provides a brief background of the selected case studies.

3.3 Case studies of Agri-food research and innovation: Institutional sustainability assessment

One of the fundamental processes in the agri-food sector is to evaluate the role of RDi and their outcomes. Nowadays, the contribution of research programs is not only limited to scientific development, rather than monitored and disseminated to sustainable and societal advancement (Markard et al., 2012). Research institutions have been assuming additional responsibilities toward economic prosperity, but also toward sustainable performances, fulfilling the regulations of the European (EU) Commission and adhering to the United Nations goals (Sanchez-Escobar et al., 2018; Thornton et al., 2013; UN, 2015). Through semi-structured interviews, open-ended surveys, and narrative data, a brief background of four research programs and a summary of their generated impacts (Table 3.1) are discussed in the following section.

Case 1: Sustainable practices in the rice cultivation

Rice cultivation has a dual effect, on the environment, as well as on farmers (Reig-Martínez et al., 2008; Sabiha et al., 2016). According to farmers, rice growers are implementing new techniques to enhance yield by incorporating efficient asset allocation, input usage, and cost-cutting methods. Through the "sustainable practices" research program, the outcome of Case 1 is mainly translated as adoption of eco-friendly and innovative strategies. The sustainable techniques consist of: land and water management, controlled pesticides usage, and efficient application of fertilizers. The research output is the development of an educational tool, i.e., theoretical and practical training and workshops, for knowledge production/transfer and awareness toward sustainability management in the sector. The practices acquired are described as: improvement of cost-effectiveness and optimization of resources usage, increase profitability of the sector, minimization of harmful impacts on the ecosystem, adequate irrigation systems, and controlled chemical dosages.

Case 2: Innovative recirculation system for aquaculture

The aquaculture industry is a core component to accomplishing the SDGs by 2030, specifically SDG 14 (conservation and sustainable use of oceans, seas, and marine resources). Growing social and political concerns around sustainable development have led to changes in aquaculture mechanisms, which have progressively integrated new strategies to build a sustainable sector (FAO, 2018). Case 2 addresses various aspects in this regard such as: extensive monitoring of the marine ecosystem and aquatic production; food safety and water quality; valuation of seafood products; and microbiological parameters, i.e., toxic phytoplankton, pollutants, organochlorines, heavy metals and water contamination. Therefore, the outcome of this research development is translated into a high-tech digitalized recirculation system. Accordingly, it provides fresh, affordable, accessible, and healthy seafood through ethical production and environmentally friendly mechanisms, minimizing the harmful impact on the maritime biodiversity. Case 2 reveals advanced regulations of various chemical factors that can be monitored and modified remotely: filtration and ultraviolet (UV) parameters, pH recording and calibration, maintenance of biological and safety milieu, water quality and transparency, feeding and balanced nutritious diets, and CO2 removal.

Case 3: Genetic cross breeding methods in the almond industry

The almond sector plays a significant role in the sustainable agriculture system and possesses a nexus of social value and a territorial importance for farmers and producers in Spain.

Consistently, the EU Commission advocates that "nuts production plays a fundamental part in protecting and maintaining environmental, social, and rural balance in many regions" (EC, 2004). Through the genetic breeding program, Case 3 identifies controlled crossing techniques of almond cultivars to maximize productivity, maintain high quality up to the EU benchmarks, and sustain economic growth. The main output is four new almond varieties, distinguished by their late blooming features with high quality and constant yield growth. Overall, these four almond products are compatible with the EU market due to the following characteristics: absence of double-kernel nuts, hard shells, minimized worm and bird damage, and prevention of aflatoxin contamination.

Case 4: Innovative technology in meat production

With the mechanization revolution, the meat industry has been shifting from traditional to modernized production systems. This transition mitigates the influence of undesirable weather factors, optimizes productivity, and ensures hygienic meat products (Akhtar and Pandey, 2015). Innovative models have been introduced to improve the production of processed meat (Stollewerek et al., 2012). These strategies are summarized as: enhance chemical composition, i.e., antioxidant, probiotics, and omega 3 fatty acids, provide healthy nutrients (reduced sodium, nitrates, and lower fat content), maintain high quality and flavor, and advance the meat sector as a whole (Toldrá and Reig, 2011). The outcome of Case 4 is an integrated drying system of meat and sausage products by reducing the processing time (approximately from 30 days to couple of hours), minimizing energy consumption, guaranteeing production consistency, meat quality and food safety, reducing contamination, and improving resource conservation (Comaposada et al., 2010; Stollewerk et al., 2012).

Table 3.1 Summary of the four case study and their impacts

	Standardized sustainable indicators			
Impacts	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Economic	• Improved productivity: 15% yield increase • Reduce costs through optimization of fertilizers and pesticides application • Continuity of family business • Sustain an economic growth	• Multi-species and multi-stage cultivation: 5% annual increase of aquaculture production • Optimization of resource consumption and energy saving • Improve the Spanish Aquaculture industry	• Increase in production capacity (2004-2009: from 200 to > 2000 kg/ha) • Improve the Spanish market in sales and exports of almond • Maintain economic growth and nuts quality abiding to the EU standards	• Increase yield 400kg/h: reduced production time, space, and costs • Reduce waste and food residuals: prolonged shelf-life and product preservation • Maintain economic growth and build sustainable value chain
Socio-territorial	• Improvement of farmers' conditions • Job creation for women and young farmers • Geographical Indication labelling • Regional expansion: Ebro Delta, Valencia, and Seville	• Improve SES through employment opportunities • Expansion in: Spain, EU, and International markets • Conservation of maritime territory and aquatic biodiversity	• Improvement of farmers' conditions • Sustain Spanish almond cultivation as second largest producer • Market expansion at EU and international level	• Initiative toward a platform for sustainable value chain • National and International expansion in Spain and some EU countries as a result of the patents exploitation and participation in global trade exhibitions
Political	• Addressing public interests within the crops and grains cultivation field • Providing new insights and scientific support to farmers: for Spanish and EU regulations (RD43/2002; EC1312/2008)	• Contribute to the public interest and policy-making by advancing the maritime sector and aquaculture industry • Use in public debate, policy negotiation, and societal importance of the policy domain (EC1421/2004)	• Addressing public interests within the tree nuts cultivation • Providing new insights to farmers and academicians • Improve Spanish production and trade balance • Contribution to the debate and policy making (EC870/2004 and EC73/2009)	• Regulatory implication to Spanish and EU laws (i.e., EC853-4/2004; EC2073/2005; RD1376/2003) • Contribution to public debate, policy negotiation, and societal importance domain in the meat production sector

Table 3.1 Summary of the four case study and their impacts (continued)

Health	• Improvement of the quality of the grains and the nutritional status of the soil • Promote well-being of the consumers • Minimize farm workers' exposure to pesticides and chemical hazards	• Animal welfare: rich nutritious cultivation environment • Contribute to the health and well-being of the population by providing a rich source of protein and omega-3 food	• Contribute to good nutritional status and well-being of the population • Reduce aflatoxin contamination fulfilling the EU regulation • Provide rich source of protein (24%), fibers (10%), and healthy oil (52%)	• Provide food products rich in protein and minerals • Control of pathogens and microbial levels: assuring food safety and quality • Customization of chemical composition by producing sliced meat with low salt and low-fat levels
Environmental	• Controlling time, frequency and use of fertilizers • Reduces losses and contamination • Water and waste management strategies • Land use efficiency: 27% of land apply “sustainable practices”	• Reduce energy consumption: 90% water and 70% electricity • Overcome sporadic problems related to the quality of water • Monitoring of the physical and chemical parameters • Sustainable aquaculture (SDG14)	• Provide diversity and variety of genetic almond cultivars • Enhancement of ecosystem biodiversity • Increase disease tolerance, self-compatibility, and improvement of nuts’ traits	• Efficient energy utilization and promotion of sustainable allocation of natural resources • 30% reduction in energy consumption compared to the conventional drying process • Waste management and minimize food losses
Capacity building	• Educational training, theoretical and practical knowledge, and scientific publications • Providing new insights of the sustainable cultivation • Formation: potential replication in other industries	• Scientific publications and conference presentations • Replication methods in others species • Training formation: scientific guidance; continuous instructions and follow-up	• New insights and scientific publications: providing promising lines for future research • Innovative investigation techniques: as model for replication	• International course: theoretical and practical knowledge production • Scientific publications: new insights for the agri-food innovation • Improvement and realization of new lines of product development

*Abbreviation used in the table: kilogram (kg); hectares (ha); hour (h); European Commission policy (EC): Royal Decree (RD)

3.4 Results and discussion

3.4.1 Descriptive analysis: dimension ranking within each case study

The following section elaborates on the results of the stakeholders´ evaluation. The standardized survey was addressed to all actors participating in the four research programs. The sample distribution is as follow: 14 respondents as program personnel, i.e., project director, partner, and consultants; 14 respondents as end users; 13 respondents as researchers; and 12 respondents as intermediary actors and policy makers. Following a ten-point rating scale, each evaluator assigns an importance score for each sub-indicator and an importance weight (*w)* for each impact reflecting the perspective of each actor. Table 3.2 displays *w* values by case.

Table 3.2 Importance weights by case

	Case 1	**Case 2**	**Case 3**	**Case 4**
Impact dimension	*w*	*w*	*w*	*w*
Economic	0.21	0.23	0.41	0.30
Socio-territorial	0.14	0.16	0.23	0.14
Environmental	0.21	0.20	0.09	0.08
Health	0.10	0.15	0.07	0.09
Capacity building	0.31	0.24	0.16	0.33
Political	0.02	0.02	0.03	0.06

The radar charts (Figure 3.1) illustrate the weighted average scores assigned by the group of stakeholders, indicating that economic impact and capacity building maintain the highest importance among the four case studies with an overall average of 6.49 and 6.85, respectively. The economic dimension is translated as enhancement of productivity, optimization of resource allocation, costs and loss reduction, and sustained economic growth (Tanzil and Beloff, 2006). Whereas, capacity building indicates knowledge production and dissemination, learning transfer, and skills development (Preskill and Boyle, 2008).

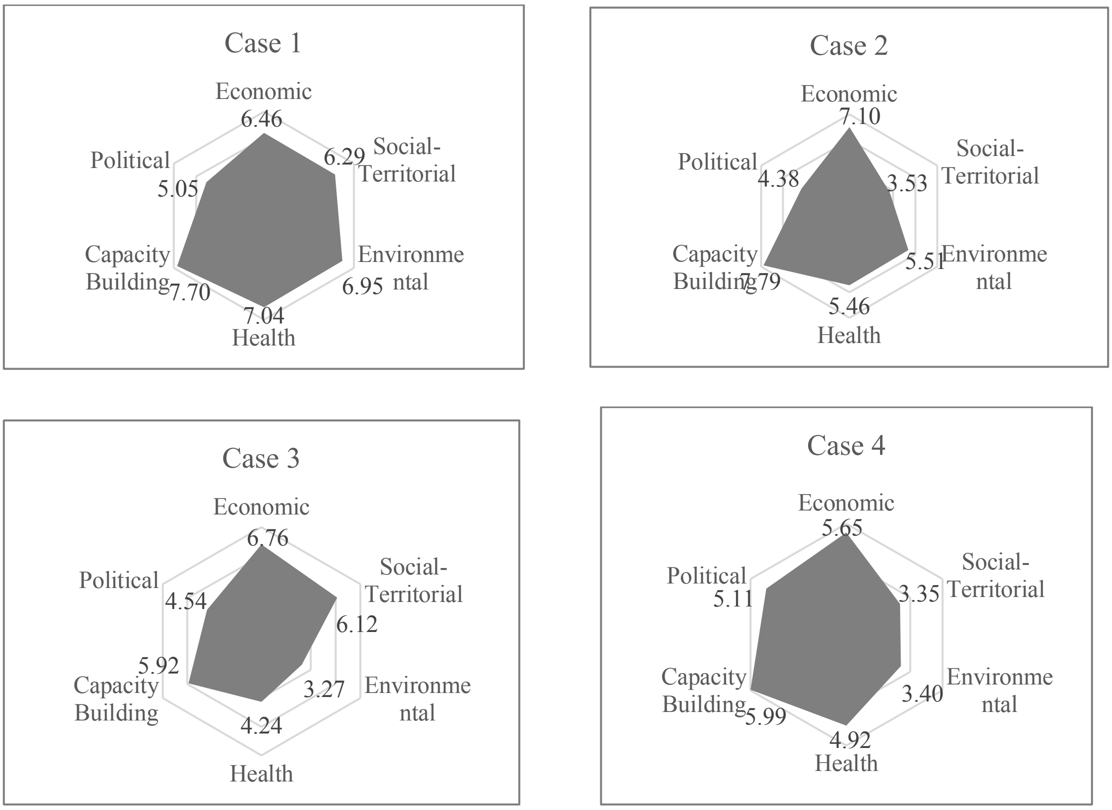

Figure 3.1 Radar charts of the four case studies

3.4.2 ELECTRE III analysis: Case study ranking based on segregate dimensions

To rank the case studies vis-à-vis sustainability pillars, firstly partial least squares discriminant analysis (PLS-DA) was performed (Appendix B). This technique is considered as an appropriate tool to deal with dimensionality reduction using a set of several "metrically scaled" independent variables and a categorical dependent variable (Brereton and Lloyd, 2014; Hair et al., 1995). Four sub-indicators were selected to measure each dimension according to the highest coefficients. For all six dimensions, coefficients are higher than 0.7, except for job creation sub-indicator of the economic impact, which is 0.5.

Like any decision modelling and project ranking, the dual challenge is defined as "no single criterion" and "no single decision maker" (Buchanan and Vanderpooten, 2007). In other words, to capture the impact generated, this requires a set of multiple criteria and consensus among the group of stakeholders. Therefore, with the support of the MCDM tool, perception of multi-stakeholder network toward the importance of RDi on sustainability performance is revealed. In the first analysis, the importance weights that were assigned by evaluators are as follows: economic 0.26; socio-territorial 0.16; environmental 0.17; health 0.11; capacity building 0.28; and political 0.03.

Moreover, three thresholds for decision modelling are derived from the method proposed by Liu and Zhang (2011). Kokaraki et al. (2019) describe q as the largest deviation and p as the smallest deviation (i.e., sufficient evidence to conclude a complete preference). Therefore, the thresholds values are calculated as follow:

q = 5% (maximum preference – minimum preference) = 0.5
p = 3 q = 15% (maximum preference – minimum preference) = 1.5
v = 3 (maximum preference – minimum preference) = 3

The findings of ELECTRE III provide further information on the alternatives' ranking, i.e., case studies, for six impacts. Table 3.3 displays a summary of the credibility matrix of each dimension. Coefficients indicate the strength of assertation to conclude that "*a* is at least as good as *b*" (Figueira et al., 2012).

Table 3.3 Credibility matrix of impacts

Credibility Matrix									
Economic	a1	a2	a3	a4	**Health**	a1	a2	a3	a4
a1	0.0	0.75	0.74	1.0	a1	0.0	1.0	1.0	1.0
a2	0.85	0.0	0.68	1.0	a2	0.0	0.0	0.98	0.75
a3	0.90	0.82	0.0	1.0	a3	0.0	0.0	0.0	0.46
a4	0.0	0.0	0.0	0.0	a4	0.0	0.75	1.0	0.0
Socio-Territorial	a1	a2	a3	a4	**Capacity**	a1	a2	a3	a4
a1	0.0	1.0	1.0	1.0	a1	0.0	1.0	1.0	1.0
a2	0.0	0.0	0.0	1.0	a2	1.0	0.0	1.0	1.0
a3	0.82	1.0	0.0	1.0	a3	0.0	0.02	0.0	1.0
a4	0.0	0.69	0.0	0.0	a4	0.03	0.04	1.0	0.0
Environmental	a1	a2	a3	a4	**Political**	a1	a2	a3	a4
a1	0.0	1.0	1.0	1.0	a1	0.0	1.0	1.0	0.98
a2	0.0	0.0	0.88	1.0	a2	0.51	0.0	0.96	0.51
a3	0.0	0.0	0.0	0.95	a3	0.33	0.95	0.0	0.66
a4	0.0	0.0	0.78	0.0	a4	0.80	1.0	1.0	0.0

Based on the credibility matrix, average preorder is displayed (Figure 3.2). Results suggest that Case 1 (a1) is ranked as the best alternative for all impacts considered in this analysis. Case 2 (a2) reveals high sustainability performance for four impacts i.e., economic, environmental, health, and capacity building. Case 3 (a3) indicates high ranking for two impacts i.e., economic and socio-territorial; and lastly, Case 4 (a4) scores high sustainability importance for two impacts, i.e., political and health. These findings indicate an indirect implication to the adoption of SDGs. Each case reflects an exclusive contribution to different set of SDGs. For instance, Case 1 "*sustainable practices in the rice cultivation*" indicates an implicit support toward SDGs: 1 (no poverty), 5 (gender equality), 8 (economic growth), 12 (responsible consumption and production), and 15 (life on land). Whereas for Case 2 "*innovative recirculation system for aquaculture*", its indirect contribution might be translated toward SDGs: 2 (no hunger), 8 (economic growth), 9 (industry and innovation), and 14 (life below water). Case 3 "*genetic cross breeding methods in the almond industry*" reveals an implication toward SDGs: 8 (economic growth) and 15 (life on land). Case 4 "*innovative technology in the meat production*" contributes to SDGs: 9 (industry and innovation) and 12 (sustainable consumption and production) (Gupta and Vegelin, 2016).

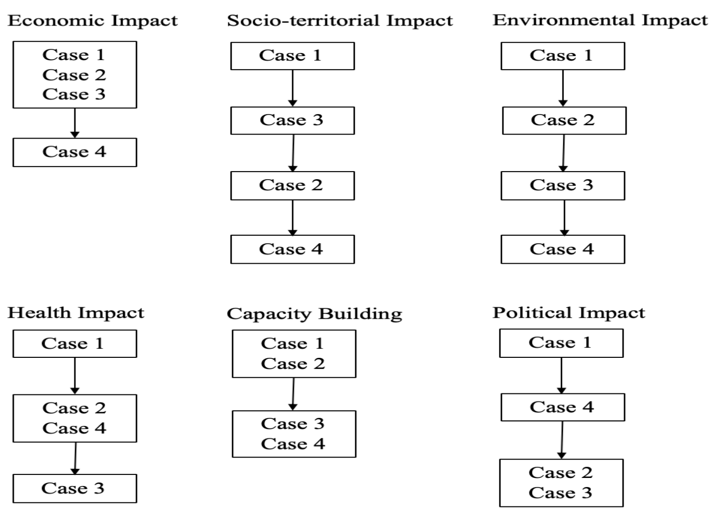

Figure 3.2 Case ranking by sustainability pillars

3.4.3 ELECTRE III analysis: Case study ranking based on global impact

Applying thresholds proposed by Liu and Zhang (2011), the second analysis consists of ranking case studies based on the global impact. Table 3.4 provides the perception of multi-stakeholder network toward the importance of RDi on sustainability performance. The empirical findings indicate that Case 1 "*Sustainable practices in the rice cultivation*" is ranked as the best alternative in regard to sustainability performance, followed by Case 2 "*Innovative recirculation system for aquaculture*" and Case 3 "*Genetic cross breeding methods in the almond industry*". Case 4 *"Innovative technology in the meat production"* is considered to be least important compared to the other cases. Furthermore, the concordance values of Case 1 reveals strong assertation with highest coefficients for all criteria (i.e., coefficients > 0.8).

Table 3.4 ELECTRE III output of the global impact

Concordance Matrix:	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Case 1	0.000	0.964	1.000	1.000
Case 2	0.570	0.000	0.842	0.993
Case 3	0.445	0.476	0.000	0.978
Case 4	0.207	0.3055	0.685	0.000
Dominance Matrix:	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Case 1	0	P+	P+	P+
Case 2	P-	0	P+	P+
Case 3	P-	P-	0	P+
Case 4	P-	P-	P-	0

Figure 3.3 illustrates the ascending distillation (smallest qualification is retained initially), descending distillation (largest qualification is retained initially), and average (combined preorder). The final ranking vis-à-vis sustainability impact implies that Case 1 is ranked as the most sustainable research project, while Case 4 is the lowest placed in this regard.

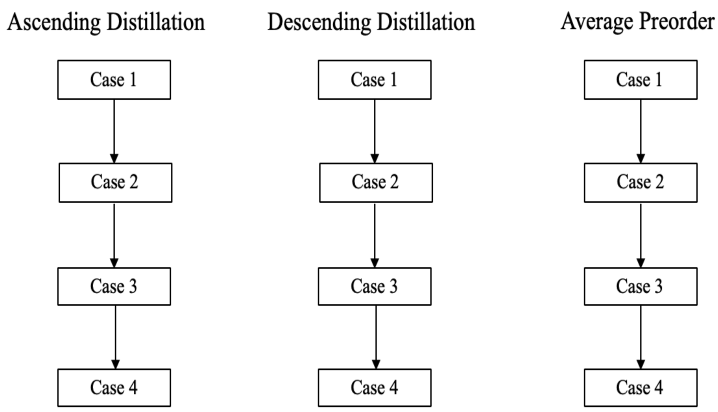

Figure 3.3 Case ranking by global impact

3.4.4 Sensitivity analysis and robustness check

The inclusion of an exhaustive list of sub-indicators (a total of 54 items) denotes some challenge as requesting from stakeholders to provide several sets of thresholds. Therefore, further sensitivity analysis and robustness checks have been conducted to validate the prior findings. The purpose of this analysis is to obtain rigorous results and mitigate thresholds selection bias. The ELECTRE III method overcomes explicitly the uncertainty criteria by iterating thresholds values in the decision making modelling (Cinelli et al., 2014; Figueira et al., 2005). Consistently, different methods have been applied to conduct sensitivity tests through assigning different values of thresholds q, p, and v (Buchanan and Vanderpooten, 2007; Khalili and Duecker, 2013; Marzouk, 2011).

Sensitivity test 1

As mentioned previously, the ranking of importance scale in the stakeholder survey varies between 0 (lowest value) and 10 (highest value as most desired performance). The first sensitivity check relies on the method suggested by Balali et al. (2014). Weight w values remain the same as the prior analysis; whereas q, p, and v are derived as follow. In this scenario, q is defined as the difference between most desired preference (i.e., end of the scale, 10) and acceptable preference (7.5). As for the preference threshold p, it is calculated as the difference between most desired preference and strictly not beyond level (3). Finally, veto threshold *v* is the difference between most desired preference and critical condition (1). Table 3.5 and figure 3.4 display the results of the first sensitivity test.

Table 3.5 Sensitivity test 1 - ELECTRE III output with different thresholds

Concordance Matrix:	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Case 1	0.000	0.777	0.971	1.000
Case 2	0.537	0.000	0.842	0.970
Case 3	0.428	0.394	0.000	0.875
Case 4	0.030	0.227	0.584	0.000
Dominance Matrix:	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Case 1	0	P+	P+	P+
Case 2	P-	0	P+	P+
Case 3	P-	P-	0	P+
Case 4	P-	P-	P-	0

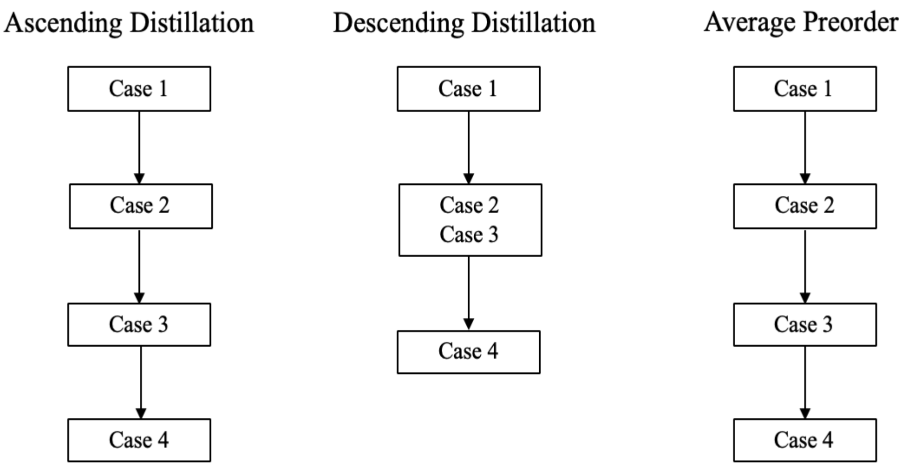

Figure 3.4 Sensitivity test 1 - Case studies ranking

Sensitivity test 2

To run the second robustness check, three thresholds are determined based on input and consultation of decision makers and experts in the field (Rogers and Bruen, 1998). The three thresholds fulfill the rule of Rogers and Bruen (1998): vi (0.7) $\geq pi$ (0.5) $\geq qi$ (0.3). Table 3.6 and figure 3.5 reveal similar ranking decision to the previous analysis. In the dominance matrix, "P+" indicates preference decision and "R" corresponds to incomparability between alternative cases. For instance, we can conclude that Case 1 (a1) is selected as the most sustainable research project. Whereas Case 2 (a2) and Case 3 (a3) are incomparable according to the set of criteria included in the ranking process. Incomparability is not interpreted as indifference in the ranking decision, rather a lack of sufficient evidence supporting either Case 2 (a2) or Case 3 (a3) (Roy, 1993).

Table 3.6 Sensitivity test 2 - ELECTRE III output with different thresholds

Concordance Matrix:	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Case 1	0.000	0.743	1.000	1.000
Case 2	0.535	0.000	0.842	0.970
Case 3	0.416	0.394	0.000	0.861
Case 4	0.030	0.188	0.584	0.000
Dominance Matrix:	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Case 1	0	P+	P+	P+
Case 2	P-	0	R	P+
Case 3	P-	R	0	P+
Case 4	P-	P-	P-	0

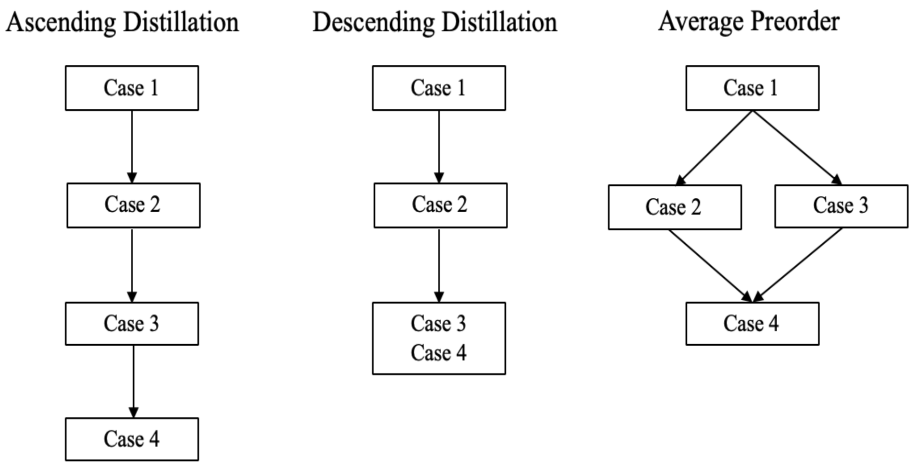

Figure 3.5 Sensitivity test 2 - Case studies ranking

Finally, the empirical results show consistent global ranking across the models using different thresholds values. The ranking modelling maintains highest sustainability performance for Case 1 (ranked as first alternative) and lowest toward Case 4 (ranked as last alternative) in all scenarios. As for Case 2 and Case 3, ELECTRE III analysis does not provide conclusive results to explicitly differentiate and rank their impacts.

3.5 Conclusion

As more practitioners, policy makers, and experts are becoming concerned about the societal value of research, sustainability assessment is becoming a holistic, systematic, and essential practice within the agri-food industry. This article has attempted to bring together knowledge about the nexus between research programs and sustainability performance. Applying the MCDM technique, four case studies have been assessed to identify and rank their generated sustainability impact from multi-stakeholder perspectives. As noted by Cinelli et al. (2014), MCDM could be an adequate tool for sustainability assessment taking into consideration multiple criteria in a flexible manner, by means of a structured framework. Inclusion of a comprehensive list of sub-indicators measuring six dimensions of sustainability impact improves the ranking criteria and classification of case studies. Although the selection of thresholds and weights might indicate some degree of subjectivity or bias, robustness checks and sensitivity analyses were conducted. Ranking schemes remain consistent with different q, p, and v thresholds. One limitation of the ELECTRE III method highlighted in the literature is the rank reversal. Due to the nature of sustainability phenomena, continuous alternatives and information might emerge throughout the assessment process. Therefore, to overcome this challenge, future work might consider the adoption of “dynamic evaluation”, which is mainly performed by expert choice of analytical hierarchical process.

This study identifies insights for policy makers to demonstrate not only the scientific and economic value of research, but to go a step further in the assessment. Nowadays, the debate in the impact assessment literature emphasizes answering the following query: *what is the societal value of science and how has scientific research been moving outside of the academic community?* This study intended to provide modest knowledge in this regard and proposed a potential answer to the unresolved question.

Further investigations embracing both qualitative and quantitative are still needed. From a methodological perspective, our analysis argues that involving stakeholder knowledge within the nexus of a research-innovation-sustainability evaluation would provide more reliable and valid results. Furthermore, the impact of research and innovation can be implicitly translated to the implementation of SDGs in the agri-food sector.

Appendix A

Table A.1 Input matrix – ELECTRE III for global impact

Indifference	**q**	0.5	0.5	0.5	0.5	0.5	0.5
Preference	**p**	1.5	1.5	1.5	1.5	1.5	1.5
Veto	**v**	3	3	3	3	3	3
Weight	**w**	0.26	0.16	0.17	0.11	0.28	0.03
		g1	**g2**	**g3**	**g4**	**g5**	**g6**
Case 1	**a1**	6.46	6.29	6.95	7.04	7.70	5.05
Case 2	**a2**	7.10	3.53	5.51	5.46	7.79	4.38
Case 3	**a3**	6.76	6.12	3.27	4.24	5.92	4.54
Case 4	**a4**	5.65	3.35	3.40	4.92	5.99	5.11

Appendix B

Table A.2 Selection of sub-indicators using PLS-DA analysis

Economic	***c***	***Socio-territorial***	***c***	***Environment***	***c***
Productivity	**0.915**	Job for female	**0.904**	Contamination	**0.844**
losses	**0.855**	landscape	**0.904**	Pesticide dose	**0.835**
Econ. Growth	**0.770**	Sustained resource	**0.893**	Gas Emission	**0.858**
Job creation	**0.556**	Rural development	**0.892**	Water protection	**0.860**
Health	***c***	***Capacity Building***	***c***	***Political***	***c***
Well-being	**0.823**	Collaboration	**0.869**	Quality & strength of research	**0.883**
Food safety	**0.822**	Knowl. Production	**0.908**	Intensity of media coverage	**0.826**
Food quality	**0.853**	Improvement	**0.915**	Quality &Intensity Debate	**0.795**
Chemical exposure	**0.866**	Post evaluation	**0.839**	Social concern	**0.799**

References

Akhtar, J., Pandey, K., 2015. Meat drying technology and drying characteristics of meat and meat products. Int. J. Appl. Pure Sci. Agric. 1, 21–25.

Ananda, J., Heralth, G., 2009. A critical review of multi-criteria decision making methods with special reference to forest management and planning. Eco. Econ. 68, 2535–2548. https://doi.org/10.1016/j.ecolecon.2009.05.010

Balali, V., Zahraie, B., Roozbahani, A., 2014. Integration of ELECTRE III and PROMETHEE II decision-making methods with an interval approach: Application in selection of appropriate structural systems. J. Comput. Civ. Eng. 28, 297–314. https://doi.org/10.1061/(asce)cp.1943-5487.0000254

Belton, V., Stewart, T.J., 2002. Multiple Criteria Decision Analysis: an Integrated Approach. Kluwer Academic Publisher

Bond, A., Morrison-Saunders, A., Pope, J., 2012. Sustainability assessment: the state of the art. Impact Assess. Proj. Appraisal 30, 53–62. https://doi.org/10.1080/14615517.2012.661974

Braunschweig, T., Janssen, W., Rieder, P., 2001. Identifying criteria for public agricultural research decisions. Res. Policy, 30, 725–734. https://doi:.org/10.1016/s0048-7333(00)00122-0

Brereton, R. G., Lloyd, G. R., 2014. Partial least squares discriminant analysis: taking the magic away. J. Chemom. 28, 213–225.

Buchanan, J., Vanderpooten, D., 2007. Ranking projects for an electricity utility using ELECTRE III. Int. Trans. Oper. Res. 14, 309–323. https://doi.org/10.1111/j.1475-3995.2007.00589.x

Buchholz, T., Rametsteiner, E., Volk, T.A., Luzadis, V.A., 2009. Multi criteria analysis for bioenergy systems assessments. Energy Policy, 37, 484–495. https://doi.org/10.1016/j.enpol.2008.09.054

Chan, K., Satterfield, T., Goldstein, J., 2012. Rethinking ecosystem services to better address and navigate cultural values. Ecol. Econ. 74, 8–18. https://doi.org/10.1016/j.ecolecon.2011.11.011

Cinelli, M., Coles, S. R., Kirwan, K., 2014. Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment. Ecol. Indic. 46, 138–148. https://doi.org/10.1016/j.ecolind.2014.06.011

Comaposada, J., Arnau, J., Ferrini, G., Sanz, D., Xargayó, M., Freixanet, L., 2010. Better control of process and product quality - impact of the dryness level on the quality of fermented sausages produced by means of quick-dry-slice process technology. Fleischwirtschaft International, 25, 87–95.

EPA, U.S., 2006. Life Cycle Assessment: Principles and Practice. National Risk Management Research Laboratory. Cincinnati, OH, USA

European Commission EC, 2004. The SAFENUT AGRI GEN RES action. Retrieved from https://ec.europa.eu/agriculture/sites/agriculture/files/genetic-resources/actions/f-068/final-fact-sheet_en.pdf.

Failing, L., Gregory, R., Harstone, M., 2007. Integrating science and local knowledge in environmental risk management: a decision-focused approach. Ecol. Econ. 64, 47–60. https://doi.org/10.1016/j.ecolecon.2007.03.010

FAO, 2018. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. Licence: CC BY-NC-SA 3.0 IGO.

Figueira, J., Greco, S., Roy, B., Słowiński, R., 2012. An overview of ELECTRE methods and their recent extensions. J. Multi-Criteria Decis. Anal. 20, 61–85. https://doi.org/10.1002/mcda.1482

Figueira, J., Salvatore, G., Ehrgott, M. (Eds.) 2005. Multiple Criteria Decision Analysis: State of the art surveys. Springer, New York. pp. 1–1045.

Freeman, R., 1984. Strategic Management: A Stakeholder's approach. Pitman. Boston, MA

Gamboa, G., 2006. Social multi-criteria evaluation of the different development scenarios of the Aysén region, Chile. Ecol. Econ. 59, 157–170. https://doi.org/10.1016/j.ecolecon.2005.10.014

Garmendia, E., Prellezo, R., Murillas, A., Escapa, M., Gallastegui, M., 2010b. Weak and strong sustainability assessment in fisheries. Ecol. Econ. 70, 96–106. https://doi.org/10.1016/j.ecolecon.2010.08.001

Gasparatos, A., El-Haram, M., Horner, M., 2008. A critical review of reductionist approaches for assessing the progress towards sustainability. Environ. Impact Assess. Rev. 28, 286–311.
https://doi.org/10.1016/j.eiar.2007.09.002

Gasparatos, A., Scolobig, A., 2012. Choosing the most appropriate sustainability assessment tool. Ecol. Econ., 80, 1–7. https://doi.org/10.1016/j.ecolecon.2012.05.005

Gibson, R.B., 2006. Sustainability assessment: basic components of a practical approach. Impact Assess. Project Appraisal 24, 170–182. https://doi.org/10.3152/147154606781765147

Greco, S., Matarazzo, B., Słowinski, R., 2004. Axiomatic characterization of a general utility function and its particular cases in terms of conjoint measurement and rough-set decision rules. Eur. J. Oper. Res. 158, 271–292. https://doi.org/10.1016/j.ejor.2003.06.004

Greco, S., Matarazzo, B., Slowinski, R., 2001b. Rough sets theory for multicriteria decision analysis. Eur. J. Oper. Res. 129, 1–47. https://doi.org/10.1016/S0377-2217(00)00167-3

Gupta, J., Vegelin, C., 2016. Sustainable development goals and inclusive development. Int. Environ. Agreements 16, 433–448. https://doi.org/10.1007/s10784-016-9323-z

Hair, J. F., Anderson, R. E., Tatham, R. L., Black, W. C., 1995. Multivariate Data Analysis with Readings Fourth Edition. New Jersey: Prentice Hall.

Hajkowicz, S. A., 2008. Supporting multi-stakeholder environmental decisions. J. Envir. Manage. 88, 607–614. https://doi.org/10.1016/j.jenvman.2007.03.020

Jamieson, D. G., Fedra, K., 1996. The 'Water Ware' decision-support system for river-basin planning. 1. Conceptual design. J. Hydrol. 177, 163–175. https://doi.org/10.1016/0022-1694(95)02957-5

Keeney, L.R., Raiffa, H., 1976. Decisions with multiple objectives: preferences and value tradeoffs. Wiley, New York.

Khalili, N. R., Duecker, S., 2013. Application of multi-criteria decision analysis in design of sustainable environmental management system framework. J. Clean. Prod. 47, 188–198. https://doi.org/10.1016/j.jclepro.2012.10.044

Kokaraki, N., Hopfe, C. J., Robinson, E., Nikolaidou, E., 2019. Testing the reliability of deterministic multi-criteria decision-making methods using building performance simulation. Renewable Sustainable Energy Rev. 112, 991–1007. https://doi.org/10.1016/j.rser.2019.06.018

Liu, P., Zhang, X., 2011. Research on the supplier selection of a supply chain based on entropy weight and improved ELECTRE-III method. Int. J. Prod. Res. 49, 637–46. https://doi.org/10.1080/00207540903490171.

Marianne, L. M., 1996. A multi-attribute spatial decision support system for solid waste planning. Comput. Environ. and Urban Syst. 20, 1–17. https://doi.org/10.1016/S0198-9715(96)00006-3

Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: an emerging field of research and its prospects. Res. Policy, 41, 955–967. https://doi.org/10.1016/j.respol.2012.02.013

Marttunen, M., Hämäläinen, R. P., 1995. Decision analysis interviews in environmental impact assessment. Eur. J. Oper. Res. 87, 551–563. https://doi.org/10.1016/0377-2217(95)00229-4

Marzouk, M., 2011. ELECTRE III model for value engineering applications. Autom. Construction, 20, 596–600. https://doi.org/10.1016/j.autcon.2010.11.026

Mendoza, G.A., Martins, H., 2006. Multi-criteria decision analysis in natural resource management: a critical review of methods and new modelling paradigms. Forest Ecol. Manage. 230, 1–22. https://doi.org/10.1016/j.foreco.2006.03.023

Meyer, J., Rowan, B., 1977. Institutionalized organizations: Formal structure as myth and ceremony. Am. J. Soc. 83, 340–63.

Munda, G., 2005. Multi criteria decision analysis and sustainable development, pp. 953-986 in J. Fiigueir, S. Greco, and M. Ehrgott, editors. Multiple Criteria Decision Analysis: State of the Art Surveys. Springer, New York. http://publications.jrc.ec.europa.eu/repository/handle/111111111/13077

O'Neill, J., Martinez-Alier, J., Munda, G., 1999. Commensurability and compensability in ecological economics. In: Cheltenham, M.O.C.C.S. (Eds.). Valuation and the Environment: Theory, Method, and Practice. Elgar

Pope, J., Annandale, D., Morrison-Saunders, A., 2004. Conceptualizing sustainability assessment. Environ. Impact Assess. Rev. 24, 595–616. https://doi.org/10.1016/j.eiar.2004.03.001

Preskill, H., Boyle, S., 2008. A multidisciplinary model of evaluation capacity building. Am. J. Eval. 29, 443–459. https://doi.org/10.1177/1098214008324182

Ramanathan, R., 2001. A note on the use of the analytic hierarchy process for environmental impact assessment. J. Environ. Manage. 63, 27–35. https://doi.org/10.1006/jema.2001.0455

Reig, E., Picazo-Tadeo, A., Estruch, V., 2008. The policy analysis matrix with profit-efficient data: Evaluating profitability in rice cultivation. Span. J. Agric. Res. 6, 309–319. https://doi.org/10.5424/sjar/2008063-324

Rogers, M., Bruen, M., 1998. Choosing realistic values of indifference. preference and veto thresholds for use with environmental criteria within ELECTRE. Eur. J. Oper. Res. 107, 542–551. https://doi.org/10.1016/S0377-2217(97)00175-6

Roy, B., 1991. The outranking approach and the foundations of ELECTRE methods. Theor. Decis. 49–73. https://doi.org/10.1007/BF00134132

Roy, B., 1993. Decision science or decision-aid science? Eur. J. Oper. Res. 66, 184–203. https://doi.org/10.1016/0377-2217(93)90312-B

Roy, B., 1996. Multicriteria Methodology for Decision Aiding. Kluwer Academic Publishers.

Saarikoski, H., Mustajoki, J., Hjerppe, T., Aapala, K., 2019. Participatory multi-criteria decision analysis in valuing peatland ecosystem services—Trade-offs related to peat extraction vs. pristine peatlands in Southern Finland. Ecol. Econ. 162, 17–28. https://doi.org/10.1016/j.ecolecon.2019.04.010

Sabiha, N., Salim, R., Rahman, S., Rubzen, M.F., 2016. Measuring environmental sustainability in agriculture: A composite environmental impact index approach. J. Envir. Manage. 166, 84–93. https://doi.org/10.1016/j.jenvman.2015.10.003

Sala, S., Farioli, F., Zamagni, A., 2013a. Life cycle sustainability assessment in the context of sustainability science progress (part 2). Int. J. Life Cycle Assess. 18, 1686–1697. https://doi.org/10.1007/s11367-012-0509-5

Sala, S., Farioli, F., Zamagni, A., 2013b. Progress in sustainability science: lessons learnt from current methodologies for sustainability assessment: Part 1. Int. J. Life Cycle Assess. 18, 1653–1672. https://doi.org/10.1007/s11367-012-0508-6

Sanchez-Escobar, F., Coq-Huelva, D., Sanz-Cañada, J., 2018. Measurement of sustainable intensification by the integrated analysis of energy and economic flows: Case study of the olive-oil agricultural system of Estepa. Spain. J. Clean. Prod. 201, 463–470. https://doi.org/10.1016/j.jclepro.2018.07.294

Slowinski, R., Greco, S., Matarazzo, B., 2012. Rough set and rule-based multicriteria decision aiding. Pesquisa Operacional 32, 213–270

Stollewerk, K., Jofré, A., Comaposada, J., Ferrini, G., Garriga, M., 2012. Ensuring food safety by an innovative fermented sausage manufacturing system. Food Control, 22, 1984–1991. https://doi.org/10.1016/j.foodcont.2011.05.016

Tanzil, D., Beloff, B. R., 2006. Assessing impacts: Overview on sustainability indicators and metrics. Environ. Qual. Manage. 15, 41–56. https://doi.org/10.1002/tqem.20101

The United Nations 2030 Agenda for Sustainable Development (2015, October 04). Retrieved from https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Thornton, P.K., Toulmin, C., Vermeulen, S.J., Godfray, H.C.J., 2013. Sustainable intensification in agriculture: premises and policies. Sci. 341, 33–34. https://doi.org/10.1126/science.1234485

Toldrá, F., Reig, M., 2011. Innovations for healthier processed meats. Trends in Food Sci. Technol. 22, 517–522. https://doi.org/10.1016/j.tifs.2011.08.007

Qin, X., Huang, G., Chakma, A., Nie, X., Lin, Q., 2008. A MCDM-based expert system for climate-change impact assessment and adaptation planning – A case study for the Georgia Basin. Canada. Expert Syst. Appl. 34, 2164–2179. https://doi.org/10.1016/j.eswa.2007.02.024

Zamagni, A., Buttol, P., Buonamici, R., Masoni, P., Guine'e, J. B., Huppes, G., Heijungs, R., Van der Voet, E., Ekvall, T., Rydberg, T., 2009. D20 Blue Paper on Life Cycle Sustainability Analysis. Institute of Environmental Sciences. Leiden University (CML). CALCAS Project. http://www.calcasproject.net/default.asp?site=calcas&-page_id=E2669B0F-9DB7-4D1E-95B0-407BC7949030

Zhou, Q., Huang, G.H., Chan, C.W., 2004. Development of an intelligent decision support system for air pollution control at coalfired power plants. Expert Syst. Appl. 26, 335–356. https://doi.org/10.1016/j.eswa.2003.09.005

Chapter 4. Between "research producers" and "research adopters": The role of knowledge and innovation transfer on sustainability impact

Abstract

This study contributes to the ongoing debate on research utilization and assessment of knowledge and innovation transfer (K&IT). The scope of this research is to move away from "evaluating processes" of knowledge transfer to "impact" of knowledge transfer and to examine how each type of knowledge production contributes to sustainability impact of research. Relying on knowledge-based theory, we intend to identify the mechanisms and indicators of knowledge and technology exchange of a research institution in the agri-food sector in Spain, through addressing two case studies in two different industries. The study consists of an explanatory analysis of a database between 2013 and 2020. Field-specific indicators are identified to better understand the mechanism bridging scientific output and impact. Our empirical findings suggest that "sectorial trainings", "consulting service" and "external & site visits" enhance and facilitate the articulation of knowledge from researchers to end-users. This research study is expected to shed new light on the micro level of research impact i.e., project level, providing tools for researchers and practitioners to improve their impact and to reach wider audience through knowledge exchange, while accomplishing a dual mission as scientific and sustainability targets.

Keywords: Knowledge & innovation transfer; research mechanisms; societal impact; stakeholders;

4.1 Introduction

Nowadays, the scientific community and policy makers have been engaged in assessing the outcome and quality of research development and innovation (R&I) from multiple perspectives, relying on holistic frameworks. The academic assessment of R&I has been limited to a set of indicators such as: scientific output, articles publication, citations count, h-index etc. (D´Este et al., 2018; Spaapen and van Drooge, 2011). While the evaluation parameters of the scientific impact of R&I are widely identified, validated indicators of assessment of the knowledge and innovation transfer (K&IT) on sustainability impact remain deficient (Spaapen and van Drooge, 2011; van Wijk et al., 2008). The reason behind conducting an evaluation of the knowledge produced and the impact generated might have several benefits (Fini et al. 2018; Nutley et al. 2007, Penfield et al. 2013) such as accountability, relevance and value of research return, and evidence-based implications (Bennett et al. 2012; Donovan 2008).

This study engages in the ongoing debate on research utilization (Dobbins et al., 2001; Landry et al., 2003) and assessment of R&I (Castka, 2003; Cooke, et al., 2003). The scope of this research is to move away from "evaluating processes" of K&IT to "impact" of K&IT (Molas-Gallart and Tang, 2011). We intend to identify the mechanisms and indicators of K&IT, examining two case studies: case study 1 "Best practices in sustainable rice cultivation and case study 2 "genetic crossbreeding of almond varieties". Moreover, we aim to analyze how each type of knowledge production contributes to the societal impact: economic, socio-territorial, environmental, health, capacity building, and political. As indicated by Spaapen and van Drooge (2011), there is a considerable deficiency of quantitative data monitoring knowledge and impact. Practically, the methodological challenge remains on linking these two concepts, due to the complexity of the innovation process and involvement of various actors in R&I.

According to the UK Research Excellence Frameworks, the new standards of research evaluation comprise three main assessment components: academic outcomes, societal or sustainability impacts, and the research environment (REF, 2011). As for the Royal Netherlands Academy of Arts and Sciences (KNAW) and the QRiH system (Prins et al. 2019), the criteria of R&I assessment consist of three global indicators: "societal quality", "societal impact", and "valorization of the work". Comparing the aforementioned frameworks, we can highlight some communalities and dissimilarities, which might be related to the third measure of valorization. A growing concern regarding tools and system models to assess both knowledge use and sustainable impacts, is rising at a global level among scholars, funders, and regulators (Morton, 2015), explicitly in Europe (League of European Research Universities, 2013), the United Kingdom (Higher Education Funding Council, 2011), Australia (Jones et al., 2004), and the United States (Hicks, 2004).

To go a step further, recently the mission of various research programs consists of an interconnection between knowledge generation and knowledge dissemination with an aim to enhance innovation, and improve the use of science (Belcher et al., 2016; Clark and Dickson, 2003). Therefore, the new trend integrated among scholars is to focus on the dual creation of scientific and societal impact with a mutual added-value to the academia and the society (Bornmann, 2013; Bozeman and Sarewitz, 2011). Accordingly, the assessment of research return is based on the nexus between the advancement of knowledge and innovation, and knowledge availability and accessibility to the communities (Salter and Martin, 2001).

Cornell et al. (2013) clearly suggested that a pre-requisite of achieving sustainability objective relies on a combination of knowledge production and knowledge exchange. For instance, to mitigate the grand challenges faced throughout the implementation process of this paradigm, a metamorphosis of the knowledge systems is recognized as key solution of this phenomenon (Jäger et al., 2013). Tàbara and Chabaya (2013) propose to "opening up" the knowledge systems by encouraging interaction between scientists and stakeholders and by promoting research which are societal- and sustainability- oriented. One of the crucial role of knowledge and innovation (K&I) is having the leading function in framing sustainability and driving solutions for both social and environmental concerns (Cornell et al., 2013; Fischer et al., 2012). It is gradually perceived as a vital element for the evaluation of R&I impacts (Fazey et al., 2013).

4.2 Literature review

On the one hand, R&I impact assessment has recently gained a considerable attention to understand the mechanism of knowledge transfer, and on the other hand to assess the knowledge economy in order to justify the scientific and social return of investments in R&I (Knight and Lightowler, 2010). From sustainability perspective, K&IT of research projects consists of a system of actors interconnected by a set of activities based on "knowing, learning, and implementing" to enhance social and environmental performance (Cornell et al., 2013; van Kerkhoff and Szlezák, 2010). In this aspect, Fazey et al. (2013) clearly state that the leading role of knowledge exchange is to facilitate the operationalization of scientific research (Cvitanovic et al., 2016). While this phenomenon has been widely deployed in Canada and UK during the last years (Lightowler and Knight, 2013), emergent concerns from policy makers and researchers have been recently appearing in Europe. The overall mechanism of assessing research encompasses overlapping stages, from identifying the relevancy of the topics tackled, to knowledge production, knowledge transfer, and knowledge impact (RCUK, 2011).

To further elaborate on knowledge production, several scholars have applied interchangeable definitions, such as democratizing science (Liberatore and Funtowicz, 2003), open innovation (Von Hippel, 2005), and collaborative research (Brown et al. 2010). Phillipson et al. (2012) suggest that strengthening the association between science and society is a key factor for effective research uptake, which requires an active K&IT and stakeholder involvement throughout the knowledge production process. Whereas, Francis and Goodman (2011) and Fazey et al. (2014) consider that multi-way interactions and co-production of knowledge between scientists and beneficiaries of science as antecedents of effective K&IT. Another group of studies described the link between scientific and societal impact as “bilateral learning” or “productive interactions” between various actors in K&IT (D’Este et al., 2018; Nowotny et al., 2001). In the same vein, Molas-Gallart and Tang (2011) and de Jong et al. (2014) claim that these interactions among researchers and end-users mitigate some challenges between scientific and sustainability targets and enhance the achievement of societal impact of R&I.

Knowledge and knowledge transfer have been perceived differently among the scientific community, inducing the use of diverse approaches and methodologies in its evaluation (Fazey et al., 2014). Various terminologies have been identified in the literature (knowledge exchange, knowledge diffusion, knowledge transfer, knowledge sharing, knowledge acquisition, and knowledge utilization, etc.) (Graham et al., 2006; Schulz, 2001; Tsai, 2002). Similarly, Landaeta and Kotnour (2005) provide another set of definitions related to knowledge: “creation, assimilation, storage, organization, protection, application, validation, verification, and identification”. However, the concept of knowledge exchange is the most widely used implying bi-directional interchange of science (Gravois Lee and Garvin, 2003). The “exchange” happens in the interaction stages between research producers and research users (Davies et al., 2005). The antecedents of the collaborative framework of K&IT relies from the one hand on users´ willingness to understand and adopt the channels of K&IT in order to become a common practice; and from the other hand on researcher´s expertise based on the capacity of knowledge creation and knowledge accessibility (Julnes and Holzer, 2001; Lomas, 1993).

Knott and Wildavsky´s (1980) model describes the pathway from knowledge to impact of a research project in seven steps: reception, cognition, discussion, reference, adoption, implementation, and impact. Whereas, Lavis (2006) categorizes K&IT in three processes: push (research producers adopt instruments to diffuse the knowledge toward the targeted audience), pull (end-users implement tools to absorb the knowledge based on their own interest), and exchange (strategies combining producer and user together in an interactive transfer of knowledge). Fazey et al. (2014) elaborate on other ingredients of K&IT evaluation: 1) planning and designing, 2) identifying explicit strategies to deliver the expected outcomes, 3) assess the outcomes, 4) integrate evaluation process, and 5) use diverse methodological frameworks to conduct the evaluation.

The conceptual framework of sustainability research is described as a learning process through engagement of knowledge producers transmitting the scientific piece to multiple actors in R&I (Lemos and Morehouse, 2005; Robinson and Tansey, 2006). However, the difficulty remains in capturing the measures of K&IT and quantifying its impact on sustainability performance. The complexity and nature of research projects engender methodological challenges to equally take into account all the actors engaged in the developmental process of knowledge. As mentioned previously, K&IT is a key component throughout the project lifetime, described as the "capability" of research (Landaeta, 2008), channelling science from "research producer" to "research adopter". Measuring the contribution of K&IT to the societal impact is still largely unknown. This can be clearly attributed to the lack of both qualitative and quantitative research which is mainly limited due to the sensitive nature of knowledge and temporal aspects of impact (Ahmad and Karim, 2019). Research organizations that attempt to evaluate the effectiveness of knowledge transfer often face challenges mainly related to: 1) the time lapse between research results and their impact on the society, 2) attribution problem of the impact to resources used to develop innovation, and 3) the complexity of the innovation process and involvement of different actors in the R&I (Chams et al., 2020).

The bulk of the literature indicates lack of knowledge synthesis and need to develop concrete tools on how to assess the impact of K&IT (Skinner, 2007). The emerging calls highlight research necessity to "recognize" and "formalize" the role of K&IT and to exploit its benefit through multifaceted processes (Easterby-Smith, 2008; Fazey et al., 2013; Gagnon, 2011). As stated by Phillipson et al. (2012), the key for an effective evaluation of K&IT exchange is a "systematic appreciation" of its outcomes and merits.

In addition, few empirical studies have been found in connecting K&IT and impact generated at interdisciplinary scale (Phillipson et al., 2012; Plummer and Armitage, 2007) and covering project-based analysis (Landaeta, 2008). The common indicators of academic outputs are reliable and validate measures (Boix-Mansilla, 2006; Erno-Kjolhede and Hansson, 2011; Feller, 2006) to translating K&IT within the scientific community. The controversy among academicians, research practitioners, and funders remains on framing the approach of knowledge produced and impacts generated (Belcher et al., 2016). In other words, to track the outcome from science to end-users, taking into account various stakeholders´ input.

4.3 Methodological framework

Various theories have been adopted for assessing research project and impact evaluation such as theory-based evaluation also known as theory of change, program theory or program logic, results chain, logic modelling, or impact pathway analysis (Morton, 2015; Rogers, 2008). In this study, we rely on knowledge-based theory, which provides support to the premise that institutions classify organizational knowledge as firm´s resource and capacity, perceived as a sustainable added-value (Alavi and Leidner, 2001; Grant, 1996; Kogut and Zander, 1992). This theory emphasizes how R&I tackle the expected activities, achieve prospected outcomes, evaluate the impact delivered, and articulate its implication to the wider society. Knowledge-based theory puts together the interconnection between resources (inputs), knowledge transfer mechanisms, and outcomes or impacts (Morton, 2015), based on time scale.

Alternative methodologies are proposed to evaluate K&IT and could comprise mixed method approaches, comparative case studies, and multi-tiered evaluations (Bell et al., 2011). A combined quantitative and qualitative assessment might be beneficial in this case, to improve the analysis of intangible parameters between the two concepts (Fazey et al., 2014) and the ability to explain the reason behind occurrence of K&IT (Bowen and Martens, 2006). Other studies suggest diverse methodological designs for K&IT evaluation such as inductive or deductive combining both quantitative and qualitative analysis (Hamdoun et al., 2018; Wehn and Montlvo, 2018). Fetterman and Wandersman (2005) and Scriven (2004) consider that evaluation could be either summative/formative or participatory/non-participatory. In this study, we adopt the formative and participatory approaches. The formative evaluation is applied to provide the foundation of knowledge exchange implementation (Roux et al., 2010; Salafsky et al., 2001) and the participatory one to engage actors contributing to the K&IT process to identify indicators and collect data (Zukoski and Luluquisen, 2002). The conceptual model (figure 4.1) illustrates the relationships between K&IT process and the impact of R&I projects.

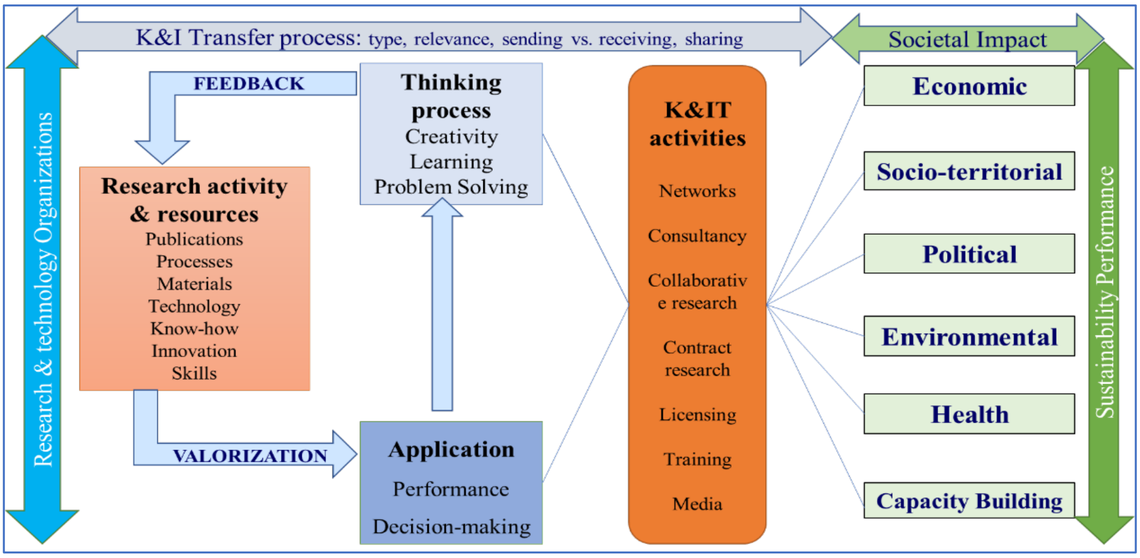

Figure 4.1 Conceptual model of K&IT activities and societal impact[1].

4.3.1 Research design

According to the policy (04/2009) issued by the Spanish-Catalan government, the main premise of this regulation is related to research centers and institutions and consists of three aspects: 1) knowledge and technology transfer; 2) scientific advancement to the agri-food sector and to its actors; 3) evaluation of technology development as contribution to modernization, amelioration of competitiveness, and sustainability of the value supply chain of the sector.

The empirical analysis relies on a micro-level approach to understand both the diversity of K&IT activities and researchers' engagement in these knowledge mechanisms, which may have a direct implication for the assessment of societal impact of R&I. Specifically, we take into account two dimensions in the K&IT process. The first one is the number of different mechanisms through which K&IT is employed; while the second one reflects the intensity with which scientists engage in the different types of K&IT activities (Iorio et al., 2017). To measure the diversity of K&IT activities

[1]Adapted from Lehyani & Zouari, 2015; Ahmad & Karim, 2019; Solans-Domènech et al, 2019.

performed by each researcher within the research project, the Shannon diversity index is used and computed as follows:

$$Shannon\ diversity\ index = -\sum_{i=1}^{N} p_i log p_i \qquad (1)$$

where i = 1 to N represents the number of different K&IT activities realized within the project, and p_i captures the share of equivalent hours that researchers allocate to the ith K&IT activity type during a regular year. From the IRTA database, p_i is calculated as the ratio of hours dedicated by the researchers to a specific type of K&IT activities over the total hours of all the types of K&IT activities. As an example, in table 4.2, p_i of the sectorial course formation (0,32) is equal to the hours dedicated by researchers to the sectorial course formation (664 hours) divided by the total hours of all the types of K&IT activities (2100 hours). The effort invested by the full-time researchers and research consultants (measured as number of working hours) is used as proxy to quantify K&I output. The Shannon index ranges from zero and increases towards infinity. Low value of Shannon index is revealed when one type of K&IT activity predominates, indicating a high degree of task concentration. Hight value of Shannon index would reflect more task diversification of K&IT (Llopis et al., 2018; Olmos-Peñuela et al., 2014).

Then, researchers' engagement in K&IT activities is defined based on the knowledge transfer engagement (KTE) indicator. The latter index is computed as the weighted average level of transfer for all assessed transfer mechanisms and stakeholders involved in the project. We start from the information at individual level about researchers' engagement, and then we use this information to establish the global effort at project level during the period of the analysis (Llopis et al, 2018). We consider p_i the frequency of researchers' interaction with the stakeholders within the project context through different transfer mechanisms during the period 2013–2020. The higher the index value, the higher the researchers' engagement in the transfer activities. The KTE index is calculated based on a scale of 0 to 100 according to the following formula:

$$KTE = \sum_{i=1}^{N} (p_i \times RS_i / N) \times 100 \qquad (2)$$

where, p_i is the weight factor of the i-th category computed as the relevance of each activity over time; RS_i is the representativeness score of participants´ category i, calculated as the number of participants engaged in the total of category i; N is the total number of participants categories assessed. Both indices defined above are constructed using the same transfer activities.

Finally, we build on the quality function deployment principle to examine the effect of K&IT activities on the societal impact of R&I. This approach is widely used to design and develop new or improved product to meet end user's requirements (Carnevalli and Miguel, 2008; Chan and Wu, 2005). Moreover, it could provide continuous evaluation and follow-up of the impact of an organization's innovation on the market (Chan and Wu, 2002; Yang et al., 2003). We adapt this technique to our empirical study to determine the contribution of each K&IT mode (carried out by different researchers in the context of their research projects) to the societal impact of R&I (main outcomes of R&I). The approach relies on the relationship matrix that defines the connection between alternative K&IT activities and the societal impact of R&I. The impact of different K&IT modes on the global sustainability performance of research projects/case studies could be defined by the following expressions:

$$I = \sum \left(\text{K\&IT}_i \times SI_j\right) \text{ and } J = \text{K\&IT}_i \sum SI_j \qquad (3)$$

Weights attributed to K&IT categories are calculated as the equivalent hours realized within each category over the total time of all K&IT activities carried within the project/case study. The assessment of the societal impact of R&I is built upon six sustainability pillars (i.e., economic, socio-territorial, environmental, health, capacity building, and political) based on the perceptions of different stakeholders involved in the research projects.

4.3.2 Data

To analyze the strategic K&IT aspect, we rely on a database from 2013 to 2020, provided by the research institution addressed in this study. The research project represents our unit of analysis. Two case studies have been selected to investigate the linkage between and the societal outcomes of R&I and K&IT activities undertaken by researchers: case study 1 "Best practices in sustainable rice cultivation" (figure 4.2) and case study 2 "genetic crossbreeding of almond varieties" (figure 4.3).

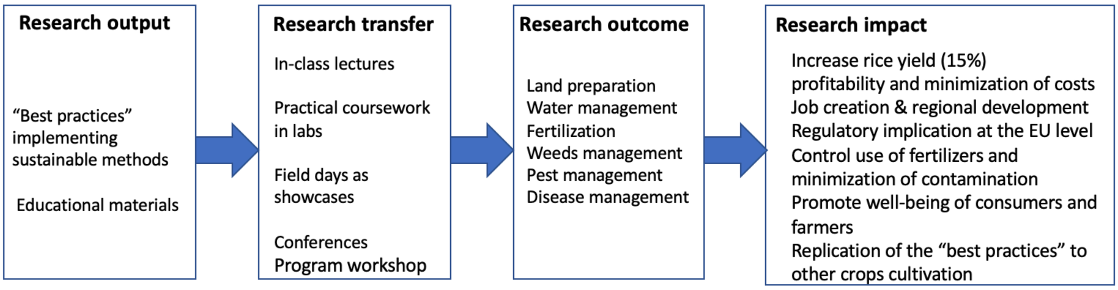

Figure 4.2 Application of research impact framework to case study 1

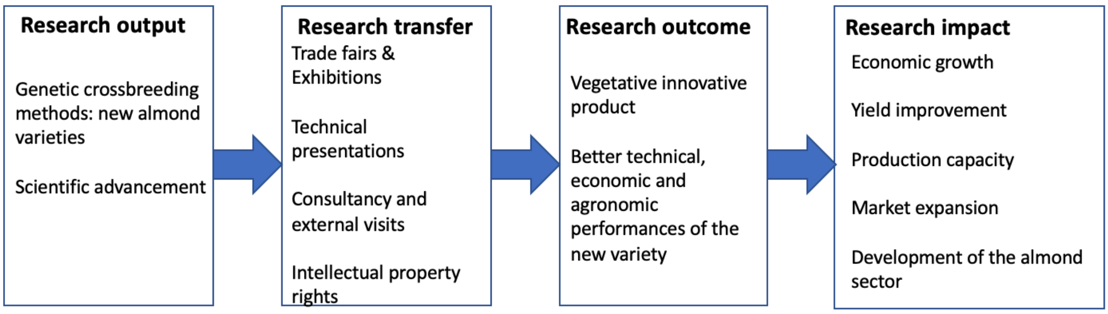

Figure 4.3 Application of research impact framework to case study 2

As a starting point, within each research project we examine a set of K&IT activities as well as the means through which knowledge have been transferred and exchanged in relation to sustainability impact. In addition, we identify the potential beneficiaries and end users of research results (farmers, professionals and practitioners, business industry, policy makers, researchers, etc.). Data are mainly gathered from standardized questionnaires as well as through project documents. Meetings/interviews and project-related documents have undergone a structured content analysis. This research focuses on K&IT mechanisms that entail direct interactions rather than indirect channels (e.g., books, scientific articles, etc.). The rationale behind selecting direct interactions is to consider only those activities that may foster the translation of knowledge from research producers to research adopters (Olmos-Peñuela et al., 2014). Accordingly, we distinguish six main categories of K&IT activities realized within the two case studies: organization and participation in conferences and workshop events, technical course formation, sectorial course formation, external and site visits, technical mission, and consultancy services. Table 4.1 provides a brief description of different K&IT mechanisms in relation to the two research projects.

Table 4.1 Definitions of K&IT activities

Activity	**Definition**
Conference, congress, technical/practical workshop events	Include events such as video editing/online notification system/advice service for research project dissemination and diffusion. Conferences of business and industrial sectors
Technical course formation	Learning activities such as formalized courses for professional and industrial groups.
Sectorial course formation	Specialized training formation tailored to socio-economic agents' needs (farmers and end-users of the sector).
External & site visits	A minimum of three field work, showcases including only those visits that target group of firms, sector, association or representative of a large community (cluster programs, associations, cooperatives, government delegation, etc.)
Technical mission	Activities orientated to a sample of producers or technicians to illustrate practical demonstration and to learn from the context of application at national and international levels.
Consultancy through committees and expert meetings	Transfer event that includes participation in meeting points as experts or references for national and international agencies, public policy makers, preparation of documents and meetings at institutional, national, and international levels.

Source: own elaboration based on archival data from the research institution

The effort invested by the full-time researchers and research consultants (measured as number of working hours) is used as proxy to quantify K&IT output. The assessment of the societal impact of R&I relies on a survey distributed to the stakeholder network. The stakeholder group consists of: researchers, project coordinators, co-partners, experts, technicians, end-users, and policy-makers. Specifically, we asked respondents to rate in a Likert scale ranging from 0 (not important) to 10 (very important) each indicator and sub-indicator generated from the two cases.

4.4 Results and discussion

The Shannon index reveals that the degree of diversity is slightly higher for case study 2 compared to case study 1 (1.59 vs. 1.55). In both projects, researchers tend to use different K&IT activities to transfer the research output and reach the maximum of target beneficiaries. Moreover, the KTE index shows a slightly higher overall score for case study 2 (28.18) than case study 1 (25.33) (table 4.2).

Table 4.2 Shannon and KTE indices

Case Study 1: Best Practices in sustainable rice cultivation	Sectorial course formation	Technical course formation	Conference technical/practical workshops events	Consultancy through committees and expert meetings	Technical mission	External & site visits	Total
Total hours K&IT	664	87	444	550	300	55	2100
pi	0,32	0,04	0,21	0,26	0,14	0,03	1,00
Number of participants	2671	545	1942	14852	455	213	20678
Shannon Index	**1,55**						
KTE Index	**25,33**						

Case Study 2: Genetic crossbreeding in almond varieties	Sectorial course formation	Technical course formation	Conference technical/practical workshops events	Consultancy through committees and expert meetings	Technical mission	External & site visits	Total
Total hours K&IT	417	1151	309	2038	751	1952	6616
pi	0,06	0,17	0,05	0,31	0,11	0,30	1,00
Number of participants	1487	2005	3732	54915	304	2486	64929
Shannon Index	**1,59**						
KTE Index	**28,18**						

Furthermore, tables 4.3 and 4.4 show the relative impact of each K&IT category on the set of sustainable impact indicators of the research project. The K&IT impact on sustainability is calculated as the sum of pi multiplied by each value assigned by the stakeholders' group to the six impact of sustainability (i.e., economic, socio-territorial, political, environmental, health, and capacity building). Though K&IT modes are complementary to translate scientific outcomes into societal contribution to the public and the ecosystem, it is worth noting that the impact of different K&IT activities is unevenly distributed across the impacts generated. Our empirical findings suggest a relevant role of "sectorial training course" and "consultancy service" in dissemination and diffusion of new sustainable practices in the rice cultivation for case study 1, perceived as knowledge production type of knowledge transfer; while "consultancy service" and "external and site visits" are the main contributor to promote the new variety of almond at regional, national and international markets for case study 2, perceived as innovation type of knowledge transfer.

The relationship matrix indicates that "sectorial training course" tailored to socio-economic agents' needs (rice farmers and end-users) might have the most important contribution to the global sustainability performance for case study 1, representing 32% of the total K&IT activities. Some scholars identified vehicles and tools that enhance knowledge transfer for instance: customized training and workshops (Hall et al., 1975); open dialogue (Pacey, 1986); inter-industry communication (Rosenberg, 1970); education and training (Stern, 1992); management techniques and timing (Tyre and Orlikowski, 1993); student exchange programs and cooperative scientific ventures (Markert, 1993). Consistent with Raelin (1997) findings, the dominant method of developing skills and capacity in case study 1 is through training. This transfer channel could be perceived as an explicit and instrumental approach to ameliorate the dissemination of science and to create individual competence, both internally and externally. As argued by Pfeffer (1998), "training is a vital component of high-performance work systems skills and initiative to resolve problems, to initiate changes in work methods, and to take responsibility for quality". In contrast, "consultancy service" seems to be the leading K&IT mechanism that affects the societal impact with respect to innovative genetic crossbreeding methods in the almond industry, representing 31% of the total K&IT activities. Furthermore, results indicate that capacity building and economic impacts are the most affected by all different K&IT activities (19%) and (22%) in case study 1 and case study 2, respectively.

In this regard, researchers deployed more time and effort in these types of training to transfer their research results to their target beneficiaries, which could improve the impact of research on the project actors and at a wider scale. Consequently, by understanding how researchers plan for and undertake K&IT activities, research organizations would focus on the effective transfer mechanism to achieve an optimal global sustainability performance without foregoing the contribution of other K&IT modes. In the same line, prior study indicates that researchers engaging in various K&IT activities might achieve greater impact than researchers involved only in individual type of K&IT activities (Landry et al., 2010). At a broader scale, Grimpe and Hussinger (2013) and Grimpe and Fier (2010) distinguish two types of K&IT activities: formal (contractual such as patents and licenses) and informal channels (conferences, trainings, workshops, consultancy, etc.). Similar to our findings, they provide evidences that informal K&IT are perceived as antecedents to improve innovative performance of firms or institutions. Fini et al. (2018) show that K&IT impact is not only limited to patents and spin-offs, but also it has an influence on the economic development and societal challenges. Iorio et al. (2017) differentiate between breadth (number of K&IT activities) and depth of K&IT (frequency of K&IT activities). The conclusion reached is that both are mutually important to enhance the impact generated from K&IT mechanisms.

Table 4.3 Measuring the impact of K&IT modes on the societal impact of case study 1 “Best practices in sustainable rice cultivation”

Case study 1: “Best practices in sustainable rice cultivation”					
Sustainability Impact	**Stakeholder evaluation**	**K&IT activities**	**pi**	**Impact of each K&IT activity on the 6 sustainability impact**	**%**
Economic	6,37	Sectorial course formation	0,32	12,49	31,62
Social-Territorial	6,3	Technical course formation	0,04	1,64	4,14
Environmental	6,98	Conference, congress, technical/practical workshops events	0,21	8,35	21,14
Health	7,04	Consultancy through committees and expert meetings	0,26	10,34	26,19
Capacity Building	7,7	Technical mission	0,14	5,64	14,29
Political	5,11	External & site visits	0,03	1,03	2,62
			Total	**39,49**	**100**

Table 4.4 Measuring the impact of K&IT modes on the societal impact of case study 2 “genetic crossbreeding in almond varieties”

Case study 2: "Genetic crossbreeding in almond varieties"					
Sustainability Impact	**Stakeholder evaluation**	**K&IT activities**	**pi**	**Impact of each K&IT activity on the 6 sustainability impact**	**%**
Economic	6,79	Sectorial course formation	0,06	1,94	6,29
Social-Territorial	6,12	Technical course formation	0,17	5,35	17,39
Environmental	3,27	Conference, congress, technical/practical workshops events	0,05	1,43	4,66
Health	4,24	Consultancy through committees and expert meetings	0,31	9,47	30,8
Capacity Building	5,92	Technical mission	0,11	3,49	11,35
Political	4,41	External & site visits	0,29	9,07	29,5
			Total	**30,75**	**100**

4.5 Conclusion

This study investigates how K&IT activity influences the sustainability performance of various scientific activities through both quantitative and qualitative assessment. Following knowledge-based theory, the inference emphasizes on the fact that "sectorial trainings", "consulting service" and "external & site visits" enhance and facilitate the articulation of knowledge from researchers to end-users. The dominant method of developing skills and capacity in case study 1 is through sectorial training and formation. Whereas for case study 2, the results indicate that external and site visits are the vehicles of K&IT diffusion in the agri-food sector. These transfer channels could be perceived as an explicit and instrumental approach to ameliorate the dissemination of science and to create individual competence, both internally and externally. As for the practical implication, research institutions are encouraged to "capitalize" on different types of K&IT activities, and in particular "sectorial trainings", "consulting service" and "external & site visits". This practice accommodates end-users in the agri-food sector with adequate capability to adjust in changing environment and to promote sustainability performances.

The antecedents of transitioning toward innovative and sustainable agri-food sector are identified through knowledge- and technology-based strategies, compromising innovative content and processes of learning. K&IT activities can be interpreted as key for R&I to move from only scientific output to become more productive knowledge output at society level. Delivering formative and participatory knowledge activities increase the probability of efficient knowledge exchange to a wider audience, while generating a competitive advantage and signaling factors to the research institute. Beaumont and Bowering (2013) advocate that maximizing impact from research would need efficient and effective knowledge transfer mechanisms that involve different stakeholders including industry, third-sector organizations, the public sector and end users at a regional, national and international scale. Last but not least, some limitations are identified in this study. First, the availability of data and K&IT types is the main shortcomings of this analysis, thus collecting additional data would increase the reliability of our empirical findings. Future research is recommended to accentuate on quantitative and qualitative design and to test K&IT indicators in different industries or/and sectors. Nevertheless, the main purpose of this study was to highlight a methodological framework to translate the knowledge transfer from research producers to research adopters

References

Ahmad, F., & Karim, M. (2019). Impacts of knowledge sharing: a review and directions for future research. Journal of Workplace Learning, 31 (3), 207–230. https://doi.org/10.1108/JWL-07-2018-0096

Agencia Estatal Boletín Oficial del Estado. (2009, April 23). https://www.boe.es/buscar/act.php?id=BOE-A-2009-8274.

Alavi, M., & Leidner, D. E. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. MIS Quarterly, 25, 107–136.

Beaumont, S. & Bowering, N. (2013). Impact and Knowledge Exchange Strategy 2013-2016 Delivering Impact from Research Excellence. University of Glasgow Press, 1-7. https://www.gla.ac.uk/media/Media_282738_smxx.pdf

Belcher, B. M., Rasmussen, K. E., Kemshaw, M. R., & Zornes, D. A. (2015). Defining and assessing research quality in a transdisciplinary context. Research Evaluation, 25(1), 1–17. doi:10.1093/reseval/rvv025

Bell, S., Shaw, B., & Boaz, A. (2011). Real-world approaches to assessing the impact of environmental research on policy. Research Evaluation, 20(3), 227–237. https://doi.org/10.3152/095820211x13118583635792

Bennett, J. W., Kelley, T. G., & Maredia, M. K. (2012). Integration of environmental impacts into ex-post assessments of international agricultural research: Conceptual issues, applications, and the way forward. Research Evaluation, 21(3), 216–228. https://doi.org/10.1093/reseval/rvs016

Boix-Mansilla, V. (2006a). Symptoms of Quality: Assessing Expert Interdisciplinary Work at the Frontier: An Empirical Exploration. Research Evaluation, 15(1), 17–29.

Bornmann, L. (2013). What is Societal Impact of Research and How Can it be Assessed? A literature survey. Journal of the American Society for Information Science and Technology, 64(2), 217–33.

Bowen, S., & Martens, P.J. (2006). A model for collaborative evaluation of university-community partnerships. Journal of Epidemiology and Community Health 60, 902–907.

Bozeman, B. & Sarewitz, D. (2011). Public Value Mapping and Science Policy Evaluation. Minerva, 49(1), 1–23.

Brown, V.A., Harris, J.A., Russell, J.Y. eds 2010. Tackling wicked problems through the transdisciplinary imagination. Earthscan: London and Washington D.C.

Carnevalli, J. A., & Miguel, P. C. (2008). Review, analysis and classification of the literature on QFD—Types of research, difficulties and benefits. International Journal of Production Economics, 114(2), 737-754.

Castka, P. (2003). Measuring teamwork culture: The use of a modified EFQM model. Journal of Management Development, 22(2), 149–170.

Chams, N., Guesmi, B., & Gil, J. M. (2020). Beyond scientific contribution: Assessment of the societal impact of research and innovation to build a sustainable agri-food sector. Journal of Environmental Management, 264, 110455.

Chan, L. K., & Wu, M. L. (2002). Quality function deployment: a comprehensive review of its concepts and methods. Quality engineering, 15(1), 23-35.

Chan, L. K., & Wu, M. L. (2005). A systematic approach to quality function deployment with a full illustrative example. Omega, 33(2), 119–139.

Clark, W. C. and Dickson, N. (2003). Sustainability Science: The Emerging Research Program, PNAS 100(14), 8059–61.

Cooke, N.J., Kiekel, P.A., Salas, E., & Stout, R. (2003). Measuring team knowledge: A window to the cognitive underpinnings of team performance. Group Dynamics: Theory, Research and Practice, 7(3), 179–199.

Cornell, S., Berkhout, F., Tuinstra, W., Tàbara, J. D., Jäger, J., Chabay, I., . . . Kerkhoff, L. V. (2013). Opening up knowledge systems for better responses to global environmental change. Environmental Science & Policy, 28, 60-70. doi:10.1016/j.envsci.2012.11.008

Cvitanovic, C., Mcdonald, J., & Hobday, A. (2016). From science to action: Principles for undertaking environmental research that enables knowledge exchange and evidence-based decision-making. Journal of Environmental Management, 183, 864-874. doi:10.1016/j.jenvman.2016.09.038

Davies, H., Nutley, S., & Walter, I. (2005). Approaches to assessing the non- academic impact of social science research. Report of the ESRC symposium on assessing the non-academic impact of research, Research Unit for Research Utilisation, University of St Andrews. Retrieved May 4, 2006, from <http://www.st-andrews.ac.uk/%7Eruru/publica- tions.htm>.

D'Este, P., Ramos-Vielba, I., Woolley, R., & Amara, N. (2018). How do researchers generate scientific and societal impacts? Toward an analytical and operational framework. Science and Public Policy, *45*(6), 752-763. doi:10.1093/scipol/scy023

De Jong, S., Barker, K., Cox, D. et al. (2014). Understanding Societal Impact Through Productive Interactions: Ict Research as a Case. Research Evaluation, 23(2), 89–102.

Dobbins, M., Cockerill, R., & Barnsley, J. (2001). Factors affecting the utilization of systematic reviews. International Journal of Technology Assessment in Health Care, 17(2), 203–214.

Donovan, C. (2008). The Australian Research Quality Framework: A Live Experiment in Capturing the Social, Economic, Environmental, and Cultural Returns of Publicly Funded Research. New Directions for Evaluation, 118: 47–60.

Easterby-Smith, M., Lyles, M. A., & Tsang, E. W. (2008). Inter-Organizational Knowledge Transfer: Current Themes and Future Prospects. Journal of Management Studies, 45(4), 677–690. https://doi.org/10.1111/j.1467-6486.2008.00773.x

Ernø-Kjølhede, E. & Hansson, F. (2011). Measuring Research Performance during a Changing Relationship between Science and Society. Research Evaluation, 20(2), 130–42.

Fazey, I., Bunse, L., Msika, J., Pinke, M., Preedy, K., Evely, A.C., Lambert, E., Hastings, E., Morris, S., & Reed, M.S. (2014). Evaluating knowledge exchange in interdisciplinary and multi-stakeholder research. Glob. Environ. Chang. 25, 204-220.

Fazey, I., Evely, A.C., Reed, M.R., Stringer, L.C., Kruijsen, J.H.J., White, P.C.L., Newsham, A., Jin, L., Cortazzi, M., Phillipson, J., Blackstock, K.L., Entwistle, N., Sheate, W.R., Armstrong, F., Blackmore, C., Fazey, J.A., Ingram, J., Gregson, J., Lowe, P., Morton, S., & Trevitt, C. (2013). Knowledge exchange: a review and research agenda for environmental management. Environmental Conservation 40, 19–36.

Feller, I. (2006). Assessing Quality: Multiple Actors, Multiple Settings, Multiple Criteria: Issues in Assessing Interdisciplinary Research. Research Evaluation 15(1), 5–15.

Fetterman, D., & Wandersman, A. (2005). Empowerment Evaluation: Principles in Practice. Guilford Press, New York, London.

Fini, R., Rasmussen, E., Siegel, D., & Wiklund, J. (2018). Rethinking the commercialization of public sci- ence: From entrepreneurial outcomes to societal impacts. The Academy of Management Perspectives, 32(1), 4–20. https://doi.org/10.5465/amp.2017.0206.

Fischer, J., Dyball, R., Fazey, I., Gross, C., Dovers, S., Ehrlich, P.R., Brulle, R.J., Christensen, C., & Borden, R.J. (2012). Human behavior and sustainability. Frontiers in Ecology and the Environment 10, 153–160.

Francis, R.A., & Goodman, M.K. (2011). Post-normal science and the art of nature conservation. Journal for Nature Conservation 18, 89–105.

Gagnon, M. L. (2011). Moving knowledge to action through dissemination and exchange. Journal of Clinical Epidemiology, 64(1), 25-31. doi:10.1016/j.jclinepi.2009.08.013

Graham, I.D., Logan, J., Harrison, M.B., Straus, S.E., Tetroe, J., Caswell, W., et al. (2006). Lost in knowledge translation: Time for a map? Journal of Continuing Education in the Health Professions, 26(1), 13–24.

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. Strategic Management Journal, 17(S2), 109–122. https://doi.org/10.1002/smj.4250171110

Gravois Lee, R., & Garvin, T. (2003). Moving from information transfer to information exchange in health and health care. Social Science & Medicine, 56, 449–464.

Grimpe, C., and Hussinger, K. (2013). Formal and informal knowledge and technology transfer from academia to industry: Complementarity effects and innovation performance. Industry and Innovation, 20(8), 683–700.

Grimpe, C., and Fier, H. (2010). Informal university technology transfer: A comparison between the United States and Germany. The Journal of Technology Transfer, 35(6), 637–650.

Hall, G.E., Loucks, S.F., Rutherford, W.L., & Newlove, B.W. (1975). Levels of use of the innovation: A framework for analyzing innovation adoption. Journal of Teacher Education, 26(1), 52–56.

Hamdoun, M., Chiappetta Jabbour, C. J., & Ben Othman, H. (2018). Knowledge transfer and organizational innovation: Impacts of quality and environmental management. Journal of Cleaner Production, 193, 759–770. https://doi.org/10.1016/j.jclepro.2018.05.031

Hicks, D. M. (2004). Bibliometric Evaluation of Federally Funded Research in the United States. Research Evaluation, 13(2), 76–86.

Higher Education Funding Council (2011). REF Assessment Framework and Guidance on Submissions. Bristol, HEFC.

Iorio, R., Labory, S., & Rentocchini, F. (2017). The importance of pro-social behaviour for the breadth and depth of knowledge transfer activities: An analysis of Italian academic scientists. Research Policy, 46(2), 497-509.

Jäger, J., Holm, P., O'Brien, K., Palsson, G., Pahl-Wostl, C., Chabay, I., & Reams, J. (2013). Responses to environmental and societal challenges for our unstable earth. Environmental Science & Policy, 28, 1-2. doi:10.1016/j.envsci.2013.01.001

Jones, L. R., & Schedler, K. (2004). Strategies for Public Management Reform. Amsterdam; London, Elsevier.

Julnes, P.D., & M. Holzer. (2001). Promoting the Utilization of Performance Measures in Public Organizations: An Empirical Study of Factors Affecting Adoption and Implementation. Public Administration Review 61, 693–708.

Knight, C. & Lightowler, C. (2010). Reflections of "knowledge exchange professionals" in the social sciences: emerging opportunities and challenges for university-based knowledge brokers. Evidence & Policy, 6 (4), 543–56.

Knott, J., & A. Wildavsky. (1980). If Dissemination Is the Solution, What Is the Problem? Knowledge: Creation, Diffusion, Utilization 1, 537–78.

Kogut, B., & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. Organization Science, 3, 383–397.

Landaeta, R. E. (2008). Evaluating Benefits and Challenges of Knowledge Transfer Across Projects. Engineering Management Journal, 20(1), 29-38. doi:10.1080/10429247.2008.11431753

Landaeta, R., & Kotnour T. (2005). Knowledge Systems. Proceedings of the American Society for Engineering Management National Conference,194-199.

Landry, R., Lamari, M., & Amara, N. (2003). The extent and determinants of the utilization of university research in government agencies. Public Administration Review, 63(2), 192–205.

Landry, R., Saïhi, M., Amara, N., and Ouimet, M. (2010). Evidence on how academics manage their portfolio of knowledge transfer activities. Research Policy, 39, 1387–1403.

Lavis JN. (2006). Research, public policymaking, and knowledge-translation processes: Canadian efforts to build bridges. J Contin Educ Health Prof 2006; 26, 37-45.

Lemos, M.C., & Morehouse, B.J. (2005). The co-production of science and policy in integrated assessments. Global Environmental Change 15, 57–68.

Lehyani, F., & Zouari, A. (2015). Evaluating and measuring knowledge management's impact on supply chain performance using HOQ. In 2015 IEEE International Conference on Service Operations And Logistics, And Informatics (SOLI) (pp. 210-215). IEEE.

LERU (League of Eurpoean Research Universities) (2013) Research Universities and Research Assessment. Position Papers. Leuven, LERU.

Liberatore, A., & Funtowicz, S. (2003). Democratising expertise', 'expertising democracy: what does this mean, and why bother? Science and Public Policy, 30(3), 146-150.

Lightowler, C., & Knight, C. (2013). Sustaining knowledge exchange and research impact in the social sciences and humanities: Investing in knowledge broker roles in UK universities. Evidence & Policy: A Journal of Research, Debate and Practice, 9(3), 317-334. doi:10.1332/174426413x662644

Link, A. N., Siegel, D., and Bozeman, B. (2007). An empirical analysis of the propensity of academics to engage in informal university technology transfer. Industrial and Corporate Change,16(4), 641–655

Llopis, O., Sánchez-Barrioluengo, M., Olmos-Peñuela, J., & Castro-Martínez, E. (2018). Scientists' engagement in knowledge transfer and exchange: Individual factors, variety of mechanisms and users. Science and Public Policy, 45(6), 790-803.

Lomas, J. (1993). Diffusion, Dissemination, and Implementation: Who Should Do What? Annals of the New York Academy of Sciences 703, 226.

Markert, L. R. (1993). Contemporary technology: Innovations, issues, and perspectives. South Holland, Illinois: Goodheart-Willcox.

Molas-Gallart, J., & Tang, P. (2011). Tracing 'productive interactions' to identify social impacts: an example from the social sciences. Research Evaluation 20, 219–226.

Morton, S. (2015). Progressing research impact assessment: A 'contributions' approach. Research Evaluation*,* 24(4), 405-419. doi:10.1093/reseval/rvv016

Nowotny, H., SCott, P., & Gibbons, M. (2001). Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty. Polity Press, Cambridge.

Nutley, S., Walter, I., & Davies, H. (2007). Using Evidence: How Research can Inform Public Services. Bristol, Policy Press.

Olmos-Peñuela, J., Castro-Martínez, E., & d'Este, P. (2014). Knowledge transfer activities in social sciences and humanities: Explaining the interactions of research groups with non-academic agents. Research Policy, 43(4), 696-706

Pacey, A. (1986). The culture of technology. Cambridge, MA: MIT Press.

Penfield, T., Baker, M. J., Scoble, R., & Wykes, M. C. (2013). Assessment, evaluations, and definitions of research impact: A review. Research Evaluation, 23(1), 21–32. https://doi.org/10.1093/reseval/rvt021

Pfeffer, J. (1998). Seven practices of successful organizations. California Management Review, 40 (2), 96-124

Phillipson, J., Lowe, P., Proctor, A., & Ruto, E. (2012). Stakeholder engagement and knowledge exchange in environmental research. Journal of Environmental Management 95, 56–65.

Plummer, R., & Armitage, D. (2007). A resilience-based framework for evaluating adaptive co-management: linking ecology, economics and society in a complex world. Ecological Economics 61, 62–74.

Prins, A., Spaapen, J., van Leeuwen, T., & van den Broek-Honingh, N. (2019). QRiH: Towards a fitting system for humanities research evaluation, Eval Journal for Research and Technology Policy Evaluation, 48, 91-97

Raelin, J.A. (1997). A model of work-based learning. Organization Science, 8 (6), 563–578

REF (2011). Assessment Framework and Guidance on Submissions. London: Research Excellence Framework.

Research Councils UK. (2011). Pathways to Impact, <http://www.rcuk.ac.uk/kei/impacts/Pages/home.aspx> accessed 4 Oct 2011.

Robinson, J., & Tansey, J. (2006). Co-production, emergent properties and strong interactive social research: the Georgia Basin Futures Project. Science and Public Policy 33 (2), 151–160.

Rogers, P. J. (2008). Using Programme Theory to Evaluate Complicated and Complex Aspects of Interventions, Evaluation, 14(1), 29–48.

Rosenberg, N. (1970). Economic development and the transfer of technology: Some historical perspectives. Technology and Culture, 11(4), 550-575.

Roux, D.J., Stirzaker, R.J., Breen, C.M., Lefroy, E.C., & Cresswell, H.P. (2010). Framework for participative reflection on the accomplishment of transdisciplinary research programs. Environmental Science and Policy 13, 733–741.

Salafsky, N., Cauley, H., Balachander, G., Cordes, B., Parks, J., Margoluis, C., Bhatt, S., Encarnacion, C., Russell, D., & Margoluis, R. (2001). A systematic test of an enterprise strategy for community-based biodiversity conservation. Conservation Biology 15, 1585–1595.

Salter, A. J. & Martin, B. R. (2001). The Economic Benefits of Publicly Funded Basic Research: A Critical Review. Research Policy, 30(3), 509–32.

Schulz, M. (2001). The uncertain relevance of newness: organizational learning and knowledge flows. Academy of Management Journal, 44, 661–81.

Scriven, M., (2004). Reflections. In: Alkin, M.C. (Ed.), Evaluation Roots: Tracing Theorists' Views and Influences. Sage Publications Inc., Thousand Oaks, CA, 183–195.

Skinner, K. (2007). Developing a tool to measure knowledge exchange outcomes. The Canadian Journal of Program Evaluation, 22(1), 49-73.

Solans-Domènech, M., MV Pons, J., Adam, P., Grau, J., & Aymerich, M. (2019). Development and validation of a questionnaire to measure research impact. Research Evaluation, 28(3), 253-262.

Spaapen, J., & Drooge, L. V. (2011). Introducing 'productive interactions' in social impact assessment. Research Evaluation, 20(3), 211-218. doi:10.3152/095820211x12941371876742

Stern, S. (1992). The relationship between human resource development and corporate creativity in Japan. Human Resource Development Quarterly, 3(3), 215-234.

Tàbara, J. D., & Chabay, I. (2013). Coupling Human Information and Knowledge Systems with social–ecological systems change: Reframing research, education, and policy for sustainability. Environmental Science & Policy, 28, 71-81. doi:10.1016/j.envsci.2012.11.005

Tsai, W. (2002). Social structure of "coopetition" within a multiunit organization: coordination, compe- tition, and intraorganizational knowledge sharing. Organization Science, 13, 179–90.

Tyre, M. J., & Orlikowski, W. J. (1993). Exploiting opportunities for technological improvement in organizations. Sloan Management Review, 35(1), 13-26.

Van Kerkhoff, L., & Szlezák, N.A. (2010). The role of innovative global institutions in linking knowledge and action. Proceedings of the National Academy of Sciences www.pnas.org/cgi/doi/10.1073/pnas.0900541107

van Wijk, R., Jansen, J. J., & Lyles, M. A. (2008). Inter- and Intra-Organizational Knowledge Transfer: A Meta-Analytic Review and Assessment of its Antecedents and Consequences. Journal of Management Studies, 45(4), 830–853. https://doi.org/10.1111/j.1467-6486.2008.00771.x

Von Hippel, E. (2005). Democratizing Innovation, MIT Press, Cambridge, Mass.

Wehn, U., & Montalvo, C. (2018). Knowledge transfer dynamics and innovation: Behaviour, interactions and aggregated outcomes. Journal of Cleaner Production, 171. https://doi.org/10.1016/j.jclepro.2016.09.198

Yang, Y. Q., Wang, S. Q., Dulaimi, M., & Low, S. P. (2003). A fuzzy quality function deployment system for buildable design decision-makings. Automation in construction, 12(4), 381-393.

Zukoski, A., & Luluquisen, M. (2002). Participatory evaluation. What is it? why do it? what are the challenges?. Community-based Public Health Policy and Practice 5, 1–6.

Chapter 5. Conclusion

Evaluation of RDi agricultural research impact has received an increased consideration by scholars, policy-makers and government due to several reasons. Some of the triggers behind the emerging concerns toward impact assessment are: accountability of project, credibility appraisal of research institutions, and prioritization of programs (Heisey et al., 2010). The common methods applied to conduct the evaluation process are the peer-revision to assess "scientific merit" and the economic analysis to quantify both market and non-market goods, such as human well-being, societal welfare, and ecological conservation. According to Heisey et al. (2010), there are four paradigms highlighting the importance of impact evaluation of research. The first one consists of "the sophistication factor" which, is known as the growing costs of scientific research and instrumentation procedures. Second, the increased limitations on public spending lead to restrain some funding in emerging areas. In addition, there is a growing attention to develop a flexible and an innovative quantitative assessment tool. While the peer-review process was able to determine and identify the emergence of new research areas and relevant topics, it failed to highlight the declining research areas and groups. The fourth paradigm is related to the growing concern of policy makers towards the benefits of public RD investments to the community.

To recapitulate, Chapters 2, 3 and 4 constitute the main body of this investigation. This final section draws the main conclusions derived from the three studies. Highlighting the research gaps in the literature and acknowledging the direct implication of the agriculture sector to the UN SDGs (Weißhuhn et al., 2017), the present thesis provides insights on: 1) RDi impact at multi-level of analysis (Chapter 2); 2) sustainability indicators and measurement of research benefits taking into account stakeholders´ perception (Chapter 3); and 3) the association between knowledge and innovation transfer and sustainability performance (Chapter 4).

This doctoral thesis postulates some evidences on the role of research institutions as intermediate actor between science and the society. Their functions are to identify and prioritize governmental interest and translate them into research project in order to unfold the communal targets. The outcome of this work highlights a step further towards the evaluation framework of RDi and emphasizes its contribution towards sustainability practices in the agri-food sector. The purpose of the methodological framework that is proposed is triangulation of the results from institution, stakeholders and end-users in order to achieve consistent and significant conclusions about the societal impact of research and innovation.

This thesis contributes to the RDi impact assessment literature both from methodological and empirical point of views. There is a growing consensus among policy makers and practitioners that there is no single impact to be measured and no single best approach for doing so (Horton and Mackay, 2003; Weißhuhn et al., 2017). In contrast to previous studies, Chapter 2 moves away from identifying any 'single best method' and instead embraces mixed-method monitoring approaches (ASIRPA and IOM) to better understand users' information needs and to improve the evaluation process of agri-food RDi impacts. Second, Chapter 3 generates a sustainability index for agricultural research impact using multi-criteria decision making techniques and stakeholders' assessment, highlighting how various case studies in the agri-food sector contribute implicitly to different SDGs. Chapter 4 accentuates on the nexus between knowledge and innovation transfer and sustainability performance. The findings of Chapter 4 indicate that research dissemination activities such as technical and sectorial trainings and conferences are perceived as channels to enhance knowledge and innovation transfer and to positively influence sustainability practices. Overall, the inference of the present work can be translated as support to decision and policy making in agricultural research, suggesting methodological tools for monitoring the impacts of RDi, as well as assisting in the accomplishment of adequate research policy planning and project management strategies.

Research impact assessment is a recent paradigm that has been receiving a considerable attention from both scholars and policy-makers. Although, various studies have been advancing and proposing methodological techniques towards RDi evaluation, there is still room for further lines of research to better articulate this concept. Firstly, there is lack of a "collaborative dialog" between management and social science theories to build a clear and unified theoretical paradigm analyzing the contribution of science to the ecosystem and to the society. Moreover, future directions are encouraged to identify an *ex-post* and *ex-ante* evaluation to better quantify and monitor RDi impacts. To improve the external validity and generalizability of the findings, additional research is well placed to empirically investigate RDi impacts on inter and intra sectorial analysis i.e., relying on bigger sample size, higher number of case studies, and across various industries.

The main limitations of this investigation are articulated as follow. In Chapter 2, the qualitative design and the limited number of case study might reflect a shortcoming to extrapolate the results and the external validity. Therefore, replicating this study with higher number of case studies may strengthen the inferences of RDi impacts and improve the synthetic process of indicators and sub-indicators of sustainability performance. Moreover, to validate the list of indicators used as proxies of sustainability measures, we recommend to introduce quantitative methods such as structure equation modeling, factor analysis or partial least square regression.

In Chapter 3, the limited participation of stakeholders´ network in the evaluation process might reveal some constraints regarding the generalizability of the results. Therefore, future research might consider a wider sample of stakeholders to accentuate the results and reveal the engagement of various actors of RDi. Other multicriteria decision making techniques such as ELECTRE TRI or Analytic Hierarchy Process might be applied to improve the significance and robustness of our findings.

As for Chapter 4, this study attempts to assess the linkage between knowledge and innovation transfer and sustainability performance of research projects. To reinforce the findings revealed, collecting additional data on alternative K&IT activities, researcher's engagement and effort and extending the analysis to more case studies might increase the reliability of our empirical findings. Further research is recommended combining both quantitative and qualitative designs and testing K&IT indicators in different industries or/and sectors. This study might be replicated at researcher level, evaluating K&IT activities based on individual rather than on project/case study level of analysis. Future work might consider to go a step further by clustering separately the indicators of "knowledge" from the indicators of "technology" in order to highlight how each category reveals different impacts on sustainability performance.

References

Alston, J. M., Pardey, P. G., James, J. S., and Andersen, M. A., 2010. The Economics of Agricultural R&D. Annual Review of Resource Economics, 1, 537–65. https://doi.org/10.1146/ annurev.resource.050708.144137

Bornmann, L., 2013. What is societal impact of research and how can it be assessed? A literature survey. J. Am. Soc. Inf. Sci. Technol. 64, 217-233. https://doi.org/10.1002/asi.22803

Bell, S., Shaw, B., and Boaz, A., 2011. Real-world Approaches to Assessing the Impact of Environmental Research on Policy. Research Evaluation, 20(3), 227–37.

Bensing, J.M., Caris-Verhallen, W.M.C.M., Dekker, J., Delnoij, D.M.J., and Groenewegen, P.P., 2003. Doing the right thing and doing it right: Toward a framework for assessing the policy relevance of health services research. International Journal of Technology Assessment in Health Care, 19(4), 604–612. https://doi.org/10.1017/S0266462303000564

Cai, Y., Golub, A. A., and Hertel, T. W., 2017. Agricultural research spending must increase in light of future uncertainties. Food Policy, 70, 71-83. https://doi.org/10.1016/j.foodpol.2017.06.002

Donovan, C., 2011. State of the art of assessing research impact: Introduction to a special issue. Research Evaluation, 20, 175-9. https://doi.org/10.3152/095820211X13118583635918

Idescat. (2020). Retrieved May 4, 2021 from https://www.idescat.cat/novetats/?id=3904&lang=en

European statistics. (2017). Retrieved March 21, 2018, from http://ec.europa.eu/eurostat/

European statistics. (2020). Retrieved May 4, 2021, from https://ec.europa.eu/eurostat/

European statistics. (2020). Retreived May 4, 2021 from
https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Main_Page

Freeman, C. (1984). The Economics of industrial innovation. Pinter, London.

Godin, B., and Doré, C., 2005. Measuring the Impacts of Science; Beyond the Economic Dimension. Presented at the Urbanisation INRS, Culture et Société. Helsinki Institute for Science and Technology Studies: Helsinki, Finland

Guinea, J., Sela, E., Gómez-Núñez, A. J., Mangwende, T., Ambali, A., Ngum, N., . . . Thepthien, B., 2015. Impact oriented monitoring: A new methodology for monitoring and evaluation of international public health research projects. Research Evaluation, 24, 131-145. https://doi.org/10.1093/reseval/rvu034

Heisey, P.W., King, J.L., Rubenstein, K., Bucks, D.A., and Welsh, R. (2010). Assessing the Benefits of Public Research Within an Economic Framework the Case of USDA's Agricultural Research Service. USDA Economic Research Service.

Horton, D., and Mackay, R., 2003. Using evaluation to enhance institutional learning and change: Recent experiences with agricultural research and development. Agriculture Systems, 78, 127–142.

Martin, B. 1996. The Relationship Between Publicly Funded Basic Research and Economic Performance: A SPRU Review. Report Prepared for HM Treasury, University of Sussex, Brighton.

Niederkrotenthaler, T., Dorner, T.E., and Maier, M., 2011. Development of a practical tool to measure the impact of publications on the society based on focus group discussions with scientists. BMC Public Health, 11, 588.

Nightingale, P., and Scott, A., 2007. Peer review and the relevance gap: Ten suggestions for policy-makers. Science and Public Policy, 34(8), 543– 553. doi:10.3152/030234207x254396

Pardey, P., Chan-Kang, C., Dehmer, S., and Beddow, J., (2016). Agricultural R&D is on the move. Nature 537.

Reed, M.S., 2018. The Research Impact Handbook, 2nd Edition. Fast Track Impact, Huntly, Aberdeenshire.

Reed, M. S., Ferré, M., Martin-Ortega, J., Blanche, R., Lawford-Rolfe, R., Dallimer, M., and Holden, J., 2021. Evaluating impact from research: A methodological framework. Research Policy, 50(4), 104147. https://doi.org/10.1016/j.respol.2020.104147

Salter, A. J., and Martin, B. R., 2001. The economic benefits of publicly funded basic research: a critical review. Research Policy, 30, 509-532. https://doi.org/10.1016/s0048-7333(00)00091-3

Weißhuhn, P., Helming, K., and Ferretti, J., 2017. Research impact assessment in agriculture—A review of approaches and impact areas. Research Evaluation, 27(1), 36-42. https://doi.org/10.1093/reseval/rvx034

Williams, K., 2020. Playing the fields: Theorizing research impact and its assessment. Research Evaluation, 29(2), 191–202. https://doi.org/10.1093/reseval/rvaa001